

PEPR Agroecology and Digital Technologies

KEY HIGHLIGHTS

2025

Production and coordination

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FOREWORD

The *Agroecology and Digital Technologies* Priority Research Programme (PEPR) was launched in January 2022 for a duration of eight years. To date, it supports 23 projects, each running for 5 years. Ten research projects and three infrastructure projects were selected at the start of the programme, with the remaining ten projects funded through two successive calls between 2023 and 2025.

At the beginning of the 2026 academic year, we wished to highlight a selection of key scientific findings emerging from the first wave of funded projects. The aim is to share original results and to showcase the multidisciplinary and multi-partner approaches developed at the interface between agroecology and digital technologies.

These examples illustrate the core objective of the PEPR: to ensure that digital technologies actively contribute to the agroecological transition. They also reflect the diversity of topics addressed and the ambition to translate scientific advances into concrete outcomes in the field, in close collaboration with relevant partners.

This publication offers an initial overview of results. Further findings will follow, as the harvest has only just begun.

We hope you enjoy reading this overview.

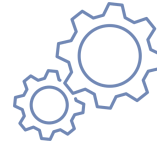
Claire Rogel-Gaillard (INRAE) and Jacques Sainte-Marie (Inria)
Scientific Directors of the Agroecology and Digital Technologies PEPR

KEY FIGURES*



years

Programme duration
(2023-2031)



23 projects

Covering research and
infrastructures



56 PhD theses et 27 postdoctoral positions

funded since 2023



More than 50 partners

including 5 technical institutes
and 4 companies



All publications are available in the PEPR HAL collection:

<https://hal.science/AGROECONUM/>

* Figures as of 6 January 2026

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- **Diversity and data science**: a key lever for agroecology
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- **Artificial intelligence** to turn images into information

Digital technologies supporting the agroecological transition: a social, political and organisational investment

The agroecological transition supported by digital technologies relies on social, political and organisational change. Projects within the Agroecology and Digital Technologies research programme promote dialogue between stakeholders, the analysis of public policies, and the co-design of solutions tailored to local contexts.

An inventory of public policies supporting digital technologies in French agriculture

© Adobe Stock

CoEDiTAG: Co-evolution of equipment, digital technologies, and agroecological models.

INRAE

Inria

esq

SciencesPo

UniLaSalle
Institut Polytechnique

Context

Digitalisation policies are caught up in a complex web of administrative layers. On the one hand, like many agricultural and rural policies, these policies lie at the intersection of different administrative levels: European, national and regional. On the other hand, they also lie at the intersection of two areas of innovation support: one specific to agriculture and a more general one, stemming from economic policies on innovation and recovery, which places significant emphasis on the digital technology sector.

Results

In response to this need, the CoEDiTAG project produced a factual, data-driven description of public innovation policies supporting the digital transformation of French agriculture. In line with open science principles, the inventory will be made available in open access as a set of detailed tables describing public policies. These tables may be updated by the research community working on digital technologies and the agricultural sector.

Impacts

This output will be valuable to public decision-makers, as well as to the various actors within the innovation system (start-ups, advisory bodies, training organisations, applied research institutes, etc.) seeking to better understand the public policy framework. It will enable them to adjust their actions and funding applications at the appropriate scale and through the most relevant policy channels.

Digital Equipment and Technologies



Agroecological Pathways

Information and contact details:
<https://www.pepr-agroconum.fr/eng/funded-projects/socio-ecosystem/targeted-projects/coeditag>

Developing new forms of multi-actor collaboration

Session of a place-based participatory serious game, combining digital and tangible components. © PEPR AgroEcoNum, LINDDA project.

LINDDA: Designing living infrastructures for responsible digital technologies in support of the agroecological transition.



Context

One of the objectives of the LINDDA project is to develop new forms of multi-actor collaboration to foster collaborative innovation, collectively define territorial challenges, and support the participatory design of organisational frameworks.

Results

Against this backdrop, the project facilitated a territorial consultation process in the Pôle d'Équilibre Territorial et Rural (PETR) of the Grand Briannonnais — a French territorial cooperation body — over nearly two years, concluding at the end of 2025. The aim was to conduct a systemic reflection on a range of territorial issues, including water use, energy production, biodiversity and landscapes, with the operational objective of developing an action plan for the coming years.

Both the design and implementation of the consultation process were highly participatory. A wide range of stakeholders (elected officials, citizens, industry representatives, technical experts, associations, etc.) were involved from the outset — from drafting a participation charter and defining the key issues to be addressed, through to co-designing the territorial action plan. The process relied on a range of collaborative methods, including serious games specifically developed for this exercise, as well as training sessions for participants. It also gave rise to numerous public events.

Impacts

The LINDDA consortium also organised the “Side Event on New Multi-Actor Organisational Forms” during the 8th International Farming System Design Conference (Palaiseau, August 2025). This event highlighted several experiences of collaborative innovation in agriculture across different countries. It helped identify both the challenges encountered and the conditions for success, notably in developing technological solutions that farmers can readily adopt through co-design processes.



Information and contact details:

<https://www.pepr-agroecinum.fr/eng/funded-projects/socio-ecosystem/targeted-projects/lindda>

Publication resulting from the FSD8 2025 event – 8th International Farming System Design Conference, August 2025, Palaiseau, France:

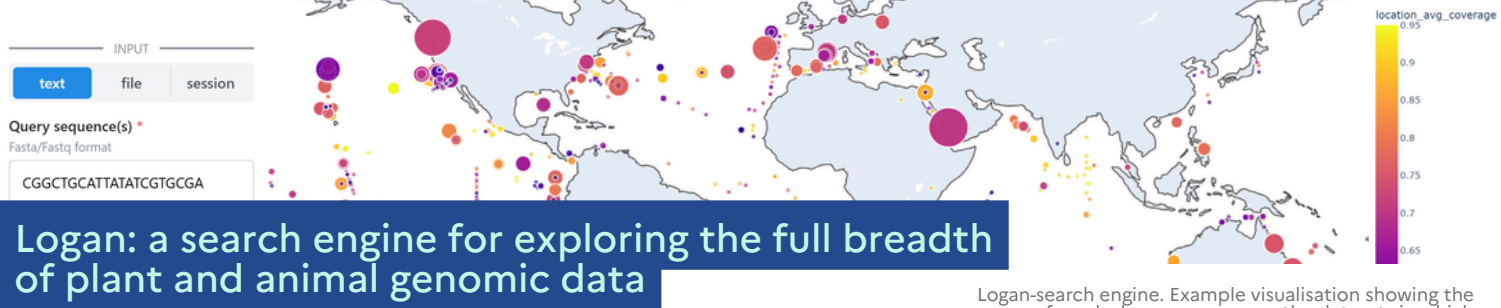
<https://hal.science/AGROECONUM/hal-05273745v1>

Software tools and serious games: TransKey [<https://hal.science/AGROECONUM/hal-04867680v1>] and EnerKey [<https://hal.science/AGROECONUM/hal-05000864v1>]

Diversity and data science: An essential lever for agroecology

The reintroduction of genetic diversity into plant and animal breeding processes and production systems represents a key lever of the agroecological transition, fostering populations that are more resilient and better adapted to climate change.

Thanks to digital technologies, researchers can now explore and characterise the genetic diversity of plants and animals at unprecedented scales. These advances pave the way for more precise breeding strategies and more sustainable management of genetic resources.



Logan: a search engine for exploring the full breadth of plant and animal genomic data

Logan-search engine. Example visualisation showing the presence of an algal sequence across the datasets in which it is detected. © PEPR AgroEcoNum, AgroDiv project

AgroDiv: Genomic and functional characterisation of plant and animal diversity as a cornerstone of agroecology: from genome to phenotype.



Context

To date, only a limited fraction of the genetic diversity of plants and animals has been exploited in breeding programmes. In the face of climate change constraints and to meet the objectives of agroecology, there is a growing need to characterise this diversity more effectively.

Results

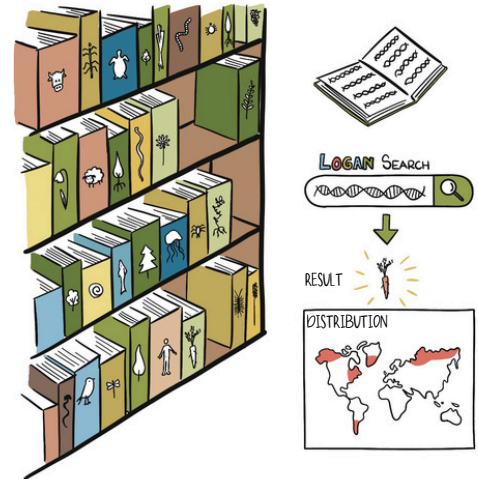
The use of sequencing data has long remained confined to a small number of specific studies. The AgroDiv participated to the development of a search engine that enables large-scale exploration of genomic sequences, making it possible to identify in which species, environments and geographical locations a given sequence occurs:

<https://logan-search.org/>

This search engine indexes all sequencing data available in the international SRA database (Sequence Read Archive) as of early 2024.

Impacts

Logan-search enables researchers to determine, within minutes, how a gene or any sequence of interest is represented across the full body of existing genomic knowledge. It supports the identification of relevant genomic sequences and enhances access to data in public databases for studies of genotype-phenotype associations, while taking environmental information into account.



Preprint: <https://doi.org/10.1101/2024.07.30.605881>

Information and contact details:
<https://www.pepr-agroecinum.fr/eng/funded-projects/genetic-resources/targeted-projects/agrodiv>

Recognising plant species in mixed cropping systems

Pea-wheat (top) and wheat-lentil (bottom) segmentation examples. © Arvalis

AgroEcoPhen: High-throughput plant phenotyping for agroecology.



Context

Agroecology is grounded in ecological processes, including the combination of species, cultivars, and innovative management practices that deliver ecosystem services alongside food production. Mixed cropping systems, for example, involve growing a cereal and a legume together within the same field. This practice helps improve soil fertility, reduce fertiliser use, and limit the spread of diseases and weeds. However, scaling up such systems requires tools capable of accurately monitoring how these systems function — including identifying which plant species dominate and understanding interactions between species.

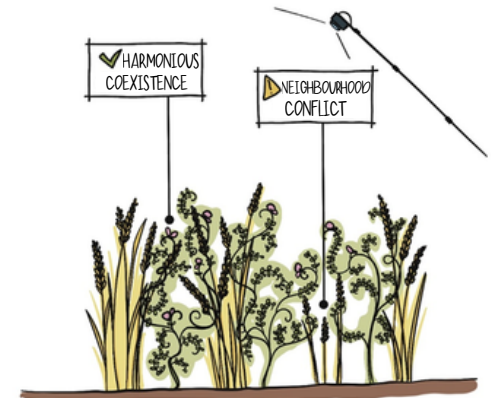
Results

The AgroEcoPhen project has developed tools to characterise mixed crop canopies based on a large image database of intercropped fields. Using artificial intelligence, a pixel-by-pixel semantic segmentation model automatically identifies different plant species and estimates the proportion of each species with an accuracy close to 90%. This approach provides a reliable indicator of the competitive pressure experienced by the main crop. Weeds can also be detected, although their high diversity makes this task more challenging.

