#DigitAg

Overview of Research topics 2017-2025

Digital Agriculture Convergence Lab

FRANCE 2030

anr agence nationale de la recherche

Stake 1 – Agricultural production improvement using ICT-enabled agriculture

Challenge 0: Transversal subjects

Main scientific field: Human and social sciences

Funded post-doc – 2024-2026

Construction and Impacts of interdisciplinarity in the Digital Agriculture Convergence Lab

Abstract: #Digitag is a Convergences Institute (CI) dedicated to digital agriculture that was created at the end of 2016 in Montpellier, with branches in Toulouse and Rennes. Its aim is to build the scientific foundations for developing responsible digital agriculture. To achieve this, its research involves understanding the impacts of digital technology on agriculture and building the technological building blocks and organizational, economic and social models enabling the development of responsible digital farming. In 2022, after 5 years of existence, #DigitAg benefits from more than 700 people who claim to be members of the IC, based on 29 research units and around 20 associate researchers.

The research conducted at #DigitAg mobilizes three "scientific domains": engineering sciences, life sciences and human and social sciences. #DigitAg funds theses and post-docs under cotutelle agreements, implementing different levels of interdisciplinarity: association of disciplines from the same "scientific field" (simple interdisciplinarity), association of disciplines from different fields (extended interdisciplinarity), with some projects mobilizing disciplines from all three fields.

The construction of this interdisciplinarity is an integral part of the Convergences Institute, as it corresponds to the demand of "Convergences". It has extended beyond theses and post-docs, to include the scientific leadership of #DigitAg (#DigitAgora, seminars, website, etc.) and its governance bodies. However, this interdisciplinarity has been organized in a pragmatic way, without any particular theoretical framework, giving priority to exchanges between researchers or students from different disciplines, and seeking to integrate knowledge to answer the questions posed, including by socio-economic partners.

Today, #DigitAg wishes to take a reflective look at the construction of this interdisciplinarity and offer an enlightened reading of it, based on a scientific approach that can be shared beyond the CI on both its advantages and its limitations. Through the experience of #DigitAg, the aim is also to analyze the conditions for the development of an interdisciplinarity that would be, in part, specific to research on digital agriculture, and, in part, positioned with regard to current issues of research responsibility that are leading to an evolution towards more participative and transformative modes of research. An interdisciplinary working group will be set up around the post-doc, for regular exchanges, with members of the Convergences #DigitAg Institute management (K. Gauche, deputy director, V. Bellon-Maurel, director, J.M. Touzard, axis leader), Julien Mary (scientific referent, MSHSud), C Lannoux (in charge of interdisciplinarity, INRAE) and P.B. Joly (ASIRPA method specialist, INRAE).

Research units: MoISA, ITAP, INRAE

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Main scientific field: Human and social sciences

Funded post-doc – 2022-2023

Value of information, digitalization of agriculture and pesticide use

Abstract: The aim of this post-doct is to identify, both theoretically and empirically, what the adoption of decision support tools brings in terms of information to farmers in their management of plant disease risks. Does this additional information optimize pesticide use? Our hypothesis is that for risk-averse farmers, the absence of information generally leads to overuse of pesticides.

Research units: CEE-M, MoISA, Université de Montpellier

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 0: Transversal subjects

Main scientific field: Human and social sciences

Labeled post-doc – 2023-2024

Digital technologies supply in agriculture: which stakeholders and which support arrangements?

Abstract: After a PhD Thesis that focused on the use of digital technology in agriculture and its effects, my current research focuses on the supply of digital technologies in agriculture, its stakeholders and its arrangements. A range of public policies aims to develop digital technology in agriculture and support the emergence and development of businesses in this field. Little is known about these support arrangements and their impact on the stakeholders and the organisation of the sector. In addition, the acquisition, merger or disappearance of companies in this field is restructuring the organisation of the sector. Based on an analysis of quantitative data on digital agricultural companies and interviews with stakeholders of the agricultural sector, this post-doctorate aims to i) analyse the role of the state in the development of the digital agricultural sector, ii) understand the role of private agro-industry and digital companies in this development and iii) discuss the effects on the agricultural sector and its power relations. This analysis will focus on the development of digital technology in France, but will also be compared with the digital agricultural sector in Chile.

Research units: AGIR, INRAE

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Main scientific field: Human and social sciences

Labeled post-doc – 2023-2025

Evaluation of human costs and benefits of digital technologies in farms

Abstract: The primary objective of this research is to thoroughly understand the benefits and costs of digitalization on humans, with a particular focus on those involved in agricultural practices. The evaluation will be conducted among farmers belonging to living labs in Europe as part of the CODECS project, and in France within the Occitanum living lab. This study will be carried out through a qualitative approach based on semi-structured interviews, aiming to capture the human transformation in farms induced by the use of digital technologies.

Research units: ITAP, INRAE

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Main scientific field: Maths and its applications

Labeled PhD – 2022-2025

The Great Green Wall and its local autonomisation in Ferlo: Commons approach and companion modeling

Abstract: Dundi Ferlo, supported by the NGOs WeForest and Agronomes et Vétérinaires Sans Frontières (AVSF), the Centre International de Recherche Agