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Annual report **2019**

INRA • IRSTEA

Annual report
2019

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Prelaunch conference
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Preface

2019 was a special year for the French National Institute for Agricultural Research (INRA) and the French National Research Institute of Science and Technology for the Environment and Agriculture (IRSTEA). Individually, the institutes pursued scientific excellence; produced knowledge to foster innovation and inform public policies; and built international collaborations. During this same period, they joined forces to create a new research institute. On January 1, 2020, the French National Research Institute for Agriculture, Food, and Environment (INRAE) was born. This annual report was written by teams from each of the former institutes, who now form a unified group. The report highlights the advances made by INRA and IRSTEA in 2019 with a view to illustrating the complementarity of their research and objectives.

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A word from our Chair and CEO

A new world leader in the agricultural, food, and environmental sciences was born in 2020: INRAE. It has brought together 11,500 talented individuals from INRA and IRSTEA. This project was made possible thanks to the **intensive brainstorming and planning** in 2019 by all our teams, which both Marc Michel, CEO of IRSTEA, and myself, CEO of INRA, had the honour to lead. The merger of the two institutes was spurred by the potential for synergies in our skills, scientific programmes, and infrastructures. It was thus only natural that we restructure our scientific divisions. To respond to societal shifts and expectations, we created a General Directorate for Expertise and Support for Public Policies and a Directorate for Open Science. Leading up to the merger, we maintained an ongoing social dialogue to ensure that all our employees retained their jobs, that all our research sites were kept open, and that everyone's occupational mobility goals were respected. A merger of this size had never before occurred in the world of French research and higher education. It would not have been possible without the help of every single member of our staff and the support of our supervisory ministries.

Even as we faced major organisational challenges, our research units steamed ahead with their scientific projects and partnerships, as detailed in this annual report. Our major achievements in 2019 were **a logical consequence of our institutes' strong relationships** with a range of collaborators: socioeconomic stakeholders, with whom we created six new start-ups; the general public, with whom we exchanged via participatory science programmes; and institutes of higher education, with whom we designed site-based strategies that arose from the merger. For example, we achieved some great successes as part of the third iteration of the Investments for the Future Programme (PIA), such as the creation of Innovation Regions, which bring together researchers and local stakeholders (e.g., regional governments, innovative companies, non-profit organisations, and everyday citizens). Indeed, we are the only organisation involved in seven of the Innovation Region projects, and we are contributing our expertise in a variety of areas: livestock farming, winegrowing, silviculture, sustainable food production, the digital transition, water quality, and the resilience of littoral zones. At the national level, the Minister of Higher Education, Research, and Innovation tasked INRA with leading the priority research programme "Growing and protecting crops differently". The aim is to identify alternatives to plant protection products, and all relevant scientific communities have been invited to participate.

INRA and IRSTEA perform targeted research, which means that they contribute to a better future by generating both knowledge and solutions. Below, we shine the spotlight on **key research published** in 2019 and thus honour the efforts of those who dedicate themselves day in and day out to confronting the world's greatest challenges. Their work aims to adapt agricultural systems to climate change, use multiperformance approaches to facilitate the ecological transition, preserve biodiversity, better manage natural resources, produce food more sustainably, boost the bioeconomy, and inform public policies.

More than ever before, our research is strengthened by its unity and its scope; our vision **includes Europe and, indeed, the world**. In 2019, we further developed our international

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partnerships while also sharing the fruit of our previous successes. For example, INRA became part of the *Partnership for European Environmental Research* (PEER), of which IRSTEA is a long-standing member. This network conducted an inventory of the best practices for supporting public policies with a view to enhancing the way for the 2030 Agenda Sustainable Development Goals. The two institutes proved their worth with regards to the Horizon 2020 Programme: INRA was number one in France in the societal challenge category "food security", while IRSTEA's success rate was 23% in the societal challenge category "Climate action, environment, resource efficiency, and raw materials". At the global scale, seven new international associated laboratories (LIAs) were created via partnerships with China, India, Japan, and Singapore. INRA representatives accompanied the French Minister of Agriculture and Food to the Ivory Coast to discuss nutritional health and explore potential collaborations with CIRAD on this topic in Africa.

Amidst the ongoing COVID-19 epidemic, we must remember that research and action naturally go hand and hand. One of our key strengths is drawing upon our combined long-term research results to efficiently direct our short-term research efforts. Given the emerging threats to our future, our research system is all the more precious, as is its holistic approach. The need for a more overarching perspective is nothing new. Over the last several years, our research using the *One Health* lens has shown that human health is tied to plant, animal, and environmental health. Prior to the merger, INRA and IRSTEA had already developed an excellent reputation because of the quality of their work in the fields of sustainable development and epidemic prevention. This expertise largely arose from their scientific skill and adroitness in carrying out zoonosis monitoring and clarifying the relationship between agricultural activities and population health. **The institute resulting from their merger, INRAE**, will bring additional strengths to the table as the world faces emerging health risks and undertakes transitions related to food production, climate change, and environmental shifts. INRAE will act as a catalyst–striving to protect the entire planet by bringing together the skills of technicians, engineers, and researchers specialising in agroecology, biodiversity, the climate, food production, human health, and aquatic systems. INRAE 2030, our participatory project for defining the institute's strategic priorities, has been incorporating input from all our employees since 2019. It will be finalised in the coming months as we add in the contributions of various social and economic stakeholders. This project will enhance our ability to take impactful action and reflects how seriously we view our responsibilities, which are, more than ever, ours to carry.

As you read this annual report, I hope you will also perceive the passion that has always driven the people of INRA and IRSTEA, who are now united under the banner of a single institute. They all have an unquenchable thirst for knowledge and an unwavering commitment to the common good. I am convinced that their complementarity will inspire innovative research that will shape the future.

Philippe MAUGUIN

INRAE Chair
and Chief Executive Officer

2019 in brief

FEBRUARY

February 22–March 1

INRA honoured for its heart-stopping stand at the Paris International Agricultural Show

The theme of INRA's stand at the 2019 Paris International Agricultural Show was "The secret lives of plants and animals". The institute placed itself at the centre of the exchanges taking place at the show by connecting with everyday citizens and industry professionals as it shared its research on the behaviour and interactions of plants, animals, and microbes. The institute was awarded the *Coup de coeur* prize for the stand's aesthetics and educational approach, which involved an array of activities led by over 350 technicians, engineers, and researchers.

February 24–28

IRSTEA-a key contributor to precision agriculture at SIMA

During this same period, IRSTEA was at the centre of exchanges on precision agriculture at the International Exhibition of Solutions and Technologies for Efficient and Sustainable Agriculture (SIMA). The institute focused on pesticide reduction, irrigation use, and water quality.

MARCH

March 17

INRA and CNRS find strength in scientific unity

Around 100 researchers from INRA and CNRS gathered to discuss common study topics and build research programmes around shared questions. The first topic of focus to emerge was renewable carbon and the carbon cycle.

March 26

Creation of two new INRA LIAs

INRA bolstered its collaboration with the Chinese Academy of Agricultural Sciences (CAAS). Two agreements were signed to create international associated laboratories (LIAs), one centred on plant protection via disease biocontrol and the other on the use of genomics to improve wheat.

APRIL

April 1

Creating INRAE

The first key step in the merger process took place on April 1, when the INRA and IRSTEA management teams met for the first time, holding a conference to discuss the future institute's objectives.

April 3

Creation of ECLA, an R&D hub for research on lake ecosystems

ECLA was established after INRA and IRSTEA signed an agreement with the French Agency for Biodiversity and the National Hunting and Wildlife Agency (now merged to form the French Biodiversity Agency); the University of Savoie-Mont-Blanc was also a signatory. The hub will dedicate itself to research on lake ecosystems, and its 70 researchers and operational staff will focus on transforming scientific discoveries into practical innovations.

MAY

May 20–25

Agroforestry experts gather to "regreen our planet"

At the 4th World Congress on Agroforestry in Montpellier, participants published a call to "make our planet treed again!". In other words, they called for dramatic changes to our global food production systems to limit the latter's negative impacts on our planet. The conference was co-organised by INRA, CIRAD, World Agroforestry, Agropolis International, and the Montpellier University of Excellence. It was agreed that agroforestry has a key role to play in these efforts.

JUNE

June 5

INRA heads the priority research programme "Growing and protecting crops differently"

An information day took place to discuss grant submissions to the priority research programme "Growing and protecting crops differently". This INRA-led

programme has a budget of €30 million and funds research exploring strategies for reducing pesticide use. The goal is to support cutting-edge research that will lead to breakthrough innovations based on prevention, agroecology, and new production systems.

June 27

A starring role for the microbiota

The microbiota starred in a French television documentary, "*Microbiote, les fabuleux pouvoirs du ventre* [Microbiota: the amazing powers of the gut]", that resulted from a partnership between INRA and the *Cité des Sciences*. The film was part of the museum's special exhibition on the microbiota and marked the 2nd World Microbiome Day. The documentary explored discoveries made by MetaGenoPolis, a research unit at the INRA centre in Jouy-en-Josas. When the film was broadcast on Arte, it attained an audience share of 4.1%, which is twice as high as the average for this type of subject matter.

JULY

July 8–11

IRSTEA in the vanguard of precision agriculture research

IRSTEA and Montpellier SupAgro co-organised the 12th European Conference on Precision Agriculture. The meeting brought together more than 350 scientists from 37 countries, who discussed their latest experiments and discoveries with a view to better rationalising and controlling agricultural inputs.

SEPTEMBER

September 17

INRA and IRSTEA–pioneers in French Innovation Regions

The prime minister announced the 24 projects that had received funding from the Innovation Regions grant programme, whose budget is €450 million. INRAE is leading or participating in seven projects, a degree of involvement that is beyond that of any other organisation.

TERRITOIRES D'INNOVATION
LE GRAND PLAN D'INVESTISSEMENT

September 23

Increasing the attractivity of French research

A working group jointly led by Philippe Mauguin submitted a report on the attractiveness of scientific jobs and careers in France to the French prime minister. The report had been written to help inform the French Framework Law on Multiannual Research (LPPR).

September 24

IRSTEA receives recognition for a high-precision spray system

The institute was awarded three SITEVI Innovation Awards, of which two were for spraying technology. The first award was for the Blade Low-Impact Spray System (BLISS), which optimises pesticide quantities via greater precision spraying. The second award was for the Pulvé label, which was developed in collaboration with the French Wine and Vine Institute. The label's objective is to encourage winegrowers to replace their older spray systems with higher-performance spray systems, thus reducing pesticide use.

SITEVI INNOVATION AWARDS 2019

OCTOBER

October 1

The foundation is laid for Agro Paris-Saclay

The first official steps were taken towards creating the Agro Paris-Saclay campus, a collaborative project between INRA and AgroParisTech. The event was marked by a visit from Frédérique Vidal, Minister of Higher Education, Research, and Innovation, and Didier Guillaume, Minister of Agriculture and Food. The campus will serve as a hub for education, research, and innovation transfer in the domains of food production, the agricultural sciences, and the environmental sciences. Indeed, 12% of the researchers and professors at the University of Paris-Saclay are working in a range of related disciplines.

NOVEMBER

November 7

IRSTEA and INRA deploy European research to inform public policies

Ahead of the merger, IRSTEA invited the directors of the institutes belonging to the Partnership for European Environmental Research (PEER) to meet INRA. The gathering took place in Antony, France, on November 7, 2019. It was agreed that it would be helpful to have a benchmark for the degree of support given to environmental policies. The goal is to increase the impact of the institutes' scientific actions within European institutions. In place since 2018, the joint project "Tackling and managing risks with SDGs (TRISD)" is clarifying the unintended risks that result when Agenda 2030 SDGs are implemented as part of European public policies.

November 25–26

INRA–an increased focus on nutrition in Africa

The Fondation Avril in Abidjan organised a colloquium that brought together scientists and stakeholders in the agricultural and agrifood industries of West Africa. The theme was nutritional deficiencies. The event was launched with a talk by Philippe Mauguin and featured a presentation by Daniel Tomé (AgroParisTech). It was also an opportunity to discuss potential future collaborations with CIRAD.

DECEMBER

December 5

INRA French West Indies-French Guiana turns 70

A series of events for the general public was held to mark the 70th anniversary of the INRA Centre of French West Indies-French Guiana. The goal was to showcase the centre's work, notably that on regional food sovereignty. A final day-long celebration was held at the Jardin d'Eau in Goyave, to which all the centre's academic and socioeconomic partners were invited.

December 10

INRA honoured at the 7th *Étoiles de l'Europe*

The *Étoiles de l'Europe* is a ceremony that recognises French excellence within the realm of European research. The awards were given out by Frédérique Vidal, Minister of Higher Education, Research, and Innovation, and Philippe Mauguin, who headed the 2019 selection committee. Among those honoured was Véronique Chable. She heads the European project DIVERSIFOOD, whose goal is to increase the range of crops that we eat.

.00

Prelaunch of INRAE /

A science-driven merger

The merger of INRA and IRSTEA began in 2017, when the institutes' CEOs tasked their scientific directorates with exploring the benefits of such a union. The findings underscored the potential advantages of the scientific collaborations, common research programmes, and shared infrastructure that would result. This exploration also highlighted a shared dedication by the institutes to targeted research on scientific questions related to major global challenges, namely the effects of climate change on agriculture, food, and the environment.

This convergent vision helped inform the shape of the merger. The process was followed up by a feasibility study exploring the creation of a single establishment with a renewed set of scientific objectives. The proposed project was approved in October 2018 by the institutes' supervisory ministries–the Ministry of Higher Education, Research, and Innovation and the Ministry of Agriculture and Food.

Several important steps in the merger were identified. They included, among others, restructuring the scientific divisions to promote disciplinary excellence; implementing a systemic approach to target issues; increasing the critical mass associated with certain topics; creating new interdisciplinary relationships, such as one between agroecology, agricultural machinery research, and the digital sciences; and pooling data resources and research infrastructures. INRAE espouses the highest standards when it comes to producing knowledge in the fields of agriculture, food production, and the environment. Its aim is to develop concrete and sustainable solutions at the international scale.

This commitment was embodied in the reorganisation of the institute's scientific divisions as well as in the creation of two new administrative bodies that are unique within the French research landscape: the General Directorate for Expertise and Support for Public Policies (DGDEAPP) and the Directorate for Open Science (DipSO).

.00 Prelaunch of INRAE /

2019-the year of INRAE's prelaunch

The merger was approved in 2018. The merger process included a prelaunch period during which strong social commitments were made. They were bolstered by a continuous social dialogue and a comprehensive approach to facilitating change. Out of this prelaunch phase arose INRAE, which was born on January 1, 2020 with its new structures, organisational framework, and regulations in place.

The new institute draws strength from its 12,000 employees with their highly diverse skill sets and from its budget of €1 billion. The merger made good on its strong social commitments: for example, all research sites were kept open, and employees were able to make choices about their occupational mobility.

The social dialogue was facilitated by specific administrative bodies at each institute (i.e., the works council and the Committee for Health, Safety, and Working Conditions) and by joint groups created ahead of the future institute. Finally, six working groups composed of staff representatives helped write the organic and statutory decrees. They also contributed to the development of human resources measures related to employment, career paths and remuneration, time management, social policies, disability policies, and occupational health and safety.

The merger was led by a strategic committee, over which the CEOs of INRA and IRSTEA jointly presided. This committee put together a plan to guide the process, bringing together the institute's human resources (e.g., defining new organisational structures and allowing employees to make choices about their assignments), occupational health and safety (e.g., creating a risk prevention committee, having licensed experts carry out an inventory of the quality of life at work) and communication departments (e.g., electronic messages, intranet, and videos). The prelaunch process made it possible to develop action plans for the different administrative bodies starting in the fall of 2019. Fine-scale impact mapping was used. Since the merger, a different dedicated committee has taken over the reins.

The supervisory ministries provided funding to cover the expenses specifically arising from the merger process (e.g., consulting services, the fusion of the employee compensation systems, and the integration of the information systems). Furthermore, the economies of scale resulting from the merger allowed resources to be shifted towards the research units, evening out funding differences between INRA and IRSTEA.

Marc Michel and Philippe Mauguin conversing with teams from INRA and IRSTEA. © INRAE

inra.fr/en

Feasibility study — 14 months
- Nov. 26, 2016 — Reflection period begins
- Nov. 30, 2017 — Scientific report released

Development — 9 months
- Feb. 6, 2018 — Ministries send engagement letter
- Oct. 17, 2018 — Interim report released

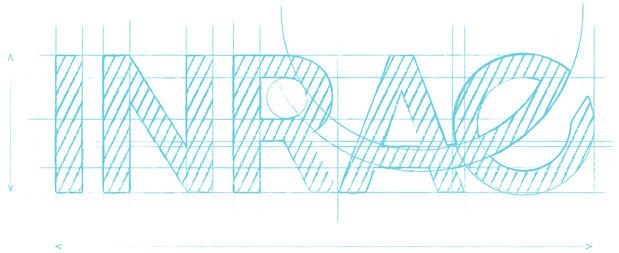
Prelaunch — 14 months
- May 22–24, 2019 — INRA and IRSTEA Boards of Directors meet
- June 11, 2019 — Meeting with CNESER–MESRI
- Late 2019 — Decrees appear

The new EPST — January 1, 2020
- **INRAE is born**

.00 Prelaunch of INRAE /

Defining our strategic priorities INRAE 2030

In 2019, as a crucial part of the merger, INRAE launched its participatory project–INRAE 2030–for defining its strategic priorities. In September, the directors of the future research units met four times. All the institute's employees were then encouraged to provide input via a dedicated platform and to join in-person workshops. The project will continue to be shaped by contributions from INRAE's national and international partners in 2020 before being finalised at the end of the year.



INRAE 2030 workshops
2019/2020
@Authors-INRAE

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Scientific highlights ›

Adapting to climate change /

The environmental, economic, and social changes taking place across the globe are causing great uncertainty and a variety of risks. To manage resources more sustainably and better ensure food and nutrition security, we need more research on the ecosystems that supply us with goods, including food. To deal with these worldwide shifts, we must use science to understand and predict ecosystem changes as well as to design and test our future production systems.

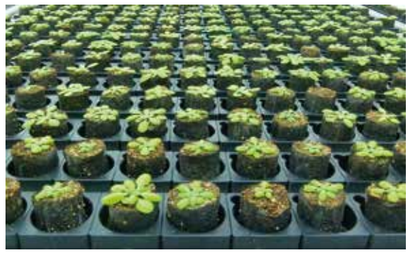
Adapting agricultural and forestry systems to climate change

Plant genetic complexity allows an array of potential adaptations

To survive in and colonise markedly different habitats, plants must be able to handle environmental variability. Over the course of evolution, plant species have acquired phenotypic plasticity in their traits, which allows them to vary in their responses to different environmental conditions. Phenoscope is a high-throughput phenotyping device for monitoring plant growth under strictly controlled, highly reproducible conditions (https://phenoscope.versailles.inra.fr/). Researchers have been using it to uncover the genetic foundations for phenotypic plasticity in plants. The device has helped reveal the startling genetic complexity responsible for variation in shoot growth resulting from differences in water availability. These findings have paved the way for new research on the uncharacterised genetic variation that controls the effect of stress on traits of adaptive and agricultural interest.
PLOS Genetics
DOI: 10.1371/journal.pgen.1007954

Predicting the characteristics of crop variety mixtures to better select and manage complex assemblages

As farmers face the effects of climate change and seek to reduce input levels, they are increasingly using crop variety mixtures. This strategy is especially common in organic agriculture. However, little information is available to help farmers choose which mixtures to employ. Via collaborative research, geneticists and statisticians have developed new methods for predicting the characteristics of variety mixtures. When these methods were applied to a set of 25 bread wheat varieties combined in various mixtures, yield predictions improved.
Field Crops Research
DOI: 10.1016/j.fcr.2019.107571



Modelling allows informed choices about crop varieties based on climatic conditions

How can we know if a plant variety is well suited to a given environment? How can we predict variety yield under different sets of climatic conditions? Yield depends on the complex interactions between the variety's genotype and ambient environmental conditions. Researchers at INRA and Wageningen University and Research (WUR) in the Netherlands developed a model that predicted the yields of different maize varieties based on the latter's genomes and growth conditions. To this end, they used the observed yields of 246 varieties grown at 25 sites in Europe and Chile. This model is a helpful tool that farmers can use to choose varieties that are well suited to a given cultivation area. This work highlights the value of maize genetic diversity and will aid efforts to adapt agricultural systems to climate change.
Nature Genetics
DOI: 10.1038/s41588-019-0414-y

Nearly 1,500 *Arabidopsis thaliana* plants growing on 2 of the 4 Phenoscope robots of the Plant Observatory
© O. Loudet - INRAE

Flowering cherry trees at the Arboricultural Experimental Research Unit of Toulenne (Centre of Bordeaux-Aquitaine)
©A.Girard - INRAE

Identifying at-risk zones for cherry production based on chilling requirements

As the average global temperature climbs, plant phenology is headed off track. Notably, the timing of flowering and fruit maturation is under threat, and, as a result, the productivity of fruit trees may be affected. It is therefore crucial to prepare for future climatic conditions by helping farmers and breeders develop better adapted varieties and more suitable practices. Using the chilling requirements of cherry varieties, researchers discovered that the size of at-risk zones, where temperatures are too mild, will increase by 2075–2100. In particular, these at-risk zones will significantly expand in the Mediterranean and along the French Atlantic Coast, especially in the case of late-flowering varieties. Consequently, areas with colder climates may become the new centres of cherry production.
International Journal of Biometeorology
DOI: 10.1007/s00484-018-1649-5

INTERVIEW WITH

Evelyne COSTES

Joint Research Unit for the Genetic Improvement and Adaptation of Mediterranean and Tropical Plants (AGAP), Centre of Occitanie-Montpellier

What role does tree architecture play in adaptations to climate change?

Tree architecture affects the leaf surface distribution in space, flowering/fruit development, and the crown microclimate, which are all associated with variation in light levels. Microclimatic conditions impact gas exchange between the leaves and the surrounding air, thus influencing carbon assimilation and water loss via transpiration. To deal with climate change, it will be crucial to increase the efficiency of tree architecture and resource use via the exploitation of genetic variation, plot management, and tree management. Other adaptive responses to climatic conditions include shifts in the various stages of the annual development cycle (i.e., from budbreak to the end of growing season); leaf senescence; and dormancy, which are all also linked to tree architecture.