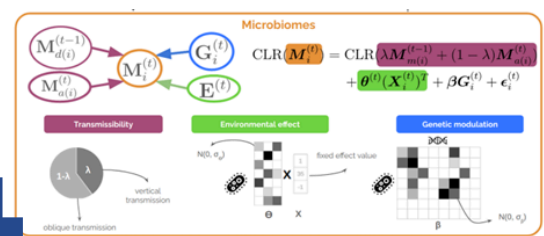
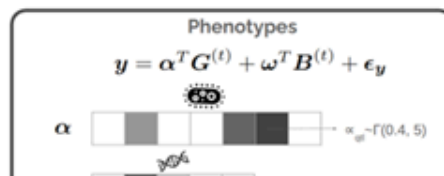
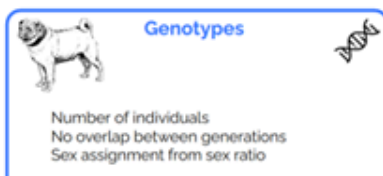
Impacts

This tool facilitates the large-scale, automated analysis of mixed cropping systems — a task that was previously time-consuming and difficult to perform through visual observation alone — and opens up two major perspectives:

- the selection of cereal and legume varieties suited to intercropping systems (e.g. alfalfa varieties that provide good ground cover while remaining weak competitors);
- support for crop management, through the identification of relevant indicators (e.g. height differences between species) to regulate competition within the crop canopy.



Information and contact details:
<https://www.pepr-agroekonum.fr/eng/funded-projects/genetic-resources/infrastructures/agroecophen>



RITHMS: a tool for tracking the co-evolution of animals and their microbiota across generations

Diagram illustrating the functioning of the RITHMS simulation tool. © PEPR AgroEcoNum, HOLOBIONTS project

HOLOBIONTS: Animal holobionts: a new biological scale for exploring genetic diversity and refining breeding strategies in agroecology.



Context

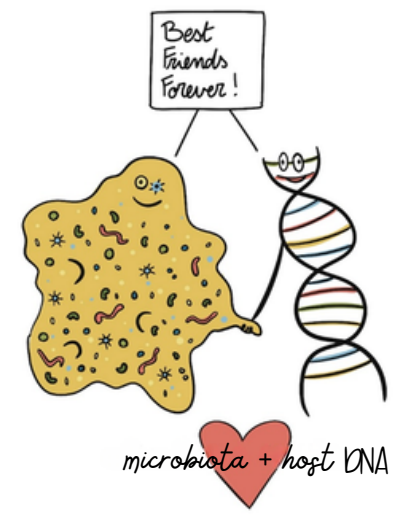
In livestock farming, productivity, animal health and disease resistance, as well as environmental impacts — such as feed efficiency or methane emissions in ruminants — depend not only on the animal's own genes, but also on those of its microbiota, defined as the community of microorganisms hosted by an individual. Understanding and monitoring this cohabitation is expected to play a major role in informing decision-making in livestock systems. Until now, studying interactions between animals and their microbiota across multiple generations has been challenging, due to the lack of sufficiently comprehensive real-world data.

Results

The HOLOBIONTS project has developed the RITHMS simulation tool, which makes it possible to virtually recreate the joint evolution of host organisms and their associated microbiota over successive generations. RITHMS enables realistic simulations of these dynamics and, for example, allows researchers to observe how jointly considering host genetics and microbiota composition over time can improve the selection of breeding animals for herd genetic improvement. The main outcome of the project is therefore the availability of a research and decision-support tool that opens up new perspectives for breeding strategies.

Impacts

In the short term, RITHMS will make it possible to virtually test different livestock management strategies by jointly integrating animal genetics and microbiota composition. This paves the way for more refined breeding approaches compatible with the agroecological transition, promoting animals that are more resilient, better able to adapt, and capable of reducing their environmental footprint.



Open-access tool: <https://github.com/SolenePety/RITHMS>
 Presented at the JOBIM Conference, July 2025, Bordeaux: <https://hal.science/hal-05344529>
 Preprint: <http://arxiv.org/abs/2502.07366>

Information and contact details:
<https://www.pepr-agroecinum.fr/eng/funded-projects/genetic-resources/targeted-projects/holobionts>



Training researchers in emerging concepts of genetic diversity: from the genome to the pangenome

Training session organised within the BReIF project.
© PEPR AgroEcoNum, BReIF project

BReIF: An e-infrastructure to accelerate the use of diversified biological resources.



Context

One of the key levers for mitigating the impacts of climate change on agriculture is the mobilisation of genomic diversity, which provides extensive reservoirs of genes relevant to adaptation. In this context, pangenomics is a core concept for modelling such diversity. Unlike approaches based on comparison with a single reference individual assumed to represent a species, pangenomics considers the full set of genes present across an entire species.

Results

The BReIF project organised several training initiatives aimed at strengthening the skills of the French research community in two key areas:

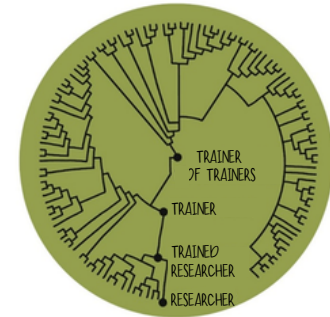
- pangenomics, a state-of-the-art approach for studying genetic diversity in plants and animals;
- best practices for data sharing.

Implementing pangenomics raises both technical and conceptual challenges, which the BReIF and AgroDiv projects address through dedicated tools and best practices. To disseminate these approaches, the INRAE BioinfOmics infrastructure, together with BReIF, organised two training days at the end of 2024, attended by around sixty specialists and trainees. The seminar covered the state of the art in pangenomic tools and applications and concluded with a hands-on workshop focused on creating and exploring pangenomes.

In addition, a train-the-trainers course on data management best practices in line with the FAIR principles (Findable, Accessible, Interoperable, Reusable) was held in 2024, in collaboration with the INRAE national training service. This programme combined a distance-learning module with four days of in-person sessions, integrating presentations, practical exercises and games to support active learning.

Cultivated grapevine diversity dataset: <https://hal.science/AGROECONUM/hal-05322783v1>

Oral presentation on progress in wheat pangenome studies, AgroDiv project General Assembly, July 2025, Versailles: <https://hal.inrae.fr/AGROECONUM/hal-05194387v1>



DATA



Findable



Accessible



Interoperable



Reusable

Information and contact details:
<https://www.pepr-agroecinum.fr/eng/funded-projects/data-processing-and-modeling/infrastructures/breif>

Digital technologies and sensors for animal welfare in livestock systems

Ensuring animal health and welfare is a cornerstone of agroecological livestock systems. Today, digital technologies provide unprecedented means for monitoring and analysing animal behaviour, opening up new possibilities for understanding, assessing and improving welfare in livestock farming.



Improving individual monitoring of farm animals through digital technologies to ensure animal welfare

Automatic water dispenser adapted for grazing systems. © PEPR AgroEcoNum / PATASEL project

PATASEL: Animal phenotyping for the agroecological transition of livestock systems.



Context

Ensuring animal health and welfare is a priority in livestock farming. To detect deviations as early as possible, one promising approach is to monitor animal behaviour continuously.

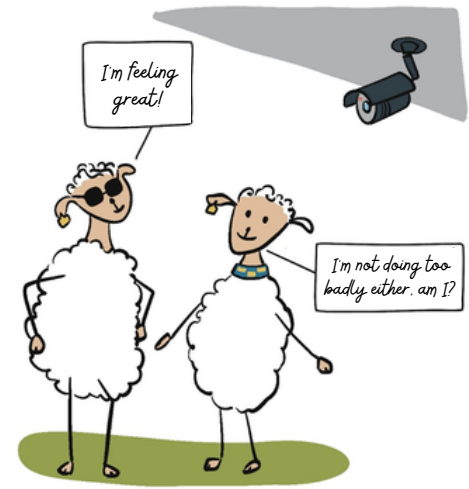
Results

The PATASEL project funded a range of digital equipment enabling continuous data acquisition in livestock systems. These included video systems capable of recording cattle continuously, including at night; connected collars equipped with accelerometers to detect postural changes in small ruminants, including while grazing; and devices for recording animal vocalisations. Together, these tools generate high-frequency data streams that can be made available to a wide range of research projects. For example, these data are used within the WAIT4 project to develop artificial intelligence-based algorithms for monitoring individual behaviours and automatically detecting deviations from normal patterns.