Is it possible to measure the performance of many perennial plants all at once in the field?

To characterise the architecture and performance of numerous trees in the field, we have begun utilising digital technology. For example, we can use drone-based data obtained using terrestrial laser scanning, multispectral imaging, and thermal imaging to build 3D reconstructions of trees, calculate indices of leaf density and chlorophyll content, and estimate leaf surface temperatures. We can then use this information to determine transpiration rates or fruit loads. We have also sought to develop new indicators for the stages of the annual development cycle and for interactions between consecutive cycles. We are currently exploring how deep and machine learning can improve algorithm performance.

What results has this high-throughput phenotyping yielded thus far?

We have phenotyped a range of French apple varieties based on multiple criteria, which are related to tree architecture and leaf responses to environmental conditions. To verify the validity of our technique, we directly characterised the volume, shape, leaf surfaces, and various functional indices of cover using control trees. This multicriteria assessment should make it easier to identify varieties and traits of interest and to pinpoint the genes at work. We will then be able bring about targeted genetic improvements. A PhD student is currently building on this research thanks to joint funding from INRA and the Digital Agriculture Convergence Lab (#DigitAg).
https://url.inrae.fr/2XL4ZJV

> To deal with climate change, it will be crucial to increase the efficiency of tree architecture and resource use

IN BRIEF

> EXPERIMENTAL TOOLS

Siclex: an experimental device that simulates extreme climatic conditions to study how grasslands adapt to climate change

Worldwide, grasslands account for the greatest percentage of usable farm area. Grasslands provide environmental benefits and increase the self-sufficiency of livestock farms. Their incorporation into agricultural systems may therefore help us confront the challenge of adapting to climate change. However, it remains unclear how grasslands will respond to the combined lower levels of water availability, higher temperatures, and higher carbon dioxide levels that will result from climate change. Siclex is a device for simulating extreme climatic conditions. It is being used at a research unit in Lusignan to carry out large-scale experiments examining how grasslands react to climate change. Precipitation intensity and duration can be controlled without affecting light levels. Funding for Siclex came from a partnership involving the European Union, INRA, the regional government of Nouvelle-Aquitaine, and the Fondation Xavier Bernard.

Siclex: an experimental device that simulates extreme climatic conditions to study how grasslands react to climate change. Multidisciplinary Research Unit for Grasslands and Forage Crops (URP 3F), Lusignan. © S.Laval–INRAE

Phenotis: an experimental tool for exploring the sustainability of winegrowing

The INRA Centre of Grand Est-Colmar possesses a unique experimental device specifically designed for studying grapevine diseases. Its name is Phenotis, and its creation was funded by the regional government of Grand Est, in the form of a planning agreement with the national government (*Contrat de Plan État-Région* [CPER] 2015–2020). The goal of the research conducted with Phenotis is to generate knowledge, resources, and tools that can be funnelled into innovations that simultaneously reduce inputs, maintain product quality, and increase climate-based adaptations in winegrowing systems.

> PARTNERSHIPS

Using spatial technologies for agricultural and environmental purposes

In July 2019, a partnership agreement was signed with the French National Centre for Space Studies (CNES). The purpose was to collaborate on future projects involving the agricultural and environmental sciences. Topics of interest include predicting yields; examining the effects of climate change on agroecosystems; developing new forms of precision agriculture; sustainably managing soils and assessing the latter's ecosystem services; and exploring forest ecosystems, biodiversity, and water resources. These collaborations will notably take the form of joint research programmes and will involve the exchange and analysis of information/data.

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FOCUS

How forests adapt

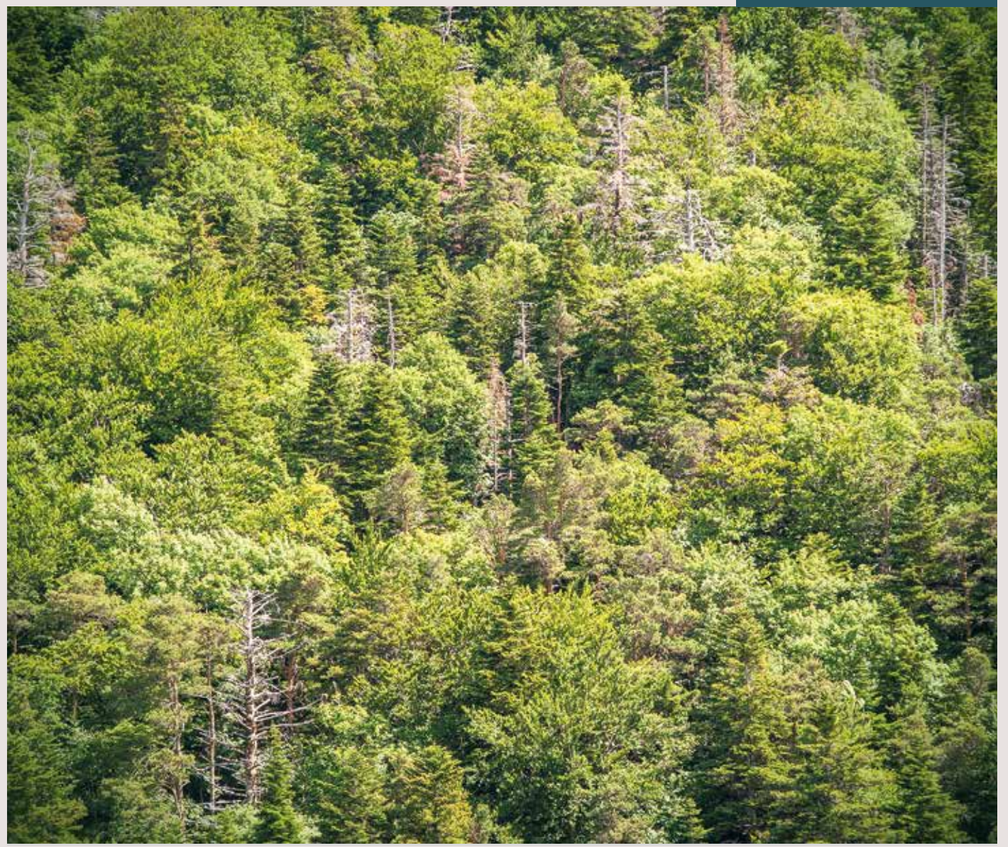
To preserve forests, we will need to deal with increasing temperatures and longer, more intense droughts. Furthermore, there is an increased demand for wood-based products, largely driven by shifts in environmental policies. Many studies have thus examined the mechanisms used by trees to respond to drought. It is also necessary to predict the longer-term susceptibility of forests to better define *ad hoc* management strategies. A series of publications examined different facets of this issue.

Stomatal dynamics depend on water availability

Three recent dissertations by PhD students in the SILVA Joint Research Unit (INRA, University of Lorraine, AgroParisTech) have enhanced our understanding of the functioning of stomata, the tiny pores found on leaf surfaces. Stomata regulate the intake of atmospheric carbon dioxide and the loss of water (i.e., *via* transpiration). More specifically, the students used poplars to understand how stomata react under the drought conditions frequently experienced by these trees. The research examined a variety of relevant factors: the rate at which the stomata opened and closed, the vapor pressure deficit of the surrounding air, light levels, stomatal morphology, and water use efficiency. The results have demonstrated that it is important to take these variables into consideration when characterising the drought tolerance of different species as well as when modelling transpiration and photosynthesis at broader scales, such as those represented by forest ecosystems.

New Phytologist
DOI: 10.1111/nph.15710
Plant, Cell & Environment
DOI: 10.1111/pce.13644
Environmental Pollution
DOI: 10.1016/j.envpol.2019.06.110

Stomata on the underside of a nectarine leaf. These pores are sites of gas exchange (e.g., of oxygen, carbon dioxide, and water vapour) between the plant and the surrounding air, and they regulate osmotic pressure. G = 680. Scale: 0.1 mm.
© C. Bodet–INRAE



The slopes of Mont Ventoux clearly illustrate the different stages of tree decline (change in leaf colouration, defoliation, desiccation, and death) resulting from climate change.
© B. Nicolas–INRAE

Greater subsoil water availability helps forests deal with drought

Two complementary experimental studies have underscored that, in karst regions, trees are better able to handle droughts when water availability is higher in the subsoil. The first study used an isotopic approach and showed that, when experiencing severe droughts, common Mediterranean forest species, such as the holm oak, the beech, and the silver fir can draw up large quantities of water from the subsoil. The second study used electrical resistivity tomography to estimate water availability in the soil and subsoil. Both studies found that, for the species studied, tree water status depended on soil and subsoil water availability as well as on tree leaf surface.

Science of the Total Environment
DOI: 10.1016/j.scitotenv.2019.134247 10.1016/j.scitotenv.2019.134332

Species distribution models better predict the susceptibility of forest species to climate change

Species distribution models (SDMs) are often used to formulate hypotheses about the effect of climate change on the natural distributions of tree species. However, these models rely on some rather simplistic assumptions. They ignore, for example, critical biological phenomena that allow species to react rapidly to changing environmental conditions. Indeed, few models currently account for a key facet of this response: the phenotypic plasticity of functional traits and the resulting impact on tree fitness. Here, fitness was defined in evolutionary terms, as the average contribution that an individual will make to the next generation as a result of its specific genotype. In several recent studies, INRA researchers developed and used a new generation of models (ΔTraitSDM) that incorporate phenotypic plasticity when simulating the distributions of forest trees. Overall, the results of these models paint a less alarming picture than those of traditional SDMs regarding the future of forests. They indicate that phenotypic plasticity should greatly help certain populations or species deal with climate change.

New Phytologist
DOI: 10.1111/nph.15716
Global Ecology and Biogeography
DOI: 10.1101/527390
Global Change Biology
DOI: 10.1111/gcb.14881

Reducing the effects of agriculture on greenhouse gas emissions

Herd of Montbéliard cows grazing on a grassland.
© C. Slagmulder–INRAE

Quantifying the methane emissions of livestock

To reduce the contributions of ruminant livestock to global warming, one strategy is to lower emissions of enteric methane. To this end, it is crucial to precisely quantify these emissions at different scales–from individual animals to entire herds within France and across Europe. Simultaneously, research must be carried out on physiological factors that cause variability in enteric methane release.
A new approach for modelling these emissions has arisen from a meta-analysis of experimental databases. The latter came from different international projects looking at the greenhouse gas (GHG) emissions of ruminant livestock systems. This work has led to the development of a new inventory method, which will help improve GHG inventories at national and international levels. Furthermore, the results of this research underscored that it is necessary to use specific equation systems for a given animal species, the nature of which will depend on the livestock system in use and the country where animals are located.

Journal of Environmental Management
DOI: 10.1016/j.jenvman.2018.10.086
Global Change Biology
DOI: 10.1111/gcb.14094
Animal Feed Science and Technology
DOI: 10.1016/j.anifeedsci.2019.114207

The rumen microbiota and enteric methane production of Holstein cows

Individual cows have been found to vary in their emissions of enteric methane. It remains unknown how much the microbial composition of the rumen (i.e., the rumen microbiota) contributes to these differences.
An analysis of the rumen microbiota in Holstein cows revealed that three groups of bacteria, or three "ruminotypes", were present. Researchers identified a set of microbial biomarkers that were linked to both the structure of the bacterial populations and the level of enteric methane emissions. These biomarkers could be useful in breeding programmes, provided that they are heritable.

Journal of Animal Breeding Genetics
DOI: 10.1111/jbg.12427

Monitoring changes in soil carbon sequestration

The 4 per 1000 initiative has asked all agricultural managers and stakeholders to take concrete action to promote carbon storage in soils. The initiative has also requested that sustainable practices be developed to minimise agricultural impacts on soils and, as a consequence, the environment. To assess the efficacy of the approaches being used, it is essential to have methods that monitor carbon sequestration at the level of agricultural landscapes. This scale is highly relevant to carbon dynamics because it incorporates both habitat characteristics and regional land use. Researchers used an innovative methodology to examine spatial variability in the carbon storage levels in the soils of 64 plots within an agricultural landscape in Brittany. Their approach combined direct measurements with spatial modelling.

Geoderma
DOI: 10.1016/j.geoderma.2019.03.005

A miniature free-air carbon dioxide enrichment (FACE) device
Centre of Clermont-Ferrand · Theix-Lyon
© S.Toillon-INRAE

Means and costs of reducing the greenhouse gas emissions associated with dairy farming

With a view to better informing public policies, economic modelling was used to simulate the costs of different strategies for reducing the greenhouse gas emissions arising from dairy farming. Implementing a carbon tax equivalent to the current price of allowances within the European Union (EU) cap-and-trade system would only reduce emissions slightly (1–6%). Increasing this hypothetical tax five-fold would result in a somewhat greater reduction (4–15%). Such a level of taxation would simultaneously lead to a decline in production. A more effective approach would be to streamline current climate change policies via common agricultural policy measures, such as green direct payments, climate-focused agroecological practices, or methods associated with the EU nitrate directive. In this way, emphasis would be placed on more effective agricultural practices, such as feeding productive livestock with forage from low-input systems and transferring dairy farms to zones that are less suitable for crop production.

Journal of Cleaner Production
DOI: 10.1016/j.jclepro.2019.07.064

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Scientific highlights >

Diverse and multiperformance agriculture /

There are challenges that face agriculture as a whole. First and foremost, we must improve food security. However, we must also work to provide environmental services, help the world adapt to climate change, and structure rural areas and their connections to urban zones.

Agroecology can be used to promote production systems that create value from biological diversity and natural processes. The agroecological transition demands that we invest resources in the biological sciences, social sciences, ecology, and economics. Research must also be conducted on the complex interactions of farming systems to better deal with the challenges of multiperformance agriculture. To enhance their relevance and impact, future studies must also take into account the knowledge and constraints of farmers.

Guiding the agroecological transition

Diversifying agricultural systems as part of the agroecological transition

As agriculture is increasingly informed by ecology, numerous highly diversified agricultural systems are emerging. It is important to analyse the multiple consequences of this phenomenon. Researchers have developed an analytical framework for quantifying the effects of different diversification systems (excluding biological interactions) and crop associations (including biological interactions) that is based on estimating variation in yield.
This framework was applied to publicly available data for agricultural crops, making it possible to identify and rank crop associations based on their potential. The researchers were also able to characterise the minimum degree of variability associated with a given type of diversification system or association, as well as the number of species beyond which risk reduction became negligible. This approach could be used with all types of diversified production systems.

It is crucial to gather additional information on certain species whose use in such systems has been proposed. For example, researchers have become interested in camelina, an oleaginous species that is highly tolerant of water stress; has few pathogens; can be used in a variety of food and non-food products; and is flexible in how it can be grown (e.g., on its own, in associations, as a main crop, or in a double-cropping system). Camelina was used in cropping system prototypes that were customised for different farm circumstances following a preparation period during which a novel design framework was used. This framework involved a brainstorming workshop with multiple stakeholders; preliminary trials that were designed and evaluated by farmers; a range of field tests at multiple locations and across multiple years that were designed and managed by agricultural scientists; and a design workshop.
Agriculture, Ecosystems & Environment
DOI: 10.1016/j.agee.2019.106711
Industrial Crops and Products
DOI: 10.1016/j.indcrop.2019.111605

Using production contracts to facilitate the agroecological transition

Diversification is often hampered because farmers lack information about techniques for growing and transforming specialty crops. Indeed, less research and development (R&D) funding has been directed towards these crops than towards more common crops. One challenge is therefore to encourage stakeholders to collect knowledge about crops that could be used to diversify production systems in a way that fits with regional diversity. Often, fostering collective efforts of this type involves creating more profitable commercial opportunities than are available through the regular market. Recent research has underscored the major role played by the establishment and regulation of production contracts in generating knowledge about the crops used in diversification.
The results of this work can help agricultural stakeholders better understand the organisational aspects of this issue and can thus promote the emergence and development of new competitive sectors.
Journal of Rural Studies
DOI: 10.1016/j.jrurstud.2019.10.040

Aerial view of hedgerow landscape in the west of France.
© INRAE [AdobeStock]

Facilitating the conversion from conventional to organic agriculture

In recent years, French dairy farmers have found themselves in a precarious situation because of industrial crises. Many livestock farmers have therefore undertaken the conversion from conventional to organic agriculture with the hope of finding greater stability. However, the conversion process involves a series of changes that are anything but certain, and farmers may have to wait 1.5 or 2 years before being able to sell their milk at organic prices. Therefore, researchers wished to investigate whether the conversion to organic agriculture affected farm vulnerability during or at the end of the conversion process. A longitudinal study was conducted in which dairy farms in this situation were monitored. The results showed that converting to organic agriculture can be an extremely effective strategy for increasing the economic stability of dairy farms, provided that farmers adopt a more self-sufficient and cost-effective system that centres on grasslands and grazing. These findings can help revise the technical manuals currently used by the advisory bodies that guide farmers through the conversion process.
Agronomy for Sustainable Development
DOI: 10.1007/s13593-019-0565-3

IN BRIEF

Saying goodbye to glyphosate: a resource centre offers concrete solutions to farmers
In June 2019, the French government adopted an action plan to stop the primary uses of glyphosate by 2020 and to stop all uses of glyphosate by 2022. To provide guidance to farmers during this transitional period, a resource centre was established by the Agricultural Technical Institutes Association (ACTA), the French Chambers of Agriculture (APCA), and INRA. The centre has already made available around 50 technical alternatives to glyphosate use; these methods have all been researched and tested. When implementing these new techniques, farmers can benefit from facilitation measures and guidance provided by agricultural stakeholders.
ecophytopic.fr

ÉCOPHYTO PIC | RÉDUIRE ET AMÉLIORER L'UTILISATION DES PHYTOS

Reducing the use of synthetic pesticides and anti-infective agents in agricultural systems

The importance of the regional scale when promoting the sustainable and parsimonious use of fungicides

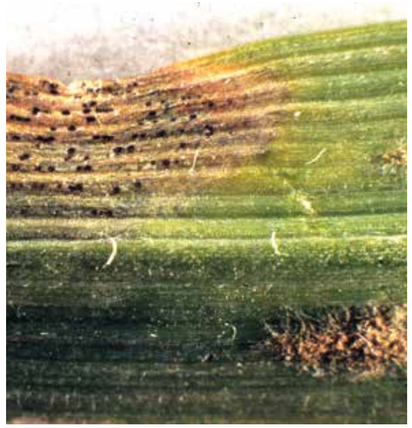
In agricultural production systems, the resistance of phytopathogenic fungi to fungicides presents a major challenge because this phenomenon complicates efforts to reduce pesticide use.
The causes behind the emergence of resistance remain poorly understood. To clarify the factors in operation, researchers analysed a data set of an unprecedented spatial and temporal scale. For 13 years and across all of France, 70 tests were conducted annually to assess the performance of the fungicides used to treat Septoria leaf blotch in wheat. The results showed that there was marked spatial variation in the emergence of resistance. This pattern was largely explained by the amounts of fungicides used within different regions. The findings also underscored that, to more effectively deal with resistant fungal pathogens, coordinated management strategies must be developed at the regional scale.

Pest Management Science
DOI: 10.1002/ps.5360

Solving the evolutionary mystery of root-knot nematodes

Understanding the biology of pests is a crucial part of developing strategies to control them. Root-knot nematodes are the world's top nematode pests because they are widely distributed and cause tremendous economic damage to agricultural production. Past research has suggested that the most devastating of the root-knot nematodes have eschewed sexual reproduction, an occurrence that is extremely rare in animals and that is viewed as an evolutionary dead end. However, this hypothesis was based on cytogenetic analyses carried out in the 1980s and had never been independently tested. Researchers used a genomics approach to perform analyses on various isolates collected from *Meloidogyne incognita* populations. They confirmed, for the first time, that the species only reproduces clonally. They also showed that *M. incognita* can exploit a very wide range of hosts thanks to the multiple independent adaptations it has acquired. It truly appears to be an "evolutionarily scandalous" pest.
These findings are of both fundamental importance, because they broaden our understanding of adaptive mechanisms, and applied importance, because they raise questions about certain current pest control methods.

bioRXiv
DOI: 10.1101/362129
Peer Community In Evolutionary Biology
DOI: 10.24072/pci.evolbiol.100077



Symptoms of Septoria leaf blotch on wheat.
Plant Health and Environment – Rennes

INTERVIEW WITH
Chloé DELMAS
Joint Research Unit for Vine Health and Agroecology (SAVE),
Centre of Nouvelle-Aquitaine-Bordeaux

What are the challenges caused by grapevine trunk diseases?
Grapevine trunk diseases (GTDs) are caused by a variety of pathogens, and they are one of the major causes of grapevine decline (i.e., decreased yields and rootstock mortality). The effects of GTDs have been particularly bad over the last 20 years because we lack efficacious treatment methods. Many facets of the interactions between grapevines, environmental conditions, and GTDs remain unexplored, leaving gaps in our understanding of foliar symptoms, notably those caused by esca.
Because of technical constraints, we have rarely been able to test the hypotheses put forth to explain why esca erratically causes foliar symptoms in grapevines. The greatest difficulty is that we have been unable to elicit these foliar symptoms under controlled conditions. However, understanding disease etiology is essential if we wish to develop growing practices that effectively prevent and/or control GTDs.

> Many facets of the interactions between grapevines, environmental conditions, and GTDs remain unexplored

What experimental approaches have you used in your research?
We adopted two creative approaches to surmount these scientific obstacles.
First, we set up experiments using older plants obtained from a vineyard that had been hit by esca. These plants were transported from the vineyard to the laboratory in pots and studied under controlled conditions. Second, we performed X-ray microtomography at the SOLEIL synchrotron facility, which allowed us to directly and non-invasively observe the vascular systems of the rootstock. This collaborative and interdisciplinary project allowed us to test, for the first time ever, whether hydraulic dysfunction was associated with esca's foliar symptoms, as hypothesised elsewhere.
We used an approach that combined plant pathology and physiology.

What are the broader implications of your results?
In our field of research, the main challenge is identifying the exact sequence of events that precedes the drop in yield and plant death, notably the loss of leaves and berries. We also need to have a better understanding of the viticultural practices and environmental conditions that influence the development of these diseases. To this end, we must shift the paradigm. Instead of viewing grapevine decline as a disease, and notably as a GTD, we need to see it as a systemic problem caused by a set of interacting factors.

(The project is part of the French National Plan for Vineyard Decline [Plan national de dépérissement du VIGNOBLE], which is funded by the Ministry for Agriculture and Food)

Plant physiology
DOI: 10.1104/pp.19.00591

Ground beetles have an appetite for weeds

Ground beetles are important biological control agents that are used to fight slugs and aphids.
Recent work suggests that they may also help deal with weeds thanks to their role as seed predators.
Researchers sampled three of the most common ground beetle species occurring in fields of organically grown grains across Central Europe. DNA analysis of the beetles' regurgitates and gastric contents were then used to characterise their diets.
The results showed that as many as 90% of individuals had consumed the seeds of weeds. The seeds represented a large proportion of the beetles' diets, a greater proportion than that represented by slugs and aphids. Furthermore, the proportion of ground beetles that had consumed the seeds of weeds was comparable among the sampling points, suggesting that this result is reliable and represents a generalised pattern.
Collaborations have been established with farmers to develop management strategies that promote ground beetle abundance and diversity.

Journal of Pest Science
DOI: 10.1007/s10340-019-01109-5

Reintroduction of a species facing extinction: *Carabus olympiae*.
© J.-C. Malausa - INRAE

IN BRIEF

Sustainable winegrowing: four grape varieties honoured

At the 2019 SIVAL Innovation Awards, the ResDur grape varieties created by INRA received a gold model in the "Varietal Innovation" category. The four varieties–Artaban, Floreal, Vidoc, and Voltis–are resistant to powdery and downy mildew but nonetheless produce wines of equivalent quality to those made with conventional grape varieties.
By allowing a drastic reduction (-87%) in fungicide use, these grape varieties can be used as the basis for high-performing and environmentally friendly winegrowing systems.

Research project on rice fungal pathogens receives Starting Grant funding from the European Research Council (ERC)

Stella Césari, a young INRA researcher, has been awarded an ERC Starting Grant for her research project, **ii-MAX**, which explores the cellular processes targeted by the fungus *Magnaporthe oryzae* in its host, rice. Césari is part of the Joint Research Unit for the Biology and Genetics of Plant-Pathogen Interactions (BGPI). This work will help identify new mechanisms of plant immunity, which can then be exploited to create rice varieties that display resistance to fungal diseases..

An agroecological layout designed to produce fruit without pesticides.
Gotheron (Drôme)
©T. Nicolas - INRAE

Priority Research Programme
"Growing and protecting crops differently"

France continues to use excessive levels of plant protection products, which contaminate the environment and negatively impact both human and ecosystem health. To respond to the serious societal concerns tied to this issue, the French government launched the priority research programme "Growing and protecting crops differently". INRA was entrusted with the programme's scientific leadership and organisation.

The programme will dedicate its €30 million budget to producing fundamental knowledge and applying what is learned to cropping system design and collective management schemes. Thanks to the input of stakeholders in the agricultural industry, this work should lead to new alternatives to the use of plant protection products.

The French National Research Agency (ANR) awards the programme's funding and encourages cutting-edge projects that will generate disruptive innovations, such as the following:

- Broad-scale integrative projects that bring together large consortia with the objective of designing new production systems; of particular interest are projects that focus on the plant microbiota and on humanities and social sciences topics that are linked to zero-pesticide systems.
- Epidemiological surveillance projects that seek to develop updated prevention methods using new types of information technology.

Boost the resilience of livestock and limit the risk of zoonotic diseases

Controlling parasitic diseases in livestock

Dealing with parasitic diseases is a major challenge in livestock farming. However, reducing the use of anti-infective medications is also a public policy objective. Two recent studies have highlighted alternative methods for controlling these illnesses. It would be possible to create more efficient and sustainable breeding programmes if we had a better understanding of the mechanisms related to the genetics of resistance. The first study examined the mechanisms underlying resistance to gastrointestinal nematodes in Creole goats. Its findings will guide future research on the mechanisms used to repair the intestinal mucosal barrier and will help identify biological markers that can be used in efforts to bolster genetic resistance.
That said, parasites will continue to be controlled via the responsible use of anti-infective medications. The second study explored the mechanisms behind drug resistance in nematodes, using the free-living roundworm *Caenorhabditis elegans* as a model species. Researchers uncovered a previously unidentified transcription factor that regulates the elimination of medicinal compounds. This transcription factor was found to reduce the efficacy of ivermectin, a commonly employed antiparasitic. This same transcription factor was also observed in parasitic nematodes of veterinary importance that infect livestock. Because of the way in which it functions, the transcription factor plays a major role in allowing nematodes to develop drug resistance, which means it may be a useful target in efforts to develop new treatments for parasitic diseases.

PLOS One
DOI: 10.1371/journal.pone.0218719
PLOS Pathogens
DOI: 10.1371/journal.ppat.1007598

Creole goats
©J.Niore - INRAE

A new major target for cryptosporidiosis control

Cryptosporidiosis is a common disease in livestock. It causes diarrhoea in newborn calves, which can be fatal. Methods for controlling cryptosporidiosis remain limited: there is a single authorised medication on the market, whose efficacy depends on treatment occurring before the first symptoms appear. This disease can be transmitted to humans and is particularly life threatening to the immunocompromised and young children. Indeed, it is the diarrheal disease with the second highest rate of mortality.
INRA and INSERM researchers recently identified a potential drug candidate for treating cryptosporidiosis. The compound's mechanism of action has yielded insights that can be generally applied to develop broad-spectrum antiparasitics.

Science Translational Medicine
DOI: 10.1126/scitranslmed.aax7161

Progress in the fight against respiratory infections in humans and cattle

Pneumonia is the main cause of human infant mortality in the world. It is also often fatal for young calves. Respiratory syncytial virus (RSV) is one of the most common causative agents. As part of an international collaboration, researchers were able to provide the first structural description of an enzyme, RNA-dependent RNA polymerase (RdRp), that is crucial to RSV's survival and replication. Currently, RSV vaccines for cattle are highly ineffective, and no vaccines even exist for humans. The characterisation of this key enzyme is a major step forward in efforts to develop RSV control strategies.

Cell
DOI: 10.1016/j.cell.2019.08.014

Researchers explore tick phylogenetics using transcriptomes

Ticks can vector pathogens, and their capacity to do so varies depending on species identity and biology. One particularly good vector is *Ixodes ricinus*, the most widely distributed tick in Europe. To better understand the evolutionary relationships among tick species, it is essential to accurately reconstruct tick phylogenies and tease apart ties between species, about which there remains uncertainty. Transcriptomes are key to understanding species biology because they can be used to reveal tick lifestyles (e.g., by determining gene sequences and expression levels). They can also illuminate patterns of species evolution. Researchers generated the first phylogeny of hard ticks (the Ixodidae family to which *I. ricinus* belongs) by using transcriptome data to clarify evolutionary relationships within the genus *Ixodes*. The same data set was used to study groups of genes other than those used in the phylogenetic analysis. More specifically, the researchers explored families of rapidly evolving genes, which can provide fodder for the adaptations of parasites.

Scientific Reports
DOI: 10.1038/s41598-019-49641-9

Sheep tick (*Ixodes ricinus*) on an ear of wheat.
© B. Chaubet - INRAE

INTERVIEW WITH
Nicolas FORTANÉ
Interdisciplinary Research Institute
of Social Sciences (IRISSO)
Centre of Île-de-France - Versailles-Grignon

You coordinate an EU-funded project, ROADMAP*, which focuses on antimicrobial use in livestock. From a One Health perspective, why does antibiotic resistance present a challenge for agriculture and human health?
Antibiotic resistance occurs when bacteria develop mechanisms for resisting the effects of antibiotics. It is part of the broader trend of microbes becoming increasingly resistant to antimicrobial drugs. The spread of these mechanisms is facilitated by the fact that bacteria can horizontally transfer resistance genes. Because it causes treatment failure, antibiotic resistance is currently among the greatest threats to global health and food security. Many different antibiotics are used to prevent and treat infections in livestock. This type of usage can give rise to resistant bacteria, which can share their resistance genes with other bacteria. Often, resistant bacteria in livestock can be passed along to humans, directly by the animals themselves or indirectly through environmental reservoirs and contaminated food. It is therefore essential that we drastically reduce our reliance on antibiotics to improve animal health. Antibiotic resistance provides a perfect example of why we need a One Health approach, which recognises that human, animal, and environmental health are all intertwined.

Why is it advantageous to use interdisciplinary approaches to tackle antibiotic resistance?
The use of antibiotics on livestock farms is affected by factors beyond health or technical concerns. There are also societal, economic, and institutional issues at play. It is thus important to build collaborations among all the scientific disciplines, which each have something to contribute, if we wish to understand why agrifood systems are still so dependent on antibiotics. This approach will also help identify solutions for promoting the more reasonable use of antibiotics.

> It is thus important to build collaborations among all the scientific disciplines, which each have something to contribute, if we wish to identify solutions for promoting the more reasonable use of antibiotics

Discoveries in the animal and veterinary sciences should be used to develop more sustainable livestock systems and to develop preventive approaches to animal diseases. The social sciences can help clarify the constraints faced by different farmers. These constraints are determined by factors such as the structure of the veterinary medicine market, the expertise and practices of those working in the field of animal health, and regulatory policies related to antibiotic usage and antibiotic resistance.
We must work together if we want to develop long-term solutions to the challenges created by antibiotic resistance. IRISSO has been carrying out interdisciplinary research in animal health for many years. This commitment started with the Integrated Management of Animal Health metaprogramme and continues today in the form of the Livestock Health and Welfare (SANBA) metaprogramme. Our collaborations grow stronger every day and have allowed us to construct an international network of interdisciplinary research.

What are the main research questions that ROADMAP seeks to answer?
Together with our 17 European research partners, we have decided to focus on three lines of research that we feel are important if we wish to promote the more sensible use of antibiotics in food systems.
First, we must understand how and why antibiotic usage is context dependent (e.g., varies among countries or production systems), which involves studying stakeholder practices and behaviours as well as examining the structure of food and pharmaceutical systems. Second, we must work with animal health professionals and other stakeholders to design and develop innovative strategies that will encourage a more cautious and customised approach to antimicrobial use in animal production systems. Third, we must evaluate and maximise the impacts of the resulting technical and/or socioeconomic innovations while also producing recommendations that can help guide the transition towards more prudent antibiotics usage.
Thus, to help create these innovations, ROADMAP uses both interdisciplinary and participatory approaches to solicit input from all the major players and stakeholders of relevance.

**Rethinking Of Antimicrobial Decision-systems in the Management of Animal Production*
https://www.roadmap-h2020.eu

Improving animal welfare: a major societal expectation

Regulating livestock reproduction with kisspeptin analogue C6 instead of with hormones

In temperate regions, the natural reproductive cycles of female goats and sheep are synchronised with the seasons. In most breeds, offspring are born in the spring. Because consumer demand for milk exists year round, farmers use hormonal treatments to cause births in the autumn as well. Such treatments often involve the administration of two hormones: 1) a progesterone analogue and 2) equine chorionic gonadotropin (eCG) obtained from pregnant mares. However, certain health risks are associated with this technique. Furthermore, the production of eCG raises questions regarding animal welfare. Research carried out on small ruminants has led to the development of a compound that can trigger the reproductive cycle outside of the normal reproductive season. It is a synthetic peptide named kisspeptin analogue C6. The results of this work suggest that kisspeptin analogues could serve as alternatives to animal hormones if we wish to regulate livestock reproduction more sustainably and in a way that respects animal health and welfare.
PLOS ONE
DOI: 10.1371/journal.pone.0214424

The French Reference Centre for Animal Welfare strengthens its role

Society is paying greater and greater attention to the issue of animal welfare. The French Reference Centre for Animal Welfare (CNR BEA) was created as part of France's national strategy for animal welfare (2016–2020), which was launched by the French Ministry for Agriculture and Food. This unique establishment brings together representatives from INRA, ANSES, ACTA, and France's four national veterinary schools. It has been headed by INRA since its creation in 2017. CNR BEA provides collective expertise and makes available scientific and technical knowledge that stakeholders can use to improve animal welfare.
In 2019, the centre reaffirmed its commitment to its objectives and developed a space where diverse organisations could come together to work and dialogue. As part of its duty to provide support, it has responded to an increasing number of requests for expertise from the French Ministry for Agriculture and Food. It is also creating a platform where resource documents can be accessed and building a website where its different partners can collaboratively monitor topics of concern.
www.cnr-bea.fr

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Ouesterel–exploring livestock conditions thanks to Innovation Regions funding

Ouesterel (Ouest territoires d'élevage) is a regional innovation laboratory (LIT) headed by INRA. It received funding from the Innovation Regions grant programme, which is part of the French Investments for the Future Programme (PIA3). To strike a balance between societal expectations and livestock farming constraints, this LIT seeks to jointly construct new models for rearing, transporting, and slaughtering animals. The objective is that these models meet the expectations of consumers and the general public while also taking into consideration the limitations of economic stakeholders in the animal production industry.
Ouesterel relies on the support of a wide-ranging network of individuals and groups: regional governmental organisations (including the three Grand Ouest regional councils); stakeholders involved in livestock production, transport, slaughter, and transformation; stakeholders in the food distribution industry; digital start-ups; non-profit organisations; and public and semi-public stakeholders involved in research and development (R&D). The goal is to generate practical and technological solutions that can be used in new equipment and buildings; tools for ensuring full event traceability, from the livestock farmer to the consumer; and reference materials related to animal health and welfare. Training and educational activities will also be employed.
In 2019, Ouesterel drafted reference materials for swine and dairy cows. Those for meat poultry have already been finalised. The first steps in R&D and innovation creation have been defined, as have the methods for implementing the co-design process with stakeholders in the pilot regions.
https://url.inrae.fr/3cII5Z3

Research scientist Guillaume Martin working with a livestock farmer
© INRAE

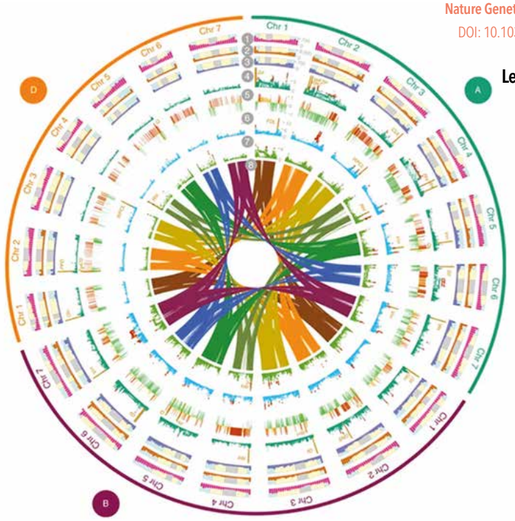
IN BRIEF

A massive open online course (MOOC) on livestock health and welfare
For various stakeholders, from livestock farmers to consumers, it has become increasingly important to account for and improve animal welfare. University professors, researchers, and veterinary specialists all came together to teach a massive open online course (MOOC) on livestock welfare. The MOOC comprised three modules: 1) "Understanding", which laid out the background for the topic; 2) "Evaluating", which discussed tools that can be used in the field; and 3) "Improving", which described a range of solutions.
https://url.inrae.fr/3cRn0KR

Characterising genomes to explore the relationships between traits and genetic diversity

Clarifying the origins of modern wheat varieties

A major research challenge is characterising the genetic diversity of wheat at the finest scale possible to explore the crop's evolutionary history. An additional challenge is optimally exploiting these genetic resources to help handle the agricultural concerns of the future. Taking on these tasks is a collective of Europe's greatest experts in wheat genetics, genomics, physiology, and agronomy; they come from the 21 research teams in the EU research consortium Whealbi. Also involved are the main public and private stakeholders working on wheat in France, who are part of the BreedWheat project, which is funded by the French Investments for the Future Programme.
Science Advances
DOI: 10.1126/sciadv.aav0536
Nature Genetics
DOI: 10.1038/s41588-019-0393-z



Map of wheat genomic diversity
©Nature Genetics

Legume genome sequenced for the first time

Pulses, notably peas, are a major part of agroecological cropping systems and are playing a significant role in the current dietary transition. The pea genome was sequenced for the first time by an international consortium composed of INRA, CEA, and research teams in the USA, Australia, Canada, and the Czech Republic. This group was led by an INRA research team.
Now that the pea genome is available, it will be easier to more effectively select for traits of agricultural interest in this crop.
Nature Genetics
DOI: 10.1038/s41588-019-0480-1

Sequencing and chromosome-level assembly of the codling moth genome–a first for an insect pest

The codling moth (*Cydia pomonella*) is a common pest in France. It is also an emerging pest in other countries, like China. It can quickly adapt to environmental conditions and has developed a strong tolerance for both the synthetic insecticides used in conventional agriculture and the natural insecticides used in organic agriculture. For the first time, the moth's genome has been sequenced and assembled. It can now be used as a reference when comparing populations of codling moths that are susceptible or resistant to pesticides and can help identify the underlying genetic determinants. This study was a collaboration between an INRA research team and Chinese, US, and Italian research teams. Its results will play an important role in the fight against this pest.

Nature Communications
DOI: 10.1038/s41467-019-12175-9

Damage caused by codling moth caterpillars in an apple orchard: apples with bore holes.
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IN BRIEF

The 12th official opinion of the INRA-CIRAD-IFREMER Ethics Committee focuses on genome editing in animals

The 12th official opinion of the INRA-CIRAD-IFREMER Ethics Committee explored genome editing in animals and primarily considered the use of new techniques, such as CRISPR-Cas9. The latter has frequently been likened to a pair of molecular scissors because it can perform very precise genomic modifications. The text examines the agricultural applications of these techniques, which include improving livestock species and developing control strategies for pests, parasites, and invasive species. The ethics committee concluded that genome editing techniques should be utilised with care in animals, especially given the difficulty of establishing clear limits on their usage and of controlling the research results.

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

Extending genome annotation to livestock species

Genome annotation is the process of associating information with a particular sequence within an organism's genome with a view to clarifying the relationship between the relevant genotype and phenotype. The data available for model species can only go so far in allowing us to understand phenotypes of interest in livestock species under real-life conditions. INRA is a major contributor to a consortium, the Functional Annotation of Animal Genomes (FAANG) project, which was launched in 2015 to remedy this problem. To date, functional maps have been developed and made available (www.fragencode.org) for four species of agricultural interest–the cow, the pig, the chicken, and the goat.

Annual Review of Animal Biosciences
DOI: 10.1146/annurev-animal-020518-114913
BioRxiv
DOI: 10.1101/316091
BMC Biology
DOI: 10.1186/s12915-019-0726-5

A genomic map of climatic adaptations in Mediterranean cattle breeds

The Mediterranean is a key zone in which exchange has long taken place between populations of European and African cattle. Researchers belonging to an international consortium characterised the demographic and adaptive history of 21 cattle breeds native to the Mediterranean. Using a pangenome analysis of genotypic data, the scientists confirmed the complex origin of these cattle populations and uncovered several genetic markers that are associated with climatic variables, which occur next to genes involved in metabolic functions, thermal tolerance, resistance to ultraviolet (UV) light, and resistance to pathogens (including the bacterium causing anthrax). These results underscore the unique traits of native Mediterranean breeds.

Molecular Ecology
DOI: 10.1111/mec.15004

What if animal breeding were not simply a matter of genetics?

At present, livestock are bred based on their genetic potential. However, non-genetic factors are also transmitted across generations and influence animal performance. These factors can be passed on physically, as in the case of the microbiota or of epigenetic markers (i.e., molecular mechanisms that modify gene expression without changing DNA sequences). They can also be transferred in non-physical ways, such as when a behaviour is transmitted via learning. Researchers consequently wish to develop a livestock selection approach that is based on inclusive inheritance, or the transmission of heritable genetic and non-genetic factors. To this end, a trait analysis model was developed that accounted for both factor types when estimating the ability of a given animal to pass on its traits to its offspring. The results pointed to changes in livestock farming practices (namely those involving animal welfare and interactions among animals) that could positively shape the non-genetic factors transmitted to future generations. This theoretical model represents a unique approach that is currently being validated using data on feed efficiency from multiple species.

Genetics
DOI: 10.1534/genetics.119.302375
Frontiers in Genetics
DOI: 10.3389/fgene.2019.01058

Gasconne cattle near Montségur (Department of Ariège)
©J. Weber - INRAE

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Scientific highlights >

Biodiversity: a key functional component of natural and cultivated ecosystems /

More and more, concerns about biodiversity are driving public policies and shaping research questions in the agricultural sciences. INRA and IRSTEA have played a major role in addressing these questions.

For example, INRA has helped conserve genetic resources and monitor pesticide use. The two institutes have also sought to better account for biodiversity in agricultural and forestry production processes, as well as to clarify biodiversity's role in the resilience and resistance of ecological systems exposed to multiple stressors.

Research is being carried out on soils, plants, and animals at a variety of scales, from genes to fields to landscapes.