Impacts

These monitoring tools make it possible to document levels of animal welfare in livestock systems while reducing the workload associated with animal supervision. By facilitating early anomaly detection, they are expected to support the timely implementation of corrective actions and help reduce medication use.

Data publication: <https://doi.org/10.5281/zenodo.15608130>



Information and contact details:
<https://www.pepr-agroecinum.fr/eng/funded-projects/genetic-resources/infrastructures/patase/>



Using light sensors to describe shade use by dairy cows at pasture

Light sensor attached to the back of a dairy cow.
© PEPR AgroEcoNum, WAIT4 project

WAIT4: Artificial intelligence and new technologies to assess relevant animal welfare indicators in the context of the agroecological transition.



Context

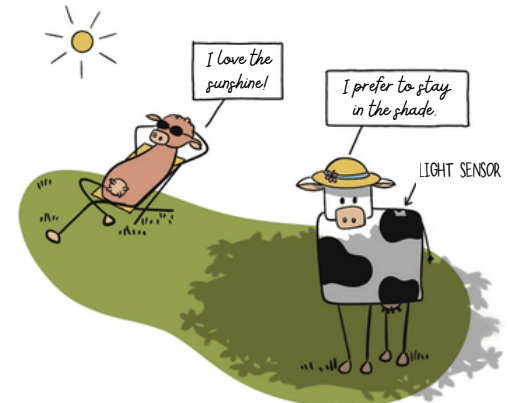
Coping with heat stress is a major challenge for dairy cow welfare. For grazing cattle, shade is a key resource for protection from solar radiation and for reducing the risk of heat stress. However, optimal conditions for access to shade, as well as individual preferences for its use, remain poorly understood. Continuous monitoring of shade use by grazing cows is therefore essential to accurately describe and better understand this behaviour.

Results

The WAIT4 project developed a method using a light sensor attached to the cows' backs to continuously monitor their use of shade in pasture environments. For validation purposes, direct behavioural observations of shade use were also conducted. The sensor demonstrated very high sensitivity in detecting cows in shaded areas (over 92% correct classifications), as well as excellent specificity in identifying cows exposed to sunlight. To determine the light-intensity threshold distinguishing shade from sunlight — and to adapt it to changing environmental conditions such as weather variability — a relatively short observation period (approximately 12 hours) proved sufficient.

Impacts

The results highlight substantial variability in shade use across breeds. Holstein cows, which have been selectively bred for milk production, make greater use of shade than Jersey cows, which are generally considered more robust, while Normande cows display intermediate behaviour. These findings will support recommendations on tree or hedge planting densities in pastures, taking breed-specific preferences into account and aligning animal welfare improvements with agroecological practices.

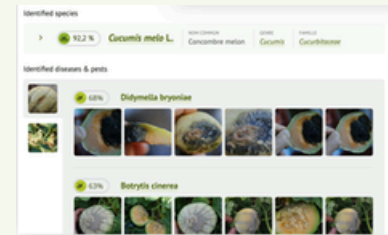
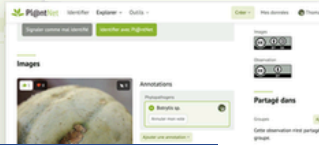
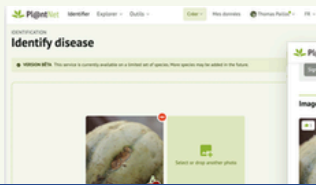
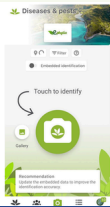