Describing the state of biodiversity and understanding its functions with a view to enhancing preservation and sustainability

Soil biodiversity: the first world map of earthworms

In a world facing climate change, it is essential to identify the environmental factors (e.g., soil and climatic conditions) and the anthropogenic factors that influence the distribution and activity levels of soil organisms. This knowledge will guide the development of tools for maintaining and/or improving this facet of biodiversity, including the functions and ecosystem services it provides. Earthworms play an essential role in furnishing these ecosystem services. As a result, a large-scale study recently constructed a world map of the spatial distribution of earthworms.
More than 140 scientists were involved in this project, which utilised data from 6,928 sites spread across 57 countries. The results underscore the major influence of temperature and precipitation on earthworm distribution patterns.
Science
DOI: 10.1126/science.aax4851

Rare species play an essential role in ecosystem multifunctionality

An international research team that included INRA scientists has revealed the key role played by the diversity of rare plant species and their evolutionary histories in maintaining the "multifunctionality" of ecosystems. Based on data from 123 sampling sites around the world, this work shows that taxonomic, functional, and phylogenetic biodiversity matters for ecosystem functioning. The results also highlight the importance of protecting rare species to ensure the proper functioning of ecosystems.
PNAS
DOI: 10.1073/pnas.1815727116

Biodiversity as a component of sustainable agricultural production

While the presence of weeds is known to decrease crop yields, the specific effect of weed diversity remains largely unknown. A three-year study of common wheat confirmed that weeds can reduce crop yield when fields are left unweeded. However, this effect was less dramatic when weed communities were more diverse. The study also identified key stages during which there was competition between weeds and crops, which is useful from a practical perspective.
Nature Sustainability
10.1038/s41893-019-0415-y

The earthworm *Aporrectodea longa*.
©C. Pelosi

The Morteratsch Glacier (Switzerland) in 2012
©Simo Räsänen

Biodiversity responses to current glacier retreat

Most glaciers have been retreating since the end of the Little Ice Age. However, the rate of retreat has been accelerating over recent decades because of climate change, resulting in environmental changes. As a consequence, ecosystems that are directly influenced by glaciers are under threat. Researchers performed a meta-analysis of 234 published studies, which included data from more than 2,100 biodiversity surveys of marine, freshwater, and terrestrial assemblages. The results suggest that biodiversity may increase locally as glaciers retreat. That said, glacier retreat appeared to be a threat for 6–11% of the populations studied, notably those in fjords. Those most threatened were populations of specialised species that are uniquely adapted to glacial conditions. The "winners" were populations of generalist species, which can colonise the newly created habitats from downstream.
Nature Ecology & Evolution
DOI: 10.1038/s41559-019-1042-8

FOCUS

Landscape diversity and crop protection

It is crucial to work at the landscape scale when determining whether areas will be cultivated or left fallow across space and time. The same is true when managing target levels of functional biodiversity.

More complex crop mosaics boost biodiversity

The intensification of agriculture and the destruction of semi-natural habitats (e.g., groves, hedgerows, and grass strips) are among the major causes of current biodiversity losses worldwide. Is it feasible to foster biodiversity and its ecosystem services within agricultural landscapes while simultaneously maintaining the amount of surface area dedicated to agricultural production? As part of FarmLand, a large-scale international study, researchers examined the effect of plot size, crop diversity, and the proportion of surface area covered by semi-natural habitats on biodiversity and ecosystem services within agricultural landscapes. The scientists found that creating more complex crop mosaics could serve as a powerful tool for bolstering these two factors without taking any land out of agricultural production.

PNAS
DOI: 10.1073/pnas.1906419116

Intensity of pesticide use conditions landscape contributions to biological pest control

In 2014, four INRA research units joined forces as part of a network for surveying the ecosystem services provided by biodiversity within agricultural landscapes (SEBIOPAG). Their objective? To study the relationships among biodiversity, landscape structure, and agriculturally useful ecosystem services, notably pest control by beneficial insects. In recent research, SEBIOPAG researchers showed that potential biocontrol levels, as measured by the consumption rate of sentinel prey, depended on interactions between landscape characteristics and the local intensity of pesticide use. Indeed, intense use counteracted the biocontrol benefits provided by semi-natural habitats. In contrast, a reduction in pesticide use must go hand in hand with an increase in semi-natural habitats to ensure that these conservation-based biocontrol methods are effective.

Proceedings of the Royal Sociéty Biological Sciences
DOI: 10.1098/rspb.2018.2898
http://sebiopag.inra.fr/

Hedgerow landscape .
© INRAE [AdobeStock]

Publication of a book on landscapes, functional biodiversity, and plant health

A multidisciplinary book, *Paysage, biodiversité fonctionnelle et santé des plantes*, was recently published on the topic of landscapes, functional biodiversity, and plant health. Edited by two INRA researchers, the intended audience is students, educators, and stakeholders involved in agricultural development. The book summarises background knowledge in this subject area, discusses research approaches, and reviews key studies that have looked at how spatial and temporal landscape structure affects pests, beneficial insects, and pollinators. It also discusses real-life case studies involving joint efforts to improve crop health via landscape management. The goal is not only to inform readers of important discoveries in this field, but also to provide information that is essential to understanding the bigger picture.

Editions QUAE, 2019,
ISBN 9782759230136

IN BRIEF

An agricultural innovation symposium (CIAg) focuses on biodiversity

A CIAg with the theme "Biodiversity and Agricultural Approaches" was held in April 2019. It highlighted the progress made by the agricultural industry over the past decade. It also detailed what must be done for agricultural systems to better account for concerns about biodiversity, as the latter is an important agroecological force. Speakers presented different lower-impact agricultural approaches that more effectively include biodiversity; described how biodiversity can be incorporated into agricultural production systems; and detailed tools for implementing public policies to further boost biodiversity.

The CIAg's target audience was wide ranging: stakeholders from different socio-occupational groups in the agricultural industry; representatives from industries upstream and downstream from the agricultural industry; managers within regional governments; stakeholders in charge of developing public policies; and representatives from various environmental non-profit organisations. The common thread binding them was the desire to place biodiversity at the core of the agroecological transition and to develop more sustainable and resilient agrifood systems.
https://url.inrae.fr/30oklpt

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Scientific highlights >

Preserving natural resources /

Water quality and availability is a major concern in France, Europe, and, indeed, the world. Climate change, pressures related to urban growth, and agricultural demand are all affecting the quality and availability of water resources and increasing the natural and environmental risks associated with the water cycle.

Research at INRA and IRSTEA is focused on a wide variety of water-related topics: the functional role of water within agricultural and forest ecosystems; the dynamics of water flow and hydrological systems and the related natural and environmental risks; the integrated management of water resources within regions; and the creation of recommendations to guide the transitions needed to preserve and conserve these resources.

Understanding and better managing the water cycle

The human footprint on the global water cycle is too often underestimated

Poor representations of the water cycle lead people to believe that water resources are inexhaustible. However, anthropogenic factors are increasingly impacting the quality and abundance of water resources, whether directly, via water use or pollution, or indirectly, via changes in land use. Furthermore, climate change often fails to be included in graphical representations of the water cycle, despite its ever-growing effects on water resources. Evidence for these assertions was recently provided by a study that analysed 464 representations of the water cycle that had been published worldwide in scientific articles, popular science articles, and educational texts. The flawed overall message conveyed by these images can negatively influence the frequently unilateral decisions made about water management, regardless of management scale.

Nature Geoscience
DOI: 10.1038/s41561-019-0374-y

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Potential water management tools

Life cycle analysis (LCA) is more and more frequently used to evaluate the environmental impacts of production systems and the consumption of natural resources. An innovative LCA tool was recently proposed by research teams in the IRSTEA Joint Research Unit for Information Technologies, Environmental Analysis, and Agricultural Processes (ITAP) in Montpellier. This tool is a water supply mix (WSmix), and its use is comparable to that of an electricity mix in environmental impact assessments. Research of this type lies at the crossroads between knowledge acquisition (i.e., defining an innovative conceptual framework) and tool development (i.e., creating a regionally structured global database with many potential applications given the current ecological transition). These research results have made a significant contribution to environmental assessments (and more), by coming up with a new global concept whose utility may be on par with that of the electricity mix and the energy mix.

Environmental Science & Technology
DOI: 10.1021/acs.est.8b04071

Has climate change affected flood patterns?

To date, researchers have been unable to identify any generalised patterns in the relationship between climate change and flood levels at the European scale, likely because of limited spatial coverage and the small number of hydrometric

Dranse River in flood in June 1974
(Department of Haute-Savoie)
©J.-C.Druart - INRAE

stations in Europe. IRSTEA participated in an international research project that examined flood discharge levels measured at 3,738 hydrometric stations over a 50-year period (1960–2010). The data from these stations were representative of hydrological dynamics in different regions of Europe. No generalised pattern was seen at the continental scale. Instead, the effects of climate change appeared to be region specific. Flooding has increased in certain regions (especially in northwestern Europe) and decreased in others (southern and eastern Europe). Prior work from this same project had already shown that such heterogeneity existed at the seasonal level. It is linked to a variety of factors, including the differences in climatic shifts among regions and the (sometimes beneficial) complex interactions between the physical processes that cause flooding.

Nature
DOI: 10.1038/s41586-019-1495-6.

International interest in a river basin restoration project in Normandy

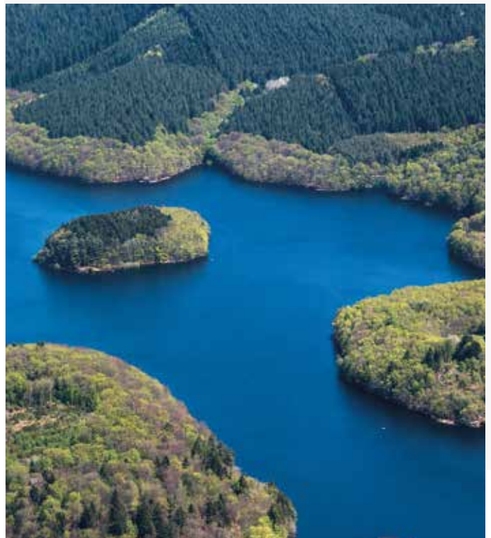
The largest hydroelectric dam removal project to date in Europe began in 2019 in Normandy's Sélune Valley.
The Sélune River Restoration Programme (Programme Sélune) was born out of the desire to restore the valley's 1,000-km² river basin, a project that has drawn a great deal of international interest. One form taken by this interest was a conference, which was organised in collaboration with the European Rivers Network. The meeting took place on September 24–26, 2019, and was attended by more than 200 people from 20 different countries. The event represented an opportunity to summarise all the research carried out on the Sélune to date. The results were compared with those obtained during dam removal projects in other parts of the world (e.g., Europe, Asia, and the Americas). The conference brought together researchers, non-profit organisations, users of the river basin, managers, elected officials, and government representatives. The aim was to keep science at the centre of a regional project behind an important transition.
https://www.ern.org/en/colloque-international-selune

IN BRIEF

The Alpine Soil Partnership
As part of the EU project Linking Alpine Soil Knowledge for Sustainable Ecosystem Management and Capacity Building (Interreg Links4Soils), IRSTEA helped create a partnership focused on soils in the Alps– the Alpine Soil Partnership (AlpSP). This informal European research network seeks to strengthen political engagements and optimise governance strategies to implement more effective management methods and create greater value from the services provided by Alpine soils.
alpinesoils.eu

Twenty-three unsolved problems in hydrology

The field of hydrology is strengthened by its strong global scientific community. Researchers within this community recently participated in an unprecedented initiative to discuss the major scientific challenges that the field still faces. Twenty-three unsolved problems in hydrology were identified by an international research group composed of 230 scientists, within which IRSTEA is well represented. The goal is for these 23 problems to inspire ambitious research in the years to come that will focus on climatic and environmental changes; scale-related issues that are difficult to represent in hydrological models; factors related to hydrological extremes (e.g., floods and low water levels) that generate societal risks; difficulties linked to making observations and taking measurements; bottlenecks in modelling; and the ties between science and society.
Hydrological Sciences Journal
DOI: 10.1080/02626667.2019.1620507



Aerial view of Lake Chaumeçon (Department of Nièvre)
©INRAE [AdobeStock]

INTERVIEW WITH
Vazken ANDRÉASSIAN
Research Unit on Hydrosystems and Bioprocesses Resources, Risks, and Restoration (HYCAR)
Centre of Île-de-France - Jouy-en-Josas-Antony

The 23 unsolved problems of hydrology: is the field still so recent that many discoveries remain to be made?
No, not at all. Hydrology, as a science, dates back to the 19th century. The goal was to spur debate on our scientific priorities by asking the international community of hydrologists to collaboratively identify the 23 most important unsolved problems in the field. A list of problems did indeed emerge from this process, even though there was sometimes disagreement. With regards to the number of problems, well, that's a nod to the German mathematician David Hilbert, who presented a list of the 23 most significant unsolved problems in maths at the International Congress of Mathematicians in Paris in 1900.

> We are currently relying on our models to predict the consequences of climate change and shifts in land use without being certain that their results can be extrapolated

Among these 23 problems, are there certain ones that especially interest you?
I will mention two in particular; one is interesting from a practical perspective, the other from a theoretical perspective. The first is building hydrological models with results that can be extrapolated. We are currently relying on our models to predict the consequences of climate change and shifts in land use without being certain that their results can be extrapolated. In my opinion, we must ideally test the extrapolation capacity of models. It is the ultimate form of crash testing, and it is an issue that concerns all types of models, from the simplest to the most complex. It is not easy to design such tests, but it is absolutely necessary. Indeed, we are working very hard on this issue in the research unit that I lead.
The second is characterising the macroscopic versus microscopic behaviours of a system, as well as any emergent properties. For example, the behaviour of a large river is not the sum of the behaviours of an equivalent set of small streams. In other words, you cannot simply aggregate the equations used to simulate microscopic phenomena to obtain the behaviour of a river basin, which is operating at a large scale. Personally, I find the theoretical question to be more interesting, and I believe it is crucial to carry out research that explores the large-scale properties of river basins.

How can international collaborations help answer these questions?
International collaborations are an essential part of modern science. Within the European scientific community, it has become common to exchange ideas and work with each other's PhD students. And that's great! As a result, we can also verify our models using river basins characterised by different climatic and geological conditions.

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Scientific highlights >

Sustainable production of healthy food /

Promoting changes in dietary regimes is a powerful tool for improving the health of human populations. Furthermore, such changes can contribute to the development of environmentally friendly food systems that are also resilient to climatic, health, and economic disruptions. To accelerate the transition towards healthier, more sustainable diets, it is essential to re-establish the connections between agriculture and food and to view health and nutrition as an integral part of the entire food production system.

When creating the dietary regimes of the future, food quality and diversity must be preserved; the competitivity of the agrifood industry must be maintained; and a balance must be struck to deal with the often-contradictory expectations of consumers. Fundamental research has many tasks ahead of it, which include exploring the contributions of open innovation approaches and clarifying the functions of the intestinal microbiota.

Annual report
2019
059
INRA • IRSTEA

More sustainable food systems, from our regions to our plates

Farm to fork strategies: giving a boost to local foods

Since the late 1990s, France has witnessed a renewed interest in short supply chains, which bring producers closer to consumers. The farm to fork movement has manifested itself in a variety of ways, including direct-to-consumer sales by farms, farm shops, and online platforms for ordering local products. Since 2014, such models have become more and more common within France's regions thanks to the Regional Food Projects written into the Law on the Future of Agriculture (Loi d'avenir agricole). This movement is often said to have positive impacts: allowing greater access to healthy, high-quality food; supporting small farms; encouraging more environmentally friendly agricultural systems; giving a boost to the local economy; and so on. However, it remains unclear whether the movement lives up to these expectations. A recently published book discusses the results of innovative research and experimental approaches at INRA, which are based on an extensive set of field data. The objective is to examine the true impact of short supply chains given the urgent need for transitions in food systems and the market economy alike.
The local-food model helps shine a light on the factors impeding the shift to new agricultural and food production models. In particular, it reveals a clear need for action to be taken via public policy. However, social, economic, and political processes must also be rethought if we wish to adopt more sustainable dietary regimes.

ERES
DOI:10.3917/eres.chiff.2019.01

A special edition of Village magazine, issue n°. 3, October 2019.

Food market
©INRAE

Consuming more plant-based proteins: where and how to start?

To improve human health and protect the environment, food systems must shift to include a greater proportion of plant-based proteins. Researchers recently performed a simulation in which products rich in animal-based proteins were slowly replaced by products rich in plant-based proteins. This process took place via a series of small changes.
The findings revealed that slowly increasing the proportion of plant-based proteins resulted in foods of greater nutritional value, improved health outcomes (i.e., a greater number of early deaths were prevented), and decreased environmental impacts (i.e., lower greenhouse gas emissions). To ensure that the nutritional transition takes place properly, it is important to diversify the sources of plant proteins by including more products containing whole grains, legumes, seeds, and nuts.

Journal of Nutrition
DOI: 10.1093/jn/nxz252 et DOI: 10.1093/jn/nxy275 ;
Climatic Change
DOI: 10.1007/s10584-019-02592-6

IN BRIEF

Diversifood Project given 2019 *Étoiles de l'Europe* award

The aim of the Diversifood Project is to renew the vitality of European agriculture by improving the economic and environmental viability of local food systems. Diversifood received the "Open Science" award at the 7th annual Étoiles de l'Europe, organised by the French Ministry of Higher Education and Research. This award recognises highly participatory and transdisciplinary projects that make their data accessible.
www.diversifood.eu

INRA and SOUFFLET launch a joint research programme focused on plant-based proteins

In 2019, INRA and the industrial group SOUFFLET launched a research programme with objectives related to both agriculture and agrifood. First, research will be conducted upstream to identify the best alternative farming practices for dealing with the bean beetles (*Bruchus spp.*) that infest lentils and fava beans. Second, research will be conducted downstream to better understand the mechanistic underpinnings of the aftertaste and bitterness associated with products made from plant-protein-rich flours. Such knowledge will guide the creation of new food products and ingredients.
inrae.fr/en/news

©INRAE [AdobeStock]

Quantifying human health risks, food waste, and energy consumption: further improving the cold chain

Refrigeration is a common tool for increasing the shelf life and decreasing the health risks of food products. However, the electricity used to maintain products at a low temperature all along the cold chain has economic and environmental costs. A multicriteria approach was developed to quantify the impact of functional conditions during the cold chain on waste production, energy consumption, and the microbiological safety of food.

Risk analysis
DOI: 10.1111/risa.13199

FOCUS

Infant nutrition

Infant formula
©INRAE [AdobeStock]

Are hypoallergenic infant formulas actually effective?

Often, hypoallergenic formulas are recommended for infants who are not exclusively breastfed and who are at risk of developing allergies. It is assumed that such formulas reduce the later development of allergies. However, it is unclear whether they are truly effective. A consortium including INRA and INSERM researchers has shown that the consumption of partially hydrolysed (hypoallergenic) formulas was not associated with a reduced risk of developing allergies. This research is part of the ELFE cohort study (Étude longitudinale française depuis l'enfance), the first broad-scale epidemiology project in France dedicated to monitoring individuals from birth to adulthood. While it is impossible to determine whether there is a causal relationship among the study variables, the results nonetheless underscore the importance of carrying out clinical studies on infant formulas before touting their potential hypoallergenic properties.

Pediatric Allergy and Immunology
DOI: 10.1111/pai.13094

INTERVIEW WITH

Blandine de LAUZON

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Sorbonne Paris Cité
Centre of Île-de-France - Jouy-en-Josas-Antony

What are the current major concerns in the field of infant nutrition?

Numerous studies have underscored that being exposed to certain factors during foetal development and the first few years of life can impact an individual's long-term health. Furthermore, research carried out by INRA has shown that dietary habits are established very early on. The World Health Organisation (WHO) recommends that children be exclusively breastfed for the first six months of life because of the associated health benefits. However, given that breastfeeding rates are extremely low in France, it is important to study the diets of infants that are not exclusively breastfed. There are numerous infant formulas present on the market, and their nutritional composition varies greatly.

> Dietary habits are established very early on in life

What are the main research questions that interest you? What methodological challenges have you encountered?

My work is primarily focused on how the health and development of children is affected by breastfeeding, the nutritional composition of infant formulas, and various types of parental practices. I therefore need access to long-term longitudinal data. Birth cohort studies, such as ELFE, yield observations that can be used to examine the different facets of our diets from a nutritional perspective. A behavioural perspective has also been made possible, thanks to a collaboration among research teams with complementary areas of expertise. However, this type of data does not allow us to establish causality. We therefore also need to perform randomised clinical trials.

What are the priority areas of research in infant nutrition?

Parents are eager to receive dietary advice related to their children, both in terms of ideal foods and behavioural approaches. To provide recommendations that are strongly backed by science, researchers must investigate how food choice and parental practices influence children's health in the intermediate to long term.

FOCUS

Effect of food-related parenting practices on the dietary patterns of young children

Relying on internal signals of hunger and satiety, infants are capable of self-regulating their food intake based on need. However, this ability tends to diminish after the first few years of childhood. We also know that parents have an important influence on the development of dietary habits in children. Based on questionnaire responses obtained from 790 parents, researchers discovered that when parents used food as a reward, children (1–6 years in age) were more likely to eat in the absence of hunger. Taken together, the results of this study highlight that parental practices have an early influence on self-regulated food intake and thus body mass index values in children.

Appetite

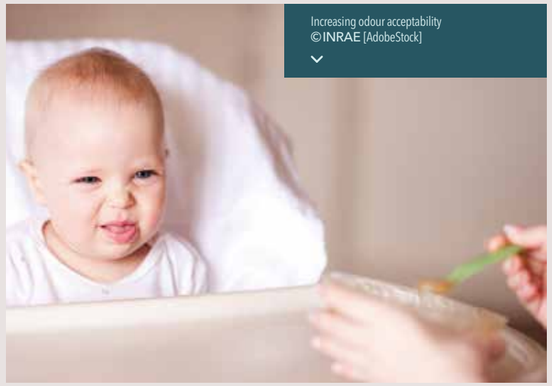
DOI: 10.1016/j.appet.2019.03.029

Infants more readily accept "unpleasant" odours to which they were exposed during gestation and early life

At birth, infants already have pronounced olfactory capacities, and their acceptance or rejection of certain odours is influenced by their experiences in the womb. Certain volatile compounds responsible for food odour can pass through the placenta into the amniotic fluid and/or can occur in breast milk. These compounds are thus perceived by foetuses and newborns, who retain a memory of the sensory experience. To explore this issue further, researchers measured how infants (aged 8, 12, and 22 months) reacted to food odours. It was found that infants previously exposed to food odours considered to be "unpleasant" by adults, such as those associated with green vegetables, cheese, or fish, were more likely to accept the odours when they had been experienced during the prenatal and perinatal period. This pattern was seen through the age of 8 months minimum. Furthermore, at 12 months of age, the infants' rejection of foods like fish and cheese was solely odour related. Consequently, parental consumption of certain foods during pregnancy and breastfeeding may render such odours less unpleasant to infants, who may then be more likely to accept complementary foods of this type when they are added to the diet. The originality of this research stems from its examination of very early olfactory experiences under normal conditions of food intake.

Chemical senses

DOI: 10.1093/chemse/bjz011



Increasing odour acceptability
©INRAE [AdobeStock]

IN BRIEF

Standardising quality when modelling *in vitro* digestion

Many models are used to study food digestion *in vitro*. Because these models often vary dramatically, it can be impossible to compare the results of different studies. INFOGEST is an international research network coordinated by INRA that has brought together more than 420 researchers from 45 different countries. It seeks to standardise such models at the international scale. Different models are used to mimic digestive conditions in newborns, healthy adults, or the elderly. They are employed across the globe and represent a helpful alternative to human and animal experiments when studying food digestion.

Nature Protocols

DOI: 10.1038/s41596-018-0119-1

Approaches for increasing food quality along the chain from production to transformation

IN BRIEF

Predicting the organoleptic properties of chocolate based on cocoa bean characteristics

INRA researchers and members of the cocoa industry carried out a major research project to explore the relationship between cocoa bean characteristics and the organoleptic properties of chocolate. They found that chocolates resulted in different sensory experiences based on the polyphenols in the cocoa beans of origin. These findings are important because they describe an alternative methodology to taste trials, which are time and cost intensive.

Journal of Agricultural and Food Chemistry

DOI: 10.1021/acs.jafc.8b06456

The sensory quality of tomatoes is genetically controlled

The taste of tomatoes is the result of a long evolutionary history. However, modern consumers are looking for more flavour. To understand and improve the genetic underpinnings of tomato quality, a pangenome meta-analysis of genome-wide association studies (GWASs) was carried out. It examined data from more than 775 varieties of tomatoes and explored over 2 million minor variations in the tomato genome. Researchers uncovered 305 associations among the levels of sugars, acids, amino acids, and aroma-related volatile compounds in tomatoes. By selecting certain combinations of alleles, it should be possible to increase the levels of volatile compounds that appeal to consumers while also reducing the levels of unattractive compounds. Furthermore, the study's results underscore the importance of shared, open-source data, which make meta-analyses of this type possible.

Nature Communication

DOI: 10.1038/s41467-019-09462-w

Tomatoes
©INRAE

A digital tool for capitalising on the artisanship of cheesemakers

Cheesemakers use their expertise and skills to work with natural variation in the characteristics of milks and cheeses. Transmitting this artisanship is often difficult and may occur haphazardly, which is risky for the industry as a whole. INRA researchers developed a comprehensive methodology for compiling knowledge and making technical recommendations related to cheese fabrication. This approach was defined in collaboration with several industrial partners and technical centres. Then, the researchers used the methodology to design an innovative digital end-user interface that can help correct defects in or maintain cheese quality during a specific manufacturing process. This tool is made for everyday use and incorporates feedback to improve and further develop its base of knowledge.

Computers and Electronics in Agriculture

DOI: 10.1016/j.compag.2019.05.052

Agricultural innovation symposium (CIAg) on improving food nutritional quality

Improving the nutritional quality of transformed food products can have major effects on the health of human populations. Recently, agrifood companies have been paying closer attention to this issue because of pressure applied by policymakers and consumer groups. As a result, these companies are either reformulating pre-existing products or launching entirely new products to improve the nutritional quality of their foods (i.e., so that they contain more fibre and less salt, sugar, or fat).
However, based on the research presented at the CIAg in November 2019, these efforts have remained relatively modest over the past few years. Indeed, they have not been sufficient to significantly impact the average quality of food products available to consumers. Improving food nutritional quality appears to be rather challenging, given the existence of various technological hurdles (e.g., the feasibility of desired changes, microbiological constraints) and/or issues rooted in consumer acceptance (e.g., sensory preferences, willingness to pay for reformulated products).
https://bit.ly/3dQ1tnh

The health benefits of the intestinal microbiota

The intestinal microbiota has a determinant influence on the functioning of skeletal muscle

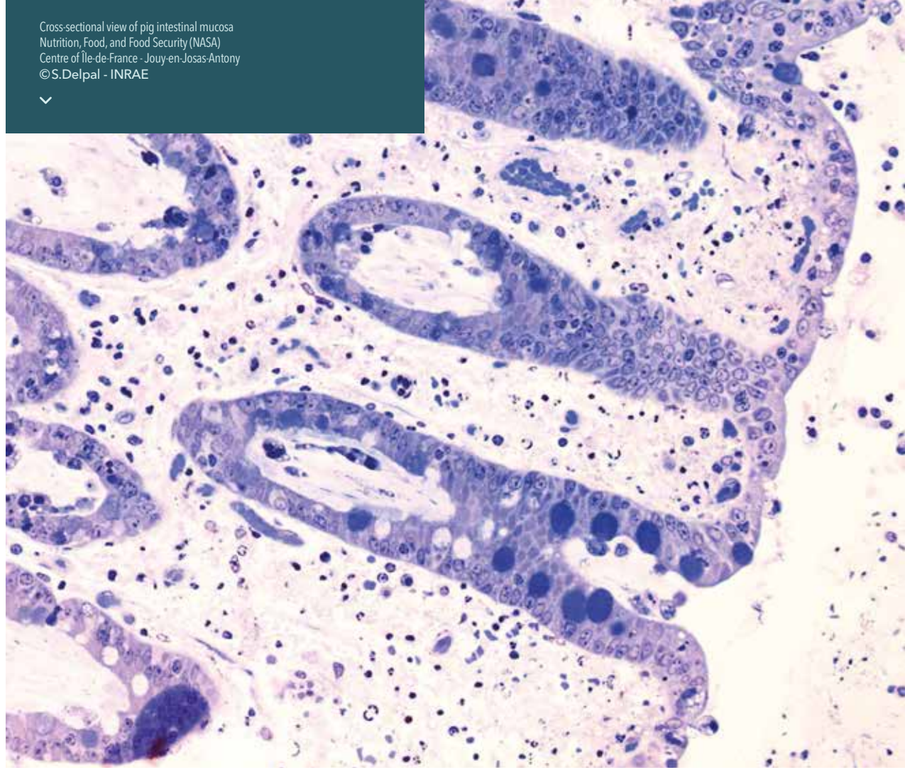
Severe muscular disorders (e.g., loss of muscle mass, metabolic dysfunction) are often tied to diseases such as cancer or diabetes. However, they are also observed in the elderly or in individuals with low activity levels. In all cases, such disorders have a significant effect on health and well-being. To deal with muscular issues, it is important to better understand the physiology of the muscular system, as well as the latter's interactions with the body's other organ systems. Over recent years, the intestinal microbiota has been recognised as a rich and complex organ with emergent functions. Experimental research has shown that mice lacking intestinal microbiota had lower levels of glycogen, the storage form of carbohydrates used by muscles. These useful results will help guide future research because they indicate that nutritional modulation of the intestinal microbiota could help restore muscular function that has been altered by physiological conditions (e.g., aging or a sedentary lifestyle) or pathological conditions (e.g., metabolic disorders leading to obesity or diabetes; chronic diseases that lead to a sedentary lifestyle, like cancer).
American Journal of Physiology Endocrinology Metabolism
DOI: 10.1152/ajpendo.00521.2018.

The iron in meat products affects the gut barrier and microbiota composition

Previous work by INRA researchers underscored the important role played by haem iron (found exclusively in animal protein) in the positive relationship between the likelihood of developing colorectal cancer and the consumption of red or processed meat. A new study in rats using a cell-based model has clarified some of the mechanisms involved. When rats consumed a haem-enriched diet, their gut barriers were altered, leading to low-grade inflammation and genotoxic damage to the intestinal mucosa. These phenomena greatly disrupted microbiota community structure.
More specifically, the haem-enriched diet increased the number of bacterial taxa described as opportunistic pathogens or as associated with inflammation and colorectal carcinogenesis.
Microbiome
DOI: 10.1186/s40168-019-0685-7

Experimental models for studying the interactions between mucus and microorganisms to develop human health applications

The entire epithelial surface of the human digestive tract is covered in mucus, a substance that plays a key role in intestinal homeostasis. Changes in the structure and/or function of the intestinal mucus are associated with certain digestive diseases and disorders.
It is therefore crucial to clarify how this mucus affects intestinal homeostasis if we wish to determine its relevance for human health. INRA researchers thus collaborated with other international experts to review current knowledge on this topic. They gathered the most recent findings on the mucus's functions, interactions with intestinal bacteria, and human health effects, including its involvement in various pathological conditions. Using a creative approach, the researchers surveyed and compared all the different *in vitro*, *ex vivo*, and *in vivo* models that can be used to study interactions between the intestinal mucus and gut microorganisms. The results will help optimise the *in vitro* digestive systems developed to date, which can be exploited in diverse ways to explore interactions among the intestinal mucus, microorganisms, and foods under different physiological and pathological conditions.
FEMS Microbiology Review
DOI: 10.1093/femsre/fuz013



Cross-sectional view of pig intestinal mucosa
Nutrition, Food, and Food Security (NASA)
Centre of Île-de-France - Jouy-en-Josas-Antony
©S.Delpal - INRAE

IN BRIEF

Liver diseases: a pan-European project for studying the microbiome
A total of 22 European organisations including INRA and Vaiomer, a biotech company, have joined forces to fight liver diseases and end-stage renal failure using customised microbiome-based treatments. Their research project, MICROB-PREDICT, received funding from the European Union and was launched in January 2019 in Barcelona.
microb-predict.eu/

MICROB-PREDICT

Preparing, storing, and managing faecal microbiota transplants

Fecal microbiota transplantation (FMT) is the process of transferring diluted faecal matter from healthy donors to the digestive tracts of recipients. FMT is a highly effective treatment for recurrent *Clostridioides difficile* infections because it restores the composition and protective functions of the microbiota. It is possible that other conditions could also be treated with FMT. To this end, it is important to develop and standardise transplant production methods. Current practices are largely experience based and thus remain inaccessible to many medical teams. The proper conservation and storage of transplants is also a challenge. An interdisciplinary research team used metagenomic and metabolomic sequencing methods to develop a safe standardised process for preparing transplants to be used in FMT. The process was verified using analyses of microbial diversity, activity, and real-time viability. The researchers were thus able to construct rigorously tested recommendations regarding transplant procurement, transformation times, cryoconservation conditions, and revivification procedures.
Nature Science Report
DOI: 10.1038/s41598-019-45173-4

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Scientific highlights >

Bioresources & the bioeconomy /

Bioresources and their uses must be diversified to meet food needs as well as to produce materials, compounds and energy in an ever-changing environment.
The living world still holds many discoveries that will make this possible, and new approaches are being developed to create compounds with targeted properties. Meanwhile, the bioresource economy must balance economic and environmental issues. Research conducted by INRA and IRSTEA aims to optimise the recovery of biowaste and raw materials as well as their co-products. To address these challenges, the two institutes draw from numerous disciplines in the biological, environmental, process, economic and social sciences.

Optimising resources for a diversity of uses

Designing a stable protein using automated reasoning methods through artificial intelligence

Proteins play a number of roles across the entire living world, from catalysis to signalling, transport and more. While there is a broad range of known natural proteins, a single protein with all desirable properties for a particular application does not always exist. But new proteins with the necessary properties can be created. An open source automated reasoning tool, developed at INRA's Applied Mathematics and Informatics unit, was used in bioinformatics to design a hyper-stable protein able to self-assemble from several basic building blocks. These findings are the result of collaborative efforts with researchers in Belgium and Japan and are based on developments achieved with the Toulouse Biotechnology Institute (TBI). Various applications on proteins of medical or biotechnological interest are under way.
International Union of Crystallography Journal
DOI: 10.1107/S205225251801480X

Models to predict metabolic functions of complex microbial communities: environmental biotechnology applications

Microorganisms are the main biogeochemical engines in the biosphere and are a key link in the Earth's nutrient cycles. Many biotechnological processes rely on their extraordinary biocatalytic capabilities. Better understanding and controlling the use of microbial communities for bioprocessing is a key challenge in bioeconomy development. For example, when large numbers of microbial populations are present under given physicochemical conditions, current mathematical models have a limited ability to predict which populations will become the majority or their associated metabolic functions. The authors of this paper hypothesised that energy flows play a leading role in structuring microbial functions in ecosystems. Based on this theory, they then proposed models that can predict the metabolic functions of complex microbial ecosystems. This research is being applied to activated sludge wastewater treatment processes.
The ISME Journal
DOI: 10.1038/s41396-018-0272-0

Characteristics of bioeconomy systems and sustainability issues at the territorial scale

The ecological and energy transition depends on developing the bioeconomy. However, knowledge on the characteristics of bioeconomy systems at the territorial level and sustainability issues is still very limited. This limits the capacity to structure territories for sustainable biomass management. An interdisciplinary review described the specific characteristics of territorial bioeconomy systems and the tools and integrated approaches to assessment and modelling needed to support their long-term development. The researchers came up with an analytical framework that sets out the characteristics and issues associated with territorial bioeconomy systems. This model can be used to conduct an integrated assessment of scenarios for reorganising biomass management activities at the territorial scale using a set of sustainability criteria (impact on natural resources and the economy, GHG emissions etc.).
Journal of Cleaner Production
DOI: 10.1016/j.jclepro.2019.05.385

IN BRIEF

> PARTNERSHIPS

INRA and ENGIE team up to develop renewable energy sectors
Using inter- and transdisciplinary approaches, INRA has developed skills on all subjects relating to agricultural and forest resource availability, anaerobic digestion, carbon cycle closure and territorial metabolism in the bioeconomy. The Institute's collaboration with ENGIE revolves around three themes: biomass availability, including developing intermediate crops for energy purposes and the environmental, societal and economic impacts in France; economic and environmental value creation; and the identification of the best resource basins in France to launch the first pyrogasification facilities while optimising the carbon cost of using biomass.

Early-stage heading on sorghum biomass
Domaine d'Estrées-Mons
Environment and Agronomy – Lille
©M.Preudhomme - INRAE

ite-rot fungi from the *Pycnoporus* genus. Institute of Microbiology, Chinese Academy of Sciences (IMCAS) ©Lin GUO – INRAE

A collective undertaking leads to the discovery of a family of metalloproteins in fungi

An international consortium led by INRA recently discovered a new family of metalloproteins in fungi. These proteins, which resemble enzymes that break down cellulose, were discovered in 2010 in bacteria and filamentous fungi. The team's work on the biological activity of one of these new metalloproteins revealed that its function appears to have diverged towards mechanisms related to copper homeostasis. Meanwhile, a team in the United States discovered that this protein is involved in the pathogenicity mechanism in the fungus that causes meningitis in humans. These findings pave the way for the study of essential biological processes.

Nature Chemical Biology

DOI: 10.15124/a034974e

INTERVIEW WITH

Bastien BISSARO

Fungal Biodiversity and Biotechnology Unit
Centre of Provence-Alpes-Cote d'Azur

Lignocellulose degradation is still a challenge to making plant bioresource use more widespread, even though many research projects have made great strides in recent years. What are the difficulties researchers face?

One key challenge in bioeconomy development lies in extracting the building blocks of plant biomass, which is mainly – but not exclusively – comprised of cellulose. The way these basic components are organised means that breaking them down is difficult. Plants evolved this structure as an effective protective measure, but it presents us with a major challenge! Filamentous fungi have co-evolved with plants for millions of years to create strategies to break down plant biomass. We have a lot to learn from them to develop effective biotechnological processes. The filamentous fungi that break down wood secrete many different enzymes that need to be identified and studied in detail to understand how they work so we can create more powerful bio-inspired processes. Natural plant degradation takes quite a long time.

Filamentous fungi have co-evolved with plants for millions of years to create strategies to break down plant biomass

What are your main findings in this area?

In 2010, new enzymes called Lytic polysaccharide monooxygenases (LPMOs) were discovered and revolutionised our understanding of biomass degradation. They are already being used in industrial enzymatic cocktails. During my first postdoctoral fellowship, I discovered that these LPMOs do not behave according to established principles. This finding had major impacts on the way we use these enzymes, especially in biorefinery processes, as well as on our understanding of the enzymatic network deployed by filamentous fungi.
The entire Fungal Biodiversity and Biotechnology unit was involved in the discovery of several new LPMO families. We're now realising that the role of LPMOs in cellulose degradation may go far beyond what we initially thought. There are major discoveries to come, especially with regards to pathogenicity processes.

You're a young researcher. What led you to these enzymes?

My path towards the world of oxidoreductases began with a Young Scientist Contract from INRA for my doctoral thesis, and then later a postdoctoral fellowship. This support allowed me to join a lab working on LPMOs in Norway, which readily welcomed me because of my curiosity for this enzyme family. The project was then supported by Agreenium's AgreenSkills programme. These opportunities, based on the confidence the Institute had in me, were clearly a springboard for me. That's also why I wanted to come back to France, and especially to INRA.

PNAS

DOI: 10.1073/pnas.1904889117

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Defining tomorrow's research priorities /

Interdisciplinary scientific **foresight studies** to unravel complex issues

INTERVIEW WITH
Carole CARANTA
Associate Deputy Director General
for Science and Innovation

Over the course of 2019, INRA and IRSTEA defined a comprehensive institutional project that led to the creation of INRAE. What resources does INRAE draw from to identify the scientific frontiers to explore?
Between 2017 and 2019, the Institute conducted six interdisciplinary scientific foresight studies on strategic and challenging topics with the aim of anticipating new research needs, shedding light on future science frontiers and expanding its choices in terms of orientation and development of scientific, socio-economic and training partnerships. The complexity, scope and often global nature of scientific and societal challenges require questioning and integrating approaches from multiple disciplines to produce relevant knowledge. Nearly 250 scientists from INRA, IRSTEA and other organisations (Inria, CNRS and INSERM) are all working on these interdisciplinary scientific areas of focus. The summary reports by the research groups have been submitted to INRAE's Scientific Advisory Board. These reports identify scientific challenges and priorities in response to the issues at stake. Additionally, they suggest actions that would support the implementation of those priorities, as well as more broadly support INRAE's strategy on chosen themes, such as scientific events to bring communities together and to develop interdisciplinary cooperation; support for innovative research projects and scientific infrastructures; skills development; setting up collaborations with academic and socio-economic partners; the Institute's influence and attractiveness; and links with expertise and support for public policies.
These interdisciplinary foresight studies will be used in particular to develop INRAE's scientific goals for 2030, to implement the Institute's second generation metaprogrammes, and to contribute to the research divisions' new strategic plans.

The foresight studies have been particularly focused on predictive approaches in biology and ecology. What are the main messages which we should keep in mind in this field and what lessons can be drawn from the approach itself?

Predictive approaches can help researchers gain a detailed understanding of biological and ecological systems, as well as predict the responses of these systems, which are complex, dynamic and uncertain in the face of change. These approaches are closely linked to the increasingly interdisciplinary nature of science as well as the explosion of big data and the upheavals brought about by the digital transition and artificial intelligence.
INRAE faces many different challenges in terms of research and exploring new scientific areas, acquiring and exploiting data, and supporting and uniting a new, international scientific community where the life sciences and formal sciences intersect.

To delve more deeply into the issues, working groups were set up to tackle seven different themes. These groups brought together nearly a hundred scientists from almost all INRA scientific divisions, as well as scientists from partner organisations. The themes cover all scales, from understanding metabolic pathways to the behaviour of individual organisms in their environments; the concept of holobiont to the prediction of risks of exposure to compounds or microorganisms, agricultural practices to consumption; and biological invasions to the ecological impacts of global change. This last theme, which is more methodological and cross-cutting, aims to address shared challenges and how they overlap in the fields of analysis and modelling.
Based on the groups' work, an action plan was adopted in March 2019 to guide the implementation of the identified scientific priorities as well as the overall INRAE strategy in the field of predictive approaches in biology and ecology.

> The complexity, scope and often global nature of scientific and societal challenges require questioning and integrating approaches from multiple disciplines to produce relevant knowledge

Predictive approaches are now an essential step in acquiring knowledge. INRAE is taking on this key issue to forge a genuinely collective ambition. The goals are clear in terms of interdisciplinary cooperation, more partnerships, digital transition and open science. A new community needs to be united through ambitious interdisciplinary research programmes that strike a balance between digital methods and experimental, observational and analytical approaches. Finally, these predictive approaches in biology and ecology will also deal with the societal impact of this research.

Six
interdisciplinary scientific foresight studies

AGROECOLOGY
Following on from discussions initiated by INRA in 2011 to make agroecology a scientific discipline in its own right, the foresight study aims to explore certain themes where ecology and agronomy intersect and integrate socio-economic and technological dimensions.

PREDICTIVE APPROACHES IN BIOLOGY AND ECOLOGY
The interest in predictive approaches goes hand in hand with the shift towards interdisciplinary cooperation in science. Such approaches can help researchers gain an in-depth understanding of biological and ecological systems, as well as predict the responses of these systems in changing environments.

SCIENCE FOR THE FUTURE OF LIVESTOCK FARMING
To rethink the role of livestock farming, future scenarios are being considered that integrate multiple sectors, consumer trends and various sustainability pillars.
This approach gives the Institute insight into actions that could be used to develop ambitious and safe research to encourage and support change for tomorrow's livestock farms.

NEXUS HEALTH – ENVIRONMENT – AGRICULTURE – FOOD
The foresight study explores the complexity of interactions between these different areas to guide research to where economic, social, environmental and health issues all come together within the food system.

BIOECONOMY
The foresight study analyses priorities for biomass production and its sustainable use and for optimising biomass conversion while limiting the creation of waste and closing carbon, nitrogen and phosphorus cycles, and organising and managing flows in periods of strong uncertainty.

NATURAL, ENVIRONMENTAL, HEALTH AND TECHNOLOGICAL RISK MANAGEMENT
The goal is to build a systemic framework for knowledge and action, to provide answers to societal questions, and to develop integrated approaches in order to better anticipate, prevent and adapt to multiple hazards to study their interactions and impacts.

.08

Supporting public policymakers through science /

The increasingly complex issues that public policymakers must tackle in the fields of agriculture, environment and food are creating new expectations for research. Supporting public policies and informing public debate are an explicit part of the missions of public research institutions such as INRA and IRSTEA.

This activity takes different forms, from expert reports, foresight studies, advanced studies to creating decision support tools.

WHAT DOES THE DIGITAL TRANSITION IN HIGHER EDUCATION AND RESEARCH ENTAIL?