Computers and Electronics in Agriculture: <http://dx.doi.org/10.2139/ssrn.4817070>

Information and contact details:
<https://www.pepr-agroecinum.fr/eng/funded-projects/agricultural-equipment/targeted-projects/wait4>

Harnessing artificial intelligence to turn images into information

Artificial intelligence applied to image analysis is opening up new avenues for diagnosing crop diseases and pests, as well as for characterising soils across agricultural landscapes. By transforming visual data into actionable information, these approaches provide valuable tools to support agronomic research and decision-making at multiple scales.



"Diseases and Pests" feature in Pl@ntNet

User interface of the new "Diseases and Pests" recognition feature in the Pl@ntNet platform. © Pl@ntNet

Pl@ntAgroEco: New perspectives on plant disease characterisation and taxon associations based on deep learning and participatory science.

Context

One of the main obstacles to improving crop health management is the shortage of specialised expertise in botany, plant pathology, and ecology. Pl@ntNet currently offers one of the most advanced plant identification services, based on state-of-the-art artificial intelligence. From photographs submitted by users, Pl@ntNet's AI generates a ranked list of plant species, from the most to the least likely.

Results

The new "Diseases and Pests" feature aims to extend these capabilities. It involves developing and directly integrating into the platform a module capable of identifying not only plant species but also the diseases or pests affecting them, solely from images. The objective is to enable automated phytopathological identification using an AI model specifically trained within the Pl@ntAgroEco project. The model currently deployed in the application can already identify several hundred pathogens affecting around thirty crops. Its performance will be further enhanced by creating a very large dataset comprising nearly 100,000 images and thousands of diseases from the EPPO (European and Mediterranean Plant Protection Organisation) standard database.

Impacts

In the short term, the aim is to provide a tool that can be used directly by plant pathologists and researchers in this field. In the medium term, the ambition is to extend this service to all stakeholders in French agriculture, from farmers to technical advisors. In the longer term, the project seeks to engage users in a participatory epidemiological surveillance approach, building on Pl@ntNet's existing contributions to biodiversity monitoring.

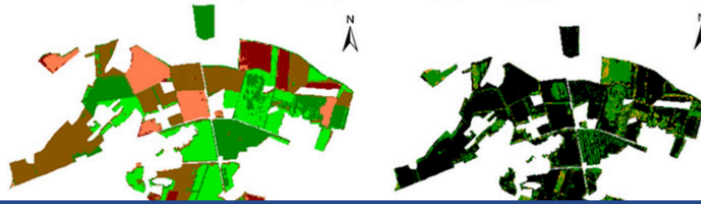
Methods in Ecology and Evolution: <https://doi.org/10.1111/2041-210X.14486>

Smart Agricultural Technology: <https://doi.org/10.1016/j.atech.2025.100813>

Computers in Biology and Medicine: <https://doi.org/10.1016/j.compbiomed.2025.110340>



Information and contact details:
<https://www.pepr-agroekonum.fr/eng/funded-projects/data-processing-and-modeling/targeted-projects/pl-ntagroeco>



Spectral monitoring of organic residual product applications at farm scale

MELICERTES: Modelling ecosystem states and dynamics: applications to carbon fluxes and stocks in ecosystems modified by agricultural activities.

Context

The application of organic residual products (ORPs) is a common agricultural practice aimed at incorporating a diversity of organic materials with soil-amending and/or fertilising properties into cultivated soils. Beyond supplying carbon and mineral nutrients, these applications may also affect environmental compartments, potentially influencing water quality (through nitrate losses) or air quality (through ammonia emissions). Improving the detection and spatial characterisation of organic residual product application practices is therefore essential to better understand and assess their overall impacts. To date, no approach has enabled accurate monitoring of these practices over time. A key challenge lies in developing regional-scale monitoring models and integrating organic residual product applications into agronomic or climate prediction tools.