The digital transition is shaking up public higher education and research institutions. It is transforming practices, organisational approaches, and relations between actors in the research and education ecosystem, while creating a feeling of acceleration that brings up images of the future tinged with a mixture of fear, excitement and fantasy. INRA and Agreenium carried out a foresight study on these transitions and how they pertain to agriculture, environment, food and animal health. The four scenarios they developed describe what the future of research and higher education might look like by 2040. They identify the challenges of the digital transition and shed light on future possibilities in terms of organisational structure, ways of working, choosing priorities and human resources. Each scenario considers a given societal, economic and political context, institutional organisation, research practices, higher education and training practices, data, and interactions between society and higher education and research institutions, as well as ethical aspects and digital literacy.
https://bit.ly/2MKSmIO

CARBON STORAGE POTENTIAL IN FRANCE

The "4 per 1000 – Soils for food security and climate" initiative was launched during the Conference of the Parties on climate change in Paris in 2015 (COP 21). Soils that contain the most carbon (i.e. organic matter), are more fertile and retain water better. The initiative thus benefits the environment as well as agriculture and global food security. At the request of the French Environment and Energy Management Agency (ADEME) and the Ministry of Agriculture and Food, INRA conducted a study on the carbon storage potential in farm and forest land in mainland France. The study used a novel methodology to assess this potential and estimate the cost of implementing actions region by region to increase soil carbon stocks by 0.4% annually. The findings show the importance of public policies to encourage farmers to maintain permanent grasslands, wetlands and forests (where the soils generally have high carbon stocks) and stop soil artificialisation.

Coastline erosion (Etretat)
© INRAE [AdobeStock]

They also show that the greatest potential for increasing the carbon content in farm land lies in areas with arable crops.
https://bit.ly/2XK2VIC

RISING SEA LEVELS: CONSEQUENCES AND MITIGATION ACTIONS BY 2100

AllEnvi, the National Research Alliance for the Environment, published the findings of a foresight study led by INRA and IRSTEA researchers. This study compares possible futures for coastal areas that take into account four physical contexts of sea level rise: moderate, serious, severe and extreme. The study covers eight scenarios, ranging from the broadly virtuous "Coastal Adaptation" to the more pessimistic "Denial" with a refusal to address climate and environmental changes and "Divided World" with an "everyone for themselves" attitude. These scenarios show that early and massive climate change mitigation, which requires concerted global efforts, would limit sea level rise and thus the necessary coastal adaptation efforts, which depend on regional and local policies and actions.
https://bit.ly/37epEJC

Decision support tools

FOCUS

SOIL DATA FOR ALL!

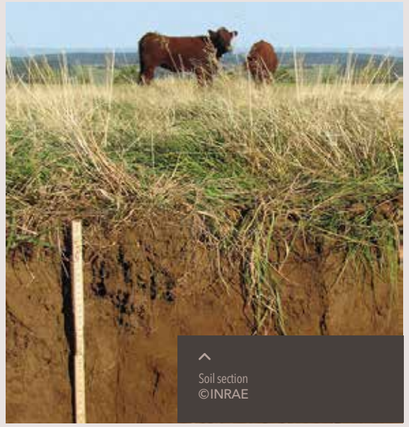
The data from the soil mapping and characterisation programme, led by the Soil scientific interest group and coordinated by INRA, are freely available from the French government's Géoportail mapping service. This programme, carried out jointly with the French National Institute of Geographical and Forest Information (IGN), will provide access to the data with information on soil type and local organisations and contacts to access additional data. This portal will make it possible to reach a wider audience than only agricultural professionals, and the data can be used for many different environmental applications.
geoportail.gouv.fr/donnees/carte-des-sols

THE OVERLAP BETWEEN AGRICULTURE, AIR QUALITY, RESEARCH AND PUBLIC DECISION-MAKING

This book, which brings together contributions from 50 different authors, gives historical and social background on the relationship between agriculture and air quality and how they are connected to global changes and shifts in farming. The book also discusses various assessment methods and tools.
It is aimed at actors in different sectors who are impacted by these issues: agricultural and environmental research, agricultural development, public decision-making and education.
Agriculture et qualité de l'air
Editions QUAE, ISBN 978-2-7592-3009-9

A CAUTIOUS APPROACH TO GOVERNING BY MODELS

Several research projects have looked at the impact that digital models and planning tools have on agricultural, food and environmental policies.
The many publications by INRA researchers involved in these projects discuss how these quantification and planning tools do not simply inform decision-makers but actually predefine the problems, subjects and measures that public action must address. Although some choices appear to be technical when building models and setting the analysis parameters, in fact, they reflect political choices and positions on such issues as proper land use, agricultural production models, degree of deforestation and biodiversity loss. This is why the use of data produced by such models meant to inform policy decisions should be carefully analysed and considered within this context.
Land Use Policy, special issue, 25 October 2019
Science & Technology Studies, special issue, 15 December 2019
Revue d'Anthropologie des Connaissances, 2019, Vol. 13, No. 4



Soil section
©INRAE

EXPERIMENTAL APPROACHES TO ENHANCE THE CAP

A special issue of the European Review of Agricultural Economics (ERAE), coordinated by two researchers from INRA and IRSTEA, summarises the interest of using experimental approaches to evaluate and improve the Common Agricultural Policy (CAP).
This synthesis is based on the work of the EU-wide Research network on Economic Experiments for the Common Agricultural Policy (REECAP).
European Review of Agricultural Economics
DOI: 10.1093/erae/jbz024

INTERVIEW WITH
Jean-Paul DOUZALS
Joint Research Unit for Information, Technologies, Environmental Analysis and Agricultural Processes (ITAP)
Centre of Occitanie-Montpellier

Your research activity focuses on agricultural equipment. What type of expertise do you provide?
Research conducted by the PEPS team on spraying optimisation has enabled government agencies to identify scientific and technical expertise in this area. This naturally led to requests from the Ministry of Agriculture and Food to draw up guidance and recommendations on regulatory changes. Thus, since 2006, IRSTEA was cited in a decree as an expert organisation for the Ministry of Agriculture for spraying, and especially as it pertains to environmental protection, whether for aquatic areas, non-target plants and crops, or operators, and more recently, for people living near sprayed areas. Around 60 substances are examined each year to be included on a regulatory list. More specifically, the aim is to verify that these substances are suitable for agricultural use as well as that they meet restrictions on spray drift. In addition to providing this type of expertise on a recurring basis, the team may also deal with more specific referrals.
One last type of activity involves creating standardised protocols and drafting international ISO or CEN standards, as well as developing – in partnership with the French Vine and Wine Institute (IFV) through the Ecotech Joint Technology Unit – a classification of devices according to their agricultural and environmental performance.

> Supporting public policymakers requires bringing partial blocks of scientific knowledge together into an operational whole

How does this expertise inform scientific inquiry?
It is easier to conduct spray research in the lab under controlled conditions to study liquid atomization or to simulate the atmospheric transfer of sprayed products in a wind tunnel. Supporting public policymakers requires bringing partial blocks of scientific knowledge together into an operational whole or developing an expert opinion that can be scaled up and implemented along with changes in user practices to meet higher agricultural and environmental standards. This may involve creating research tools on an intermediate scale between the laboratory and the field such as artificial vine and orchard vegetation, or a 25-square-metre artificial wind turbine. This scale is key to quickly developing useful basic knowledge that can help us first understand different phenomena by removing variability in plant architecture in the field to then be able to inform more responsive policy decisions.

So ultimately, there are several dimensions to this expertise?
There are two main dimensions to this expertise. The first ranges from a local to an international level, because the issues my team handles are the same in many other countries. Useful results are produced through joint scientific efforts in European projects such as H2020 OPTIMA or international standards. The second dimension goes from the public sector, with, for instance, the European BTSF training courses, to industry, with collaborations such as R&D partnerships with agricultural equipment or adjuvant manufacturers. We may also play a role as mediator between these two worlds, especially when it comes to regulatory changes.

.09

Partnerships and innovation /

Academic, national and international partnerships lie at the heart of the excellence and impact of INRA and IRSTEA research. Today, an academic partnership policy, ambitious international projects, a commitment to participatory research and innovation with stakeholders across society (companies, farmers, local authorities, associations etc.) all help strengthen these partnerships.

Stronger engagement with the academic world and regional partnerships

Aerial photo of the University of Paris-Saclay AGRO Campus
©DRONEA

CONSOLIDATING THE ACADEMIC PARTNERSHIP POLICY

The French decree of December 2018 to allow the creation of experimental public institutions (EPE) has led to changes at several universities (those referred to as communities of universities and establishments, or ComUE). INRA is closely monitoring these developments in order to ensure the Institute has a place at the table when these institutions determine their research strategies.

In particular, the Institute maintains close ties with the **University of Paris-Saclay**, which became an experimental public institution on 1 January 2020, and with which INRA signed a partnership agreement in December 2019. Additionally, the start of construction on the future Agro Paris-Saclay Campus in early 2019 and the visit to the site by the supervisory ministers on 1 October are a tangible reflection of our joint ambition with AgroParisTech, which is becoming a component establishment of the University of Paris-Saclay for life and environmental sciences.

INRA is continuing its efforts to establish academic partnerships wherever relevant, and signed agreements with the following institutions: (i) in May with the **Université de Bourgogne**, AgroSup Dijon and the ComUE **Université Bourgogne-Franche-Comté**; (ii) in July with the **Université de Lorraine**, CNRS, Inria, INSERM and the University Hospital (CHRU) in Nancy, confirming the role of the Coordination and scientific orientation committee of Lorraine (CCOSL) that was created in 2007; (iii) in August with the **University of Reims Champagne-Ardenne** and AgroParisTech, in order to continue and expand our partnership in the field of the bioeconomy.

INRA PARTICIPATES IN THREE NEW GRADUATE SCHOOLS OF RESEARCH (EUR)

These new EUR are **BIOECO** and **TULIP**, managed by the Université Fédérale de Toulouse Midi-Pyrénées, and **IMPLANTEUS**, managed by Avignon Université. The results of this second call for projects brings the total number of EUR the Institute's researchers work with to nine.

THE INSTITUTE DEEPENS ITS INVOLVEMENT IN THE FIELDS OF MATHEMATICS – COMPUTER SCIENCE – MODELLING ARTIFICIAL INTELLIGENCE

As part of the interdisciplinary artificial intelligence programme launched by the French government, INRA is involved in two of the four **Interdisciplinary Institutes of Artificial Intelligence** (3IA) selected in April 2019: "ANITI" led by the Université Fédérale de Toulouse Midi-Pyrénées and "Côte d'Azur" led by the Université Côte d'Azur. INRA is working on both basic and applied research in the smart agriculture, environment and health sectors.

Artificial intelligence
© INRAE [AdobeStock]

INRA researchers involved in international Master's programmes

- **Infectious Diseases and One Health (IDOH)**
  Coordinated by the INRAE-University of Tours "Animal Infectiology and Public Health" Unit created in 2016, this programme has once again been selected to receive European funding. A total of 31 academic and private partners across the world participate in the IDOH project.
- **Global Quality in European Livestock Production (GLOQUA)**
  This programme is co-accredited by VetAgro Sup and the University of Clermont Auvergne and organised in partnership with Bordeaux Sciences Agro, Université de Lorraine/ENSAIA and INRA.
- **Biocontrol solutions for plant health (MSc BOOST)**
  This programme is a new international and multidisciplinary degree created by the Université Côte d'Azur, in collaboration with INRA and the CNRS.

Participatory research at different scales

TEASER-LAB, A TERRITORIAL INITIATIVE TO SUPPORT THE TRANSITION OF AN AGRICULTURAL REGION (MIRECOURT) TOWARDS MORE SUSTAINABLE AGRICULTURE AND FOOD PRODUCTION, CREATED WITH COMMUNITY INPUT

Designed as a living lab, this initiative has drawn from an ecosystem of diverse actors – local citizens – for three years to allow the community to lead the development and connection of various programmes such as participatory agricultural projects and the diversification of organic and local food production. The INRA ASTER research unit in Mirecourt plays a unique and important role in this dynamic: the benefits of this approach have been recognised by the Fondation de France, which honoured the initiative with a prize in 2019 which recognises "actors for a better life".
https://bit.ly/3eZ2ny2

THE *CLÉS DE SOL* CITIZEN SCIENCE PROJECT

Although soils are generally under the public's radar, they are connected to many environmental issues. Society at large must be made aware of the importance of soils to ensure that public policies better protect them. The need for knowledge on soil is often expressed at the territorial scale. The participation of local actors in data production over time is useful. The Clés de Sol project, developed jointly by academic and civil society

©INRAE

partners, aims to improve and disseminate knowledge on soil and raise awareness about the issues at stake. It has received support from the Fondation de France since 1 January 2019 and is co-managed by the Union Nationale des Centres Permanents d'Initiatives pour l'Environnement (UNCPIE) and INRA. Other partners are Agro-Campus Ouest, the Tous Chercheurs lab in Nancy, France Nature Environnement (FNE) and the Grand Est Regional Chamber of Agriculture.
https://bit.ly/37g1fmV

VIGIL'ENCRE: JOINING FORCES TO BETTER FIGHT CHESTNUT INK DISEASE

Chestnut ink disease is currently the main obstacle to cultivating chestnut trees in France and Europe. Soil-borne pathogens (*Phytophthora cinnamomi*, *Phythophthora cambivora*) are responsible for the disease, which causes hydraulic dysfunction in trees. INRA scientists created a mobile app, called Vigil'encre, that can now be downloaded from app stores. Citizens, forest managers and arboriculturists can all add to the growing body of knowledge about this disease by reporting symptoms observed on trees and sending samples to the lab.
These data will aid decisions regarding orchard and forest management.
ephytia.inra.fr

Chestnut tree dieback in a forest caused by the *Phytophthora Cinnamomi* fungus.
©X. Capdevielle - INRAE

IN BRIEF

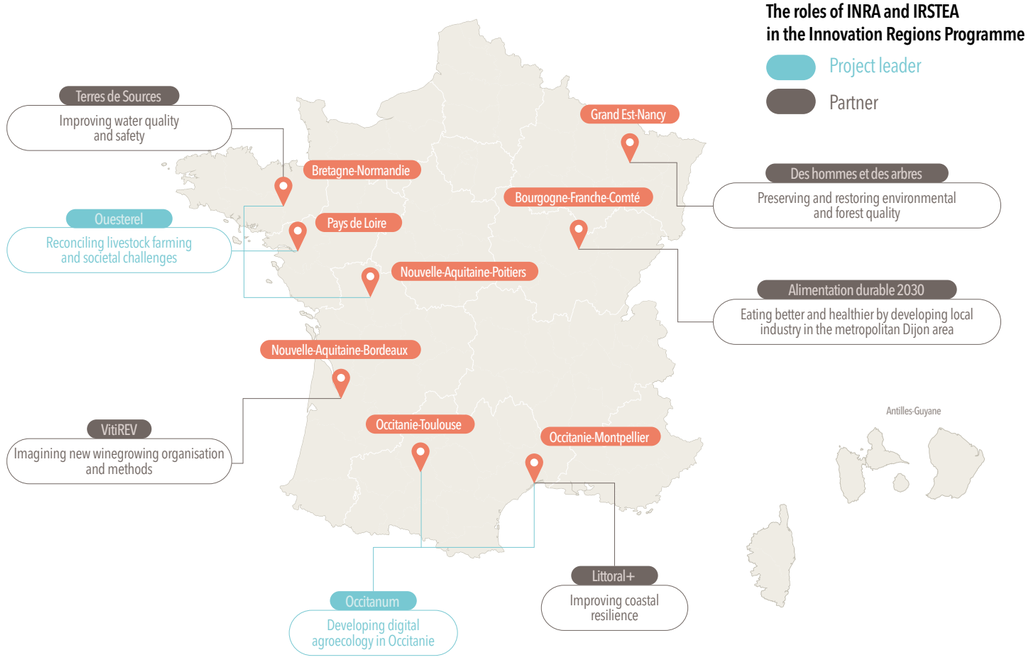
INRA and the Civam* network renew their collaboration
During the 2019 Paris International Agricultural Show, Philippe Mauguin, INRA Chair & CEO, and Jacques Morineau, Administrator of the Civam Network, signed a new framework agreement in the field of agroecology. The collaboration will focus on two main themes: analysing and implementing agricultural and agroecological food systems that rely on a range of practices, crops, livestock, commercialisation techniques, and functionalities suited to their local area and social environment; and improving the sharing and blending of farmers' and scientists' knowledge.

** Centres of initiatives to enhance the value of agricultural and rural areas*

Innovation at the regional level

INRA AND IRSTEA, WINNERS OF THE PIA3 FRENCH INNOVATION REGIONS PROGRAMME, STEP INTO NEW MULTI-STAKEHOLDER COLLABORATION SCHEMES

These programmes reflect the ambition of the two institutions in terms collaborative and participatory research. Their purpose is to encourage innovation by regional players to support and accelerate major transitions, particularly environmental and agroecological changes, and inspire new research at INRA and IRSTEA.



INTERVIEW WITH
Véronique BELLON-MAUREL
Deputy Director of the MATHNUM Division,
Director of the Digital Agriculture Convergence Lab #DigitAg,
Coordinator of the Occitanum Innovation Region Laboratory

Occitanum: an innovation scheme for digital agriculture

How are digital technologies impacting the future of agriculture?
Digital technology can drive capacity building among agriculture and food stakeholders to support transformation in the industry. Alone, it does not trigger transformation – it is more like an "assistant" that speeds and facilitates the transformation that society wants, especially with regards to reducing inputs. It also helps stakeholders scale up environmentally friendly practices. For example, a manual practice that can be carried out on a small scale (such as early disease detection) may no longer be feasible or effective (e.g., delays) when scaling up, even on family farms.
In short, digital technologies will aid the agroecological transition by enabling problems to be detected earlier or recommendations (including for intra-plot or intra-flock systems) to be better adapted by taking into account farmers' individual technical conditions and strategies. They also add value to products through transparency (traceability) around practices.

> We believe that digital technologies will facilitate the transition to agroecology

What is an Innovation Region laboratory?
The Innovation Region programme, supported by the Secretariat General for Innovation, seeks to achieve open innovation. Each laboratory acts as a hub in a given region to connect various stakeholders (users, farmers, regional authorities, equipment suppliers, researchers etc.) to share their knowledge and ensure scientific rigour to create this "research-action" and capitalise on the data and knowledge produced.

What type of research is Occitanum conducting?
Occitanum is an abbreviation of *Occitanie Agroécologie Numérique*, or Occitanie digital agroecology. We believe that digital technologies will facilitate the transition to agroecology, which is not only what society wants but also a response to climate change and a way to transition to local food production with new logistical solutions. Our hypothesis is being tested in six production sectors (livestock farming, arable crops, viticulture, arboriculture, market gardening, apiculture) and distribution channels. Beyond this scope, we're looking to develop new knowledge in agroecology from the data collected and to understand the dynamics of innovation within the Living Lab initiatives.

START-UPS

Seven new start-ups from INRA and IRSTEA labs

AgriOdor
Sustainable and innovative solutions to protect arable crops by using olfactory attractants as a biocontrol tool.

Oleoinnov
Biotechnology tools to develop sustainable processes and products made from biobased substances that draw from the potential of fungi.

Nutrithéragène
(Created in June 2019; Grand Prize 2018 winner of the i-Lab competition): A biotechnology project to treat cancer

Wetruf
Innovations developed in the laboratory for the truffle industry. Expertise in fungus biology and biotechnology that supports truffle farming projects.

Aiova
Innovative vaccine solutions for livestock to strengthen and optimise the immune response in vaccinated animals.

Sol & Co
Studies and advice for better knowledge and conservation of soil and its biodiversity in regional and landscape development.

Pollinova
Optimisation of hybrid cereal seed production. Creation based on an innovative process that improves pollen transport between plants and reduces farmers' workloads.

JOINT TECHNOLOGY UNITS

Four new certified joint technology units have strengthened INRA's partnerships with technical institutes in agriculture and agrifood.

SI BIO
A first all-organic joint technology unit in partnership with the Organic Food and Farming Institute to support the development of organic horticultural systems.

Digiporc
A joint technology unit between INRA and the French Pork and Pig Institute-Agrocampus (IFIP) which develops livestock farming applications using digital data.

SC3D
Led by INRA and the French Livestock Institute (Idele), this joint technology unit aims to provide goat farmers and the goat industry the tools they need to adopt more sustainable and resilient practices and systems.

Pactole
This Terres Inovia-INRA-ENSAT-Université Toulouse III joint technology unit aims to produce knowledge and tools that can help diversify crop systems through the use of oilseeds and grain legumes. The joint technology unit has a twofold aim: to support adaptation to climate change and the agroecological and nutritional transition.

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Europe and the world /

Success of INRA and IRSTEA teams in the Horizon 2020 call for projects

INRA'S RESEARCH

INRA's research in the H2020 programme mainly falls within the Societal Challenge No.2 on "Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy".

- 4th leading French public beneficiary of the H2020 programme with 211 projects selected since 2014 for the H2020 calls for projects.
- A success rate of 17.7%, which exceeds the rate for France (15.3%) and the overall programme success rate (12.1%).
- For 2019, INRA was awarded the highest grant amount in the Challenge 2 category.

IRSTEA'S RESEARCH

The IRSTEA projects selected since 2014 mainly address Societal Challenge 5 on "Climate action, environment, resource efficiency and raw materials".

- A success rate of 16.7% since the start of the programme.
- For 2019, a success rate of 23% (seven projects selected).

AGREENSKILLS: EIGHT YEARS OF EUROPEAN PROJECTS ON INTERNATIONAL MOBILITY FOR RESEARCHERS

The **AgreenSkills+** project, a continuation of the original AgreenSkills project, allowed INRA to coordinate a vast European programme for the international mobility of postdoctoral researchers from 2012 to 2019. Half of the project's funding came from the MSCA CoFund Programme, Marie Sklodowska-Curie Actions, the FP7's Priority Scientific Excellence programmes and H2020 programmes.

A seminar in Brussels in April 2019 closed the eight-year project. It brought together postdoctoral researchers and alumni as well as the various scientific advisory boards and steering and ethics committees that governed the programme. As in previous years, this seminar gave researchers the opportunity to attend conferences on pioneering areas of science and research practices, including data publication strategies, impacts and integrity within the context of open science.

In all, the programme enabled 212 researchers to benefit from mobility (114 incoming researchers and 68 outgoing researchers) who brought their skills, energy and research projects to INRA's units and partners. The programme is still having an impact through the recruitment of postdoctoral researchers abroad and in France in INRA's labs and infrastructures as well as in other research organisations. It has also helped researchers achieve success with the Marie Curie-Individual Fellowships and European Research Council (ERC) programmes.
www.agreenskills.eu/

INRA ADDS TO ITS NETWORK OF INTERNATIONAL ASSOCIATED LABORATORIES (LIA) WITH CHINA, INDIA, JAPAN AND SINGAPORE

- **Plantomix:** plant diversity and mixing for crop protection. Partners: Yunnan Agricultural University (YAU, China), CIRAD and Montpellier SupAgro in France.
- **FoodPrint:** agrifood process engineering. Partners: Soochow University (China), AgroCampus Ouest (France).
- **Génomique et amélioration du blé** Chinese Academy of Agricultural Sciences (CAAS)
- **Bipi:** plant protection, bacteria-plant-insect interactions for biocontrol of plant diseases. Partner: Chinese Academy of Agricultural Sciences (CAAS).
- **GIMIC:** genetic improvement in cattle and buffaloes. Partner: BAIF Development Research Foundation (India).
- **FreQUenCE:** fruit quality in changing environments. Partner: Tsukuba University (Japan).
- **SynBioEco:** synthetic biology and bioeconomy. Partners: National University of Singapore and Agency for Science, Technology and Research (Singapore); INSA and CNRS in France.

THE EURAQUA NETWORK CELEBRATES 25 YEARS

This network now brings together more than 20 European public research organisations. IRSTEA, which co-manages the secretariat for EurAqua with its partner Deltares (Netherlands), held an event in Brussels in 2019 to celebrate the network's 25th anniversary. The network is recognised by the European Commission as a key player in freshwater issues in Europe. Several representatives from European institutions and initiatives attended as the network presented its thematic priorities in its Strategic Agenda.
www.euraqua.org

FRENCH AGRICULTURAL RESEARCH AND THE CONSULTATIVE GROUP FOR INTERNATIONAL AGRICULTURAL RESEARCH (CGIAR) STRENGTHEN THEIR COLLABORATION FOR AGRICULTURE, FOOD AND CLIMATE

The French research organisations INRA, CIRAD, IRSTEA, IRD and Agreenium decided with CGIAR to strengthen their collaboration by signing a joint declaration in May 2019. This declaration set out joint actions on three major themes: agriculture and climate change; agroecology; and nutrition and sustainable food systems. Specific actions to strengthen their cooperation will include researchers and experts being assigned to different institutions, shared resources, joint participation in international programmes and capacity-building activities.

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Planning for and supporting change /

Modernising support functions during the merger

Research support services were as important as ever throughout the merger. Support service personnel from both institutes worked together to continue the modernisation process undertaken at INRA and expand it to encompass IRSTEA's activities. As a result, all of INRA's initial targets were met and applied to the new INRAE structure thanks to the excellent management of the project by Human Resources.

The major milestones for 2019 were focused on the support services required to ensure the merger was completed on time. This required considerable efforts from those at the head offices as well as local staff in the individual centres, and work will continue in the coming years to bring stability to the newly modernised processes. The human resources, information systems, financial and occupational health and safety departments were all directly impacted. They went above and beyond in terms of their professionalism throughout the process.

QUALITY WORKING CONDITIONS: A PILLAR OF HUMAN RESOURCES MANAGEMENT

The quality of working conditions barometer project, which began in 2018, was adapted to IRSTEA's activities and integrated into the merger process. A first survey was completed in the second quarter of 2019.
With an average score of 7/10 for the 48% of responses gathered by both institutes, the results of the barometer were satisfactory, although they did highlight several areas for improvement: stress felt at work, change management, needs for support, and the digital transition.

INRAE: THE FIRST PUBLIC RESEARCH ORGANISATION TO RECEIVE DIVERSITY-EQUALITY CERTIFICATION

Based on the data from the 2018 report on gender equality at INRA, a two-pronged action plan was implemented to improve gender equality and fight discrimination. The plan was rolled out on a trial basis to four centres (IdF Versailles-Grignon, Occitanie-Montpellier, Val de Loire, head office) and focused on communication and awareness and the creation of a diversity committee and a dedicated support unit. The year-long certification process came to a close in January 2020, with the Institute receiving the dual "Diversity-Equality" certification from AFNOR. Efforts will continue with the creation of a network of liaisons and additional actions to address seven of the 25 discrimination criteria: gender, disability, age, family situation, union involvement, ethnic origin and religion.

HR EXCELLENCE IN RESEARCH

LABEL EGALITÉ

LABEL DIVERSITÉ

This comprehensive HR policy was strengthened in 2019 with **a new initiative to support new unit directors** when they take up their posts as well as to help them prepare for their departure. Directors from both INRA and IRSTEA worked together on this initiative.

STRUCTURING INRAE'S INTEGRITY POLICY

Along with the ethics committee INRAE shares with IRD, CIRAD and IFREMER, the newly created Institute has also benefitted from a scientific integrity policy managed by a delegation on professional conduct, scientific integrity and research project ethics and by a network of experts.

INRAE'S NEW INFORMATION SYSTEM

Although the creation of a new institute entailed a substantial workload for the Information Systems Department teams, it was also an opportunity to develop a new IS governance system. The IS teams had their work cut out for them with the merger in 2019: they had to create a single @inrae.fr email system, consolidate the management information system, get payroll up and running for all employees, and develop an interface for all applications with a unified INRAE directory.

A new IS governance system that combines stronger coordination and decentralisation was put in place to tackle these different projects.

Communication

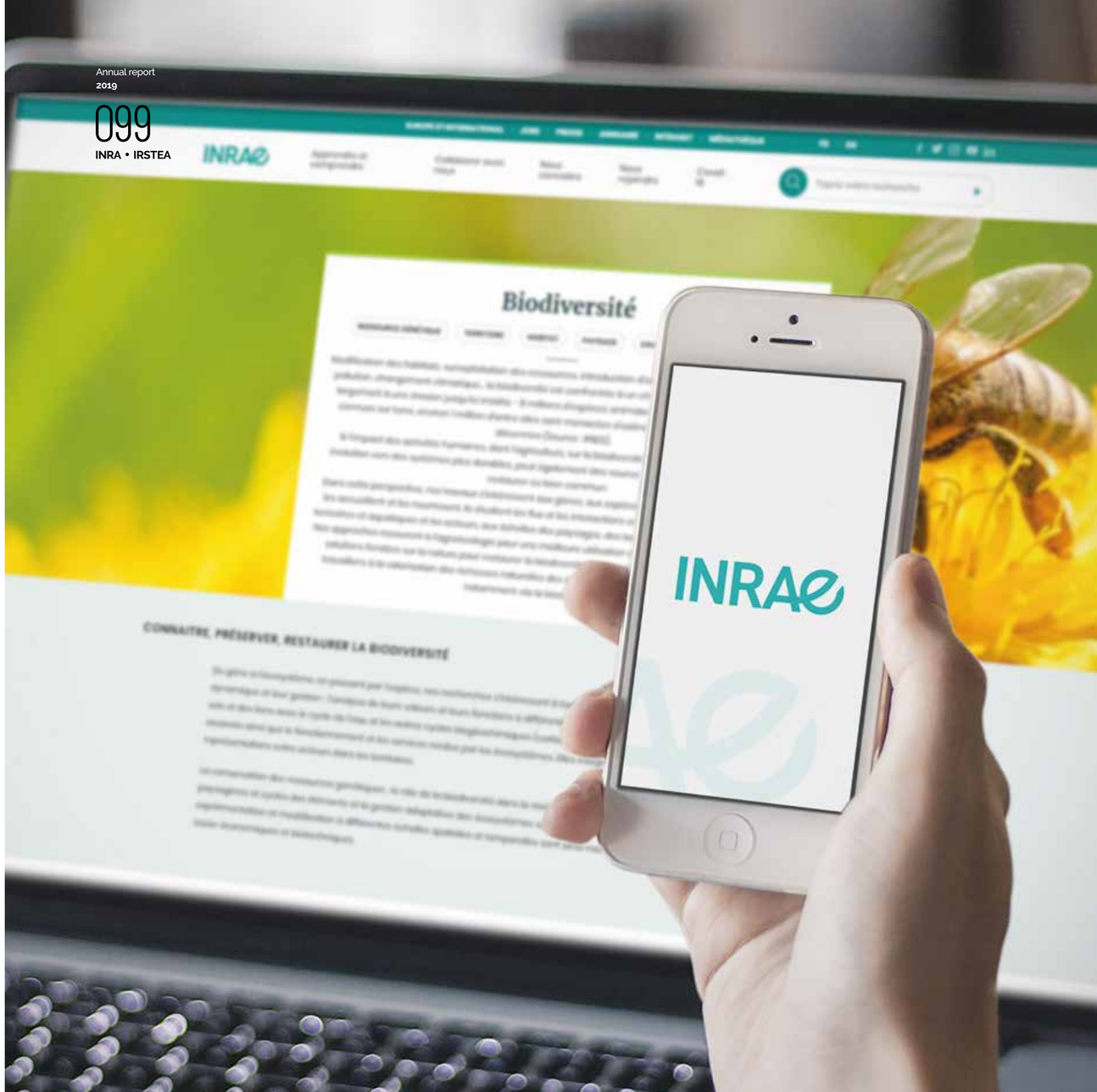
Doubling up on communication in 2019

Creating INRAE not only required additional communication about the merger, especially to support employees through the change, but also involved three major projects: the future website, a unifying intranet portal and the INRAE logo.

The website benefitted from the revamp of INRA's website initiated in 2018, which was focused on user experience and organised around societal issues and major themes.

Since June 2019, internal communication, which was intensively developed to support the merger, relied on a new visual intranet portal promoting interactivity with staff. Additionally, the Jamespot enterprise collaborative social network was tested with 350 employees, with the end goal of rolling it out to the entire Institute.

Finally, the new logo, which was unveiled in September and supplemented by an institutional film in December, emphasises the "e" in INRAE that symbolises "INRA's commitment to the agroecological transition and sustainable food systems while highlighting IRSTEA's expertise on the environment" and the creation of a new professional community built on the legacy of the two former institutes.



Stronger public outreach

2019 PARIS INTERNATIONAL AGRICULTURAL SHOW: INRA STANDS ABOVE THE CROWD

For the 56th Paris International Agricultural Show (SIA), INRA chose to tell the story of "the secret life of plants and animals". A total of 350 researchers from 20 research units participated in activities at the stand (which was recognised as outstanding by sector professionals), where the public could learn about the interactions that take place between plants, animals and microorganisms and the major challenges on which the Institute works. Additionally, a symposium, a dozen conferences and – for the first time – public debates put scientists front and centre in discussions with professionals and visitors.

INDUSTRY PROFESSIONALS AND RESEARCHERS AT SIMA FOCUS ON REDUCING INPUTS

Meanwhile in Villepinte, IRSTEA presented its latest findings at the International Exhibition of Solutions and Technologies for Efficient and Sustainable Agriculture (SIMA), with many discussions with farmers and industry professionals at its "Precision agriculture - sustainable agriculture" stand.

NEW FORUMS FOR COMMUNICATION: A DOCUMENTARY AND A FESTIVAL

The Institute also looked to new forums through which it could communicate, with a documentary film called "Microbiota: The Amazing Powers of the Gut" and co-produced with Arte and Yuzu Productions. *Les Utopiales*, the international science fiction festival, held in October in Nantes, was also an opportunity to reach a new and enthusiastic audience through eight conferences and games led by INRA researchers.

Awards and honours

2019 INRA Awards

The INRA Awards, which were created in 2006 under the leadership of Marion Guillou, celebrated their 14th and final edition in 2019. The honours were awarded by a jury chaired by Philippe Gillet, Vice-President of the École polytechnique fédérale in Lausanne (EPFL) and President of the INRA Scientific Advisory Board, and presented in the presence of Frédérique Vidal, French Minister of Higher Education, Research and Innovation, and Isabelle Chmitelin, Chief of Staff for Didier Guillaume, French Minister of Agriculture and Food. The awards recognised the accomplishments of women, men and a team with remarkable careers driven by the values of openness to the world and its challenges along with scientific rigour and innovation.

The Research Support Award went to **Laetitia Lançon** and **Olivier Lalouette**. Laetitia Lançon, Executive Assistant of the INRA Occitanie-Toulouse centre, was honoured for the extraordinary support she provides to the scientific teams of the world-renowned French Plant Genomic Resources Center that was created in 2004. Olivier Lalouette, Administrator of the Centre for Taste, Food and Nutrition Sciences at INRA's Bourgogne Franche-Comté centre, was recognised for his talent and drive to simplify the lives of the researchers with whom he works.

The Innovation Award went to **Pascal Neveu**, Director of the INRA Occitanie-Montpellier centre and big data pioneer, for his groundbreaking work in an increasingly collaborative research environment where the volume and complexity of data is steadily rising.

The Science with an Impact Award went to **"Potato team"** at the Institute for Genetics, the Environment and Plant Protection at INRA's Brittany-Normandy centre. Researchers from various disciplines and scientists running field experiments have been working together for 30 years to be able to grow the world's leading non-grain food crop without using pesticides by creating resistant varieties, pathogen detection tools and innovative cropping systems.

The Promising Researcher Award recognised **Guillaume Martin**, a research scientist at INRA's Occitanie-Toulouse centre whose work focuses on the agroecological transition for livestock farming. Using serious games and participatory approaches, he explores, shares and takes action with industry stakeholders.

Yann Guiguen, Research Director at the INRA Brittany-Normandy centre, has worked on sex determination in fish since 1993. He was involved in describing the main function of the sdY gene in salmonid species. He received the **Scientific Breakthrough Award** for his work in aquaculture and the study of wild populations.

This year's **Lifetime Achievement Award** was given to **Claire Chenu**, a researcher at the INRA Île-de-France – Versailles-Grignon centre and professor at AgroParisTech. She developed an innovative approach combining microscopy and biogeochemistry, revealing the role of soil structure in carbon dynamics. She served as the special ambassador for the International Year of Soils in 2015 and participates in the "4 per 1000" initiative launched during the COP 21.

INRA and IRSTEA scientists honoured this year

FRENCH ACADEMY OF AGRICULTURE AWARDS

RECOGNITION OF THREE DISTINGUISHED RESEARCHERS

Three research directors received the gold medal **Pascale CHAVATTE-PALMER**, Research Director at INRA Île-de-France – Jouy-en-Josas, was rewarded for her internationally recognised and innovative research in foetal-placental physiopathology and developmental origins of health and disease in domestic animals. **Fabienne TROLARD**, Research Director at INRA PACA, was honoured for the discovery of fougerite, a ferrous mineral that is typical in gley hydromorphic soils, and for expanding the existing knowledge of the biogeochemical cycle of iron. The work and teaching skills of **Jean-Pierre RENOU**, Director of the Research Institute of Horticulture and Seeds (IRHS) at INRA Pays de la Loire, were also commended.

ONE MEDAL AND TWO AWARDS RECOGNISE THE USEFULNESS OF SCIENTIFIC RESEARCH TO SOCIETY

Nathalie CHEVIRON, an engineer at INRA's Île-de-France – Versailles-Grignon centre, received the silver-gilt medal for her research on the development of ecotoxicity bioindicators in soils. **Isabelle COUSIN**, Director of the Soil Sciences unit at INRA Val de Loire, was honoured with the Xavier-Bernard Foundation Prize for her work on soil structure, properties and hydraulic functions and their applications for sustainable and efficient water management in agriculture. **Michel CHAUVET**, a former researcher at the INRA Occitanie-Montpellier centre, received the Clément Jacquiot award for his book L'Encyclopédie des plantes alimentaires (The Encyclopaedia of Edible Plants).

BOLSTERING YOUNG SCIENTISTS

The seven theses that received the Academy's *Médaille d'Argent Dufrenoy* dealt with: Multi-actor multi-criteria evaluation using computer simulations, **Sandrine ALLAIN**, AGIR (AGroecologies, Innovations, Ruralities) unit, INRA Occitanie-Toulouse; The dynamics and modelling of dew retting of industrial hemp under controlled environments for the production of multi-use natural fibres, **Laurent BLEUZE**, Joint Research Unit for the Fractionation of Agricultural Resources and the Environment (FARE), INRA Grand Est-Nancy; The forest transition in France, combining statistics, tree growth modelling and environmental history, **Anaïs DENARDOU-TISSERAND**, Silva Joint Research Unit, INRA Grand Est-Nancy; The territorial metabolism of French livestock farming with an environmental accounting approach, **Joao Pedro DOMINGUES**, Science for Action and Sustainable Development: Activities, Products, Territories (SADAPT), INRA Île-de-France-Versailles-Grignon; Fine characterisation, via optimised and high throughput methods, of the impact of chemical pollutants on aquatic environments, **Duarte GOUVEIA**, RiverLy, IRSTEA Lyon-Villeurbanne; The implementation of agroecology in vineyards, with the design of multifunctional agricultural landscapes enabling biodiversity conservation and maximisation of natural regulations, **Lucile MUNERET**, Joint Research Unit for Vine Health and Agroecology, INRA Nouvelle-Aquitaine-Bordeaux; Spatial epidemiology, with the modelling of a plant disease taking into account the geography of the epidemic, **Coralie PICARD**, Joint Research Unit for Biology and Genetics of Plant-Pathogen Interactions (BGPI), INRA Occitanie-Montpellier.

THOMAS SCHIEX RECOGNISED BY THE AAAI FELLOWS PROGRAMME FOR HIS CONTRIBUTION TO THE DEVELOPMENT OF ARTIFICIAL INTELLIGENCE

Thomas Schiex, Director of Research at the Occitanie-Toulouse centre, has conducted research in artificial intelligence (AI) and bioinformatics for nearly 40 years. He co-created the software program OpenSource Toulbar, and is pushing the limits of AI and putting his developments to work for biology and agriculture, such as by analysing mass genetic data, decoding plant and bacterial genomes, supporting assisted design of orchards and market gardens, and designing new proteins. With this award, the Association for the Advancement of Artificial Intelligence (AAAI) is recognising the impact of his work for the field.

VERONIQUE BELLON-MAUREL: IMT GRAND PRIZE FROM THE FRENCH ACADEMY OF SCIENCE

Véronique Bellon-Maurel is the Director of IRSTEA's Ecotechnologies Division as well as the #DigitAg Digital Agriculture Convergence Lab. This agricultural scientist with a PhD in process engineering was honoured for her research career, highlights of which include her work in the characterisation of products and objects by spectrometry, territorial environmental assessment and currently the development of digital agriculture for high-performance and ecological farming.

INRA and IRSTEA Governance

INRA's Board of Directors

(31 December 2019)

Chair and CEO
Philippe MAUGUIN

State Representatives
- Philippe VINÇON, Director General for Higher Education and Research, Ministry of Agriculture and Food
- Serge LHERMITTE, Head of Competitiveness and Environmental Performance, Ministry of Agriculture and Food
- Vincent MOTYKA, Head of Performance, Funding and Contractualisation for Research Organisations, Directorate General for Research and Innovation, Ministry of Higher Education, Research and Innovation
- Marie-Hélène TUSSEAU-VUILLEMIN, Head of Environment and Universe Sciences, Agronomy, Ecology and Earth System Science, Ministry of Higher Education, Research and Innovation
- Thomas COLIN, Head of the Office of Research and Higher Education (3 MIRES), Ministry of Public Action and Accounts
- Marie-Hélène JOUIN-MOULINE, Deputy Head of the Office of Consumer Goods, Agrifood Industries and Design, Ministry of Economy and Finance
- Annick BIOLLEY-COORNAERT, Assistant Director of Food Products and Agriculture and Food Markets, Ministry of the Economy and Finance
- Laurent BERGEOT, Head of the Research Department, CGDD/DRI, Ministry for the Ecological and Inclusive Transition
- Carole ROUSSE, Head of the Office of Food and Nutrition, Ministry for Solidarity and Health

President of INRA's Scientific Advisory Board
Philippe GILLET, Professor at the *École polytechnique fédérale* in Lausanne, Switzerland (EPFL)

Higher Education Establishment Director (article L. 812- 3 of the French rural and maritime fishing code):
Anne-Lucie WACK,Director General of Montpellier SupAgro

Members of the Agricultural Production, Development and Cooperation Sector
- Daniel PRIEUR, Deputy Secretary General of the French National Federation of Agricultural Holders' Unions (FNSEA)
- Sébastien WINDSOR, President of the Normandy Regional Chamber of Agriculture
- Anne WAGNER, R&D Director of TEREOS
- Nicolas BACHELET, National Administrator, Young Farmers (JA) union
- Pierre GUEZ, Managing Director of BJCLP, farming and agrifood consultancy
- Stéphane VIEBAN, Director General of the Alliance Forêt Bois cooperative

Members representing employees of the agricultural and agrifood sectors, respectively, appointed by the most representative confederations
- Jocelyne HACQUEMAND, SFederal Secretary, FNAF-CGT
- Betty HERVÉ, National Secretary, FGTA-CFDT

Members from approved environmental protection associations (article L. 141-1 of the French environmental code):
François LETOURNEUX, Honorary President of the French Committee of the International Union for the Conservation of Nature

Member from approved consumer rights associations (article L. 441-1 of the French consumer code):
Marie-Claude FOURRIER, Head of Consumers' Office, French national association for consumer and user rights

Elected Staff Representatives:
Julie WOHLFAHRT, CFDT – INRA ; Elisabeth TABONE, CFDT – INRA
Patrick LEMAIRE, CFDT - INRA Dominique DESBOIS, CFDT - INRA
Pascale MAILLARD, CGT – INRA Laurence ARTIGE, CGT – INRA
Eric LATRILLE, CGT – INRA Michel BERTRAND, CGT – INRA
Fanny GUYOMARC'H, SUD Recherche EPST - Bernard ROLLAND, SUD Recherche EPST

IRSTEA's Board of Directors

(31 December 2019)

IRSTEA Representatives
- Marc MICHEL, CEO of IRSTEA
- Patrick FLAMMARION, Director General for Research and Innovation
- Pierre-Yves SAINT, Advisor in Charge of Modernization and Governance
- Laurence EYMARD, President of the Scientific and Technical Advisory Board