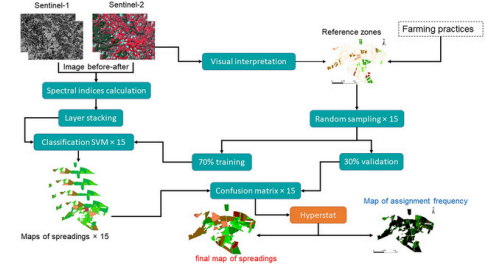
Results

The MELICERTES project explored the potential of optical remote sensing to: (i) spectrally characterise applications of organic residual products carried out on bare soil and on vegetated surfaces, using proximal sensing measurements at field scale; and (ii) assess the feasibility of monitoring these practices using Sentinel-2 satellite imagery, including several days after application.

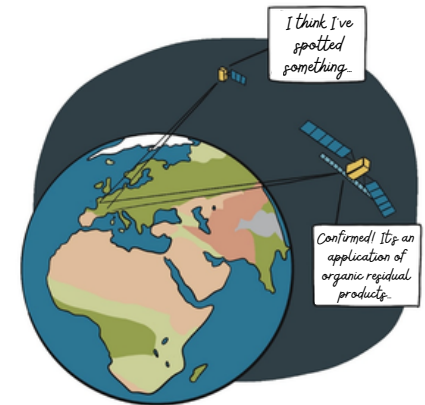
The results showed that ORP applications induce a decrease in reflectance in the visible–near infrared (VNIR) region, with effects that may persist for several days. This impact was found to be less pronounced in the presence of well-developed vegetation or following soil tillage. Dedicated spectral indices make it possible to track these effects using bi-temporal Sentinel-2 satellite imagery (optical domain), with potential complementary use of Sentinel-1 (radar).

At farm scale, the combined use of bi-temporal Sentinel-2 (optical) and Sentinel-1 (radar) imagery enabled the detection of organic residual product applications. At the regional scale, the project highlighted that the potential of remote sensing varies depending on the territory studied, the season, and the types of organic residual products applied. Overall, the results demonstrate that remote sensing represents a promising tool for detecting and characterising organic residual product application practices.

International Journal of Applied Earth Observation and Geoinformation: <https://dx.doi.org/10.1016/j.jag.2025.104555>
 Geocarto International: <https://dx.doi.org/10.1080/10106049.2023.2245371>



Spectral monitoring of organic residual product application practices at farm scale (sources: Dodin et al., 2023, 2025; MELICERTES mid-term report (Vaudour, 2025))



Information and contact details:
<https://www.pepr-agroecoonum.fr/eng/funded-projects/data-processing-and-modeling/targeted-projects/melicertes>

In the face of climate change, agriculture is rising to the challenge of sustainability and agroecology. The **Agroecology and Digital Technologies Priority Research Programme (PEPR)** aims to **harness the power of digital technologies** — including artificial intelligence, modelling and data science — to **accelerate the agroecological transition**, by producing new scientific knowledge and supporting responsible innovation. The programme focuses on social ecosystems, genetic resources, agri-equipment and data use, and fosters the emergence of a community operating at the interface between agroecology and digital technologies.

INRAE and Inria jointly coordinate the *Agroecology and Digital Technologies* PEPR. It contributes to the **SADEA acceleration strategy** (Sustainable Agricultural Systems and Agricultural Equipment Contributing to the Ecological Transition) under the **France 2030 plan**.

*Launched in October 2021, the France 2030 plan is designed to prepare France for the **major economic, industrial, technological and environmental transformations** of the coming decades. Its ambition is to position France as a leader in the world of tomorrow. It notably funds **Priority Research Programmes and Infrastructures (PEPRs)**, to **mobilise and structure** French scientific communities as broadly as possible, overcoming knowledge bottlenecks, and fostering innovations that enhance the **competitiveness of the French economy**, improve products and services, and inform public decision-making.*



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