Elected staff representatives
Full Members
- Marina COQUERY, SUD - Recherche - EPST
- Fabrice GUIZIOU, SUD - Recherche - EPST
- Françoise VERNIER, Force Ouvrière
- Lynda AISSANÏ, CGT

Alternate Members
- Jean-Marc LE BARS, SUD - Recherche - EPST
- Baptiste HAUTDIDIER, SUD - Recherche - EPST
- François TRINQUET, Force Ouvrière
- Serge GUILLAUME, CGT

State Representatives
Research
Vincent MOTYKA, Head of Performance, Funding and Contractualisation for Research Organisations
Budget
Nicolas HENGY, Head of Office, Research and Higher Education
Agriculture
Valérie BADUEL, Deputy DG, Directorate General of Education and Research
Industry
Robert DJELLAL, Head of the Office of Eco-Industries and Sustainable Industrial Development
Environment
Thierry COURTINE, Deputy Director for Research and Innovation

Experts
Representing research organisations
- Pascale MARGOT-ROUGERIE, Deputy Director General of AgroParisTech
- Hélène JACQUOT-GUIMBAL, Director General of IFSTTAR
- Michèle ROUSSEAU, President and CEO of BRGM

Scientific and Technical Experts
- Corinne BOREL, Deputy Director
- Marie-Odile HOMETTE, Managing Director
- Emmanuelle BOUR-POITRINAL, President of the "Forest-Water-Territories" section of the French Council on food, agriculture and rural areas (CGAAER)

Economic and Social Experts
- Michel MASSON, former President of the Loiret Chamber of Agriculture, Chair of the Agricultural Equipment Steering Committee
- François ENGUEHARD, Director of Research Centres, VEOLIA
- Bruno GENTY, Honorary Chair, FNE

Elected Official
Michel CAFFIN, Île-de-France Regional Councillor, Chair of the Agriculture Committee for the Île-de-France Regional Council

Financial Controller
Béatrice AVOT, Auditor General, Ministry of Higher Education, Research and Innovation – DAF

INRA's Scientific Advisory Board

(31 December 2019)

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

Ex-Officio Members
- Philippe MAUGUIN, Chair and CEO of INRA
- Christine CHERBUT, Deputy Director General for Scientific Affairs at INRA
- Philippe VINÇON, Director General for Higher Education and Research, Ministry of Agriculture and Food
- Representative: Marion BARDY, Head of the Office for Finalisation of Research, Sub-Directorate of Innovation, Ministry of Agriculture and Food
- Anne-Sophie BARTHEZ, Director General for Higher Education and Professional Integration, Ministry of Higher Education, Research and Innovation
- Bernard LARROUTUROU, Director General for Research and Innovation, Ministry of Higher Education, Research and Innovation

Nominated members
- Daniel BARTHELEMY, Scientific Director of CIRAD's Bios Division
- Sylvie BAUDINO-CAISSARD, Director of the Plant Biotechnologies Laboratory, Université de Saint-Etienne
- Nozha BOUJEMAA, Director of the DATAIA Institute
- Dominique BUREAU, Managing Director of the French Economic Council for Sustainable Development (CEDD)
- Gérard DENARIAZ, Director of Strategic Partnerships & Prospective, Danone Nutricia Research
- Krotoum KONATE, Director of the Institut de l'Alimentation Bio
- Philippe LECOUVEY, Director General Emeritus of Acta
- Annick MERCENIER, Former Director of Research at Nestlé, Chief Information Officer at Nutrileads
- Marie-Laure NAVAS, Professor of Ecology, Montpellier SupAgro
- Gilles PINAY, Unit Director, IRSTEA
- John R PORTER, Professor, Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen
- Anne VARET, Director of Research & Foresight, French Environment and Energy Management Agency (ADEME)

Elected INRA Members

Sector 1: Environment and Agronomy, Forest, Grassland and Freshwater Ecology
- Philippe ROZENBERG, Forest Tree Breeding, Genetics and Physiology Research Unit (AGPF), INRA Val de Loire
- Jean-Philippe STEYER, LBE, Laboratory for Environmental Biotechnology (LBE), INRA Occitanie-Montpellier

Sector 2: Plant Health and Environment
- Didier ANDRIVON, UMR 1349 Institute for Genetics, the Environment and Plant Protection, INRA Brittany-Normandy
- Thierry CANDRESSE, UMR 1332 Fruit Biology and Pathology, INRA Bordeaux-Aquitaine

Sector 3: Plant Breeding and Biology, French Group for the Study and Control of Varieties and Seeds
- Juliette SALVAING, Plant Cell Physiology Laboratory, CEA-Grenoble, INRA Auvergne-Rhône-Alpes
- Denis LECLERCQ, GEVES Experimental Unit in Lusignan, INRA Poitou-Charentes

Sector 4: Science for Food and Bioproduct Engineering
- Jean-Michel SALMON, INRA Montpellier, Experimental Unit of Pech Rouge, INRA Occitanie-Montpellier
- Veronique PLANCHOT, Géraudière site, INRA Pays de la Loire

Sector 5: Animal Physiology and Livestock Systems
- Davi SAVIETTO, UMR1388 GenPhySE Genetics, Physiology and Livestock Systems, INRA Occitanie-Toulouse
- Eliel GONZALES GARCIA, Mediterranean and Tropical Livestock Systems (SELMET) Unit, INRA Occitanie-Montpellier

Sector 6: Animal Health, Animal Genetics
- Claire ROGEL-GAILLARD (DR2), Director for the Animal Genetics and Integrative Biology Unit, INRA Île-de-France-Jouy-en-Josas
- Isabelle OSWALD, ToxAlim Food Toxicology, INRA Occitanie-Toulouse

Sector 7: Nutrition, Chemical Food Safety and Consumer Behaviour Division; Microbiology and the Food Chain
- Jean-Paul LALLES, Nutrition, Chemical Food Safety and Consumer Behaviour (AlimH) Division, INRA Auvergne Rhone-Alpes
- Emmanuelle MAGUIN, Food and Gut Microbiology for Human Health (MICALIS) Unit, INRA Île-de-France-Jouy-en-Josas

Sector 8: Social Sciences, Agriculture and Food, Rural Development and Environment; Applied Mathematics and Informatics; Science for Action and Sustainable Development
ECO-PUB Public Economics, INRA Île-de-France Versailles-Grignon

Sector 9: Research Support Services, Central Administration, Documentation and Publications, IT
- Christine CHARLOT, Research Support Services (SDAR), INRA Nouvelle-Aquitaine-Bordeaux
- Sandra ARRAULT, Department of Human Resources & Sustainable Development, INRA Head Office

Union Observers
- CFDT – INRA: Dominique DESBOIS
- CFTC – INRA: non désigné
- CGT - INRA: Jean-Louis DURAND
- Sud-Recherche EPST: Isabelle GOLDRINGER

IRSTEA's Scientific Advisory Board

(31 December 2019)

President
Laurence EYMARD, OSU Ecce Terra and LOCEAN

External members
- Valérie ARCHAMBAULT, Deputy Director for Research in Charge of Industrial Partnerships, MINES ParisTech
- Arnaud NICOLAS, Director of the National Institute for Earth Sciences and Astronomy (CNRS-INSU)
- Gudrun BORNETTE, Research Director at the CNRS 6249 Joint Research Unit
- Bénédicte BUCHER, Head of the Research at the National Institute of Geographic and Forest Information (IGN)
- Marianne CERF, Research Director at the Science in Society Unit and Deputy Director of the Science for Action and Sustainable Development Division (INRA)
- Jérôme CHAVE, Deputy Director of the Evolution and Biodiversity lab (ledb) at CNRS/UPS
- Michel DIMOU, Director of the Applied Development Economics Laboratory (LEAD) at the Université de Toulon
- Pierre FRANCKHAUSER, Professor of Geography at the University of Franche-Comté
- Gilles GRANDJEAN, Programme Director at BRGM
- Corinne LEYVAL, Research Director at LIEC CNRS, Université de Lorraine
- Valérie MAZZA, Scientific Director of Limagrain
- Etienne PAUL, LISBP INSA Toulouse
- Julie RUIZ, Université du Québec à Trois-Rivières
- Eric SERVAT, IRD, IRD, Director of the Institut Montpelliérain de l'eau et de l'environnement (IM2E)

Ministry Representatives

- Marion BARDY, Head of the Office for Finalisation of Research, Sub-Directorate of Innovation, Ministry of Agriculture and Food
- Laurent BELANGER, Deputy to the Sub-Directorate of Scientific and Technical Management at the Ministry for the Ecological and Inclusive Transition
- Marie-Hélène TUSSEAU-VUILLEMIN, Head of Environment and Universe Sciences, Agronomy, Ecology and Earth System Science, Ministry of Higher Education, Research and Innovation

Staff Representatives

Research Support

- Marie-Hélène THIVET, Chief Procurement Officer at the Antony centre
- Corinne LE ROY, Financial Affairs and Procurement Directorate, Procurement Officer

Water Division

- Evelyne TALES, Research Engineer, Hycar Unit, IRSTEA Antony
- Vazken ANDREASSIAN, Director of the Hycar Unit, IRSTEA Antony
- Cécile MIEGE, Deputy Director of the RiverLy Unit, IRSTEA Lyon-Villeurbanne
- Soizic MORIN, Research Scientist, EABX Unit, IRSTEA Bordeaux

Ecotechnologies Division

- Marie-Line DAUMER, Research Engineer, OPAALE Unit, IRSTEA Rennes
- Laurence FOURNAISON, Research Director, FRISE Unit, IRSTEA Antony
- Sonia GRIMBUHLER, Research Engineer, UMR ITAP, IRSTEA Montpellier
- Sylvain MOREAU,Experimentation Centre Leader, PROSE Unit, IRSTEA Antony

Territories Division

- Thomas SPIEGELBERGER, Director of the LESSEM Unit, IRSTEA Grenoble
- Yoan PAILLET, Assistant Research Engineer, LESSEM Unit, IRSTEA Grenoble
- Tina RAMBOLINAZA, Research Director, ETBX Unit, IRSTEA Bordeaux
- Christophe BOSCHET, Research Engineer, ETBX Unit, IRSTEA Bordeaux

The INRA-CIRAD-IFREMER Ethics Committee

(31 December 2019)

Axel KAHN
President of the Ethics Committee. Research Director at INSERM.

Michel BADRÉ
Vice-President of the Ethics Committee. Member of the Economic, Social and Environmental Council, in the group of environmental associations.

Madeleine AKRICH
Research Director at MINES ParisTech (Centre for the Sociology of Innovation).

Bernadette BENSAUDE-VINCENT
Professor Emeritus at the Université Paris 1 Panthéon-Sorbonne.

Jean-Louis BRESSON
Nutritionist and Physician, University Professor, Founder of the Necker-Cochin Clinical Research Centre.

Céline BOUDET
Scientific Coordinator at the French National Institute for Industrial Environment and Risks (Ineris).

Mireille DOSSO
Director of the Institut Pasteur in Côte d'Ivoire.

Françoise GAILL
Research Director at CNRS, Officer for the CNRS Directorate General.

Stéphanie LACOUR
Research Director at CNRS, Deputy Director of the Institute for Social Sciences of Politics (ISP) – ENS Paris-Saclay. Director of the "Standards, Science and Techniques" research group at CNRS.

Lyne LÉTOURNEAU
Professor, Department of Animal Sciences at Laval University in Quebec.

Marie-Geneviève PINSART
Philosopher, Professor at the Université Libre de Bruxelles.

Pere PUIGDOMENECH
Professor of research at the Spanish National Research Council (CSIC) at the Institute of Molecular Biology in Barcelona.

Michel SAUQUET
Lecturer specialising in intercultural issues.

Hervé THÉRY
Geographer, Associate Professor at the University of Sao Paulo (Brazil).

Joint Administrative Staff

INRA
Christine CHARLOT, General Secretary, with the support of Nathalie Hermet

CIRAD
Philippe FELDMANN,
Marie DE LATTRE-GASQUET

IFREMER
Philippe GOULLETQUER

IRD
Chloé DESMOTS

Key figures INRA & IRSTEA 2019

Staff numbers 2019

INRA

7,497 permanent staff (FTE),
of whom 3,686 men and 3,811 women

50.8% 49.2%

1,833 researchers
2,605 engineers and assistant engineers
3,059 technicians

2,484 staff with contracts (FTE)

570 PhD candidates
(139 of whom are foreign nationals)
69 post-doctoral fellows
(51 of whom are foreign nationals)
2,280 trainees
(338 of whom are foreign nationals)

IRSTEA

844 permanent staff (FTE)
of whom 485 men and 359 women

42.6% 57.4%

157 researchers
560 engineers and assistant engineers
127 technicians

327 staff with contracts (FTE)

141 PhD candidates
(49 of whom are foreign nationals)
7 PhD candidates
(3 of whom are foreign nationals)
279 trainees
(60 of whom are foreign nationals)

2019 Budget

INRA

Resources
€899.8 million

- Subsidy for public service expenses
  €706.5m
- INRA resources (contractual and non-contractual resources
  €193.3m
  - INRA resources (from research contracts) €132.8m
    - ANR €28.5m
    - PIA €15.3m
    - Other public institutions €6.9m
    - Local authorities €21.9m
    - Europe €22.9m
    - Ministries €7.3m
    - Research and higher education institutions €5.0m
    - Agricultural and industrial business partners €24.9m
  - Non-contractual INRA resources €60.5m
    - Allocated grants €4.0m
    - Donations and bequests €0.1m
    - Royalties for patents, licences €6.0m
    - Services rendered €16.4m
    - Product sales €17.1m
    - Other subsidies €2.4m
    - Other operating income €6.1m
    - Financial and exceptional income €8.4m

IRSTEA

Resources
€109 million

- Subsidy for public service expenses
  €83.6m
- IRSTEA resources (contractual and non-contractual resources)
  €25.4m
  - IRSTEA resources (from research contracts) €21.4m
    - ANR €3.3m
    - PIA €1.2m
    - Other public institutions €1.8m
    - Local authorities €1.7m
    - Europe €1.8m
    - Ministries €4.0m
    - Research and higher education institutions €1.2m
    - Agricultural and industrial business partners €6.4m
  - Non-contractual IRSTEA resources €4m
    - Allocated grants €0.0m
    - Donations and bequests €0.0m
    - Royalties for patents, licences €1.0m
    - Services rendered €2.2m
    - Product sales €0.2m
    - Other subsidies €0.1m
    - Other operating income €0.5m
    - Financial and exceptional income €0.0m

Partnerships and innovation

	INRA	IRSTEA
Socio-economic Partnerships		
New partnership contracts signed with socio-economic players	319	57
Revenue from research contracts with socio-economic partners	€24.9m	€3.8m
Number of partnership arrangements with socio-economic partners	**27** Joint Technology Units, **4** Carnot Institutes, **4** Labcom	**1** Carnot Institute **1** Labcom
Intellectual Property		
Declarations of inventions & exploitable research results	130	18
Patents submitted	33	5
Patent families held	333	88
Applications for plant variety rights	13	N/A
Plant variety rights held	425	N/A
Creating Value		
New licences for patents, expertise, software, brands, models etc.	47	6
Licences held	515	102
New plant variety rights licences	44	N/A
Plant variety rights licences held	893	3
Creating New Companies		
New companies set up based on INRA or IRSTEA results	7	1
Companies created in the INRA or IRSTEA environment since 1999	126	17

INRA 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
- €15,000,000 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
- 15 research programmes

The **Éditions Quæ** publishing house was founded in 2006 by four French research institutes: CIRAD, IFREMER, INRA and IRSTEA. With more than 1,000 publications to its name, Quæ seeks to foster exchanges 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 forestry to the environment, food, the sea, aquatic and marine resources, life and Earth sciences, and the humanities and social sciences. Quæ began publishing digital publications in 2008. With around 100 books currently available at no cost, Quæ is working to meet French and European directives requiring free distribution of documents published from activities financed by French public research or EU funds.

INRA Transfert is a project engineering and technology transfer company for innovation in food, agriculture and the environment, with the following missions:

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

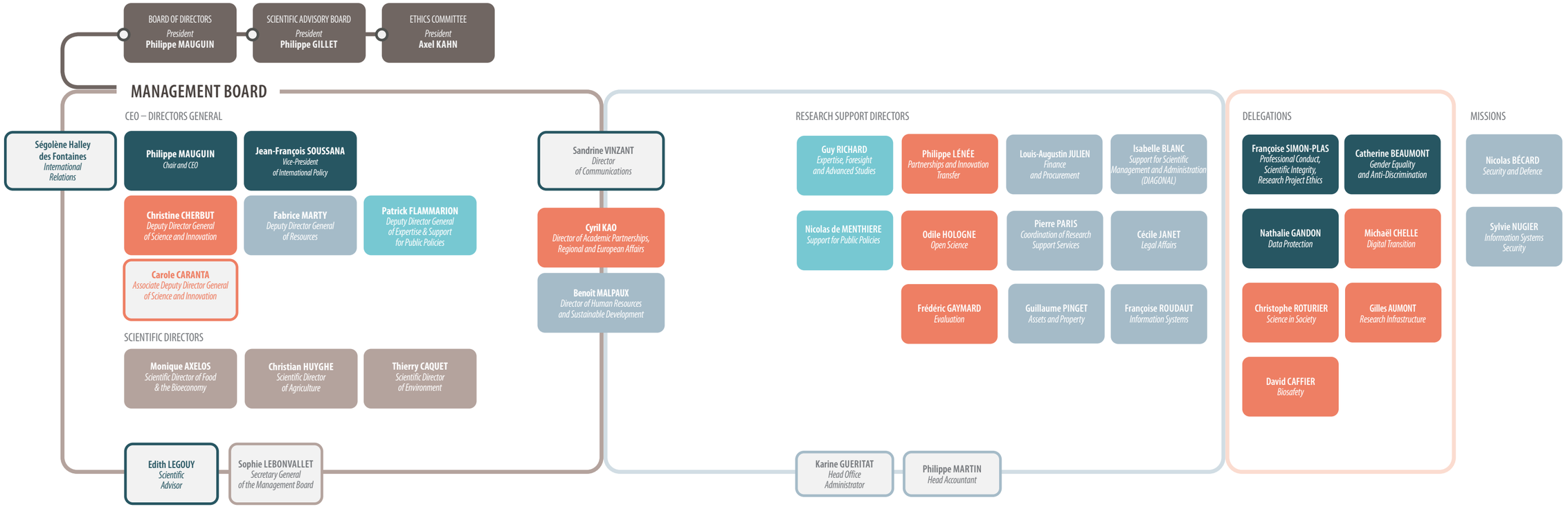
SAS **Château Couhins** was created in 2018 on the 50th anniversary of this Cru Classé in the Classification of Graves wine produced under the INRA umbrella. The simplified joint stock company (*société par actions simplifiée*) is fully integrated into the Graves Crus Classés professional collective while also enjoying the support of INRA'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 INRA 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

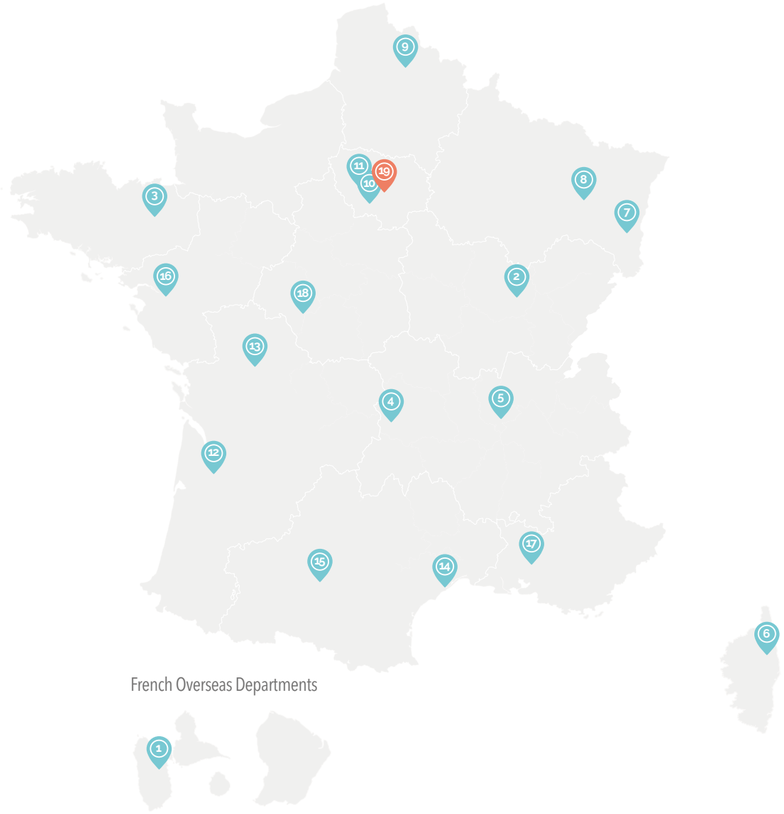
Organisation Chart

(as of 1st January 2020)



INRAE's 18 centres

18 research centres reflect INRAE's involvement in key regional dynamics.
The Institute also has two head offices.



1. **French West Indies and Guiana**
   President: Harry Ozier-Lafontaine
2. **Bourgogne-Franche-Comté**
   President: Nathalie Munier-Jolain
3. **Brittany-Normandy**
   President: Hélène Lucas
4. **Clermont – Auvergne-Rhone-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**
    President: Catherine Beaumont
19. **Paris-Antony Head Office**
    Administrator: Karine Gueritat

INRAE'S 14 scientific divisions

- **Agroecosystems**
  Philippe HINSINGER
- **Human Nutrition and Food Safety**
  Jean DALLONGEVILLE
- **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
- **Microbiology and the Food Chain**
  Sylvie DEQUIN
- **Mathematics and Digital Technologies**
  Hervé MONOD
- **Animal Physiology and Farming**
  Françoise MEDALE
- **Animal Health**
  Muriel VAYSSIER-TAUSSAT
- **Plant Health and Environment**
  Christian LANNOU
- **Action and Transitions**
  Christophe SOULARD
- **Food, Bioproducts and Waste**
  Michael O'DONOHUE

INRAE'S Units

203 research units

42 experimental units

21 support service units

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Annual report
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INRA • IRSTEA

French National Research Institute for Agriculture, Food and Environment

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INRAE

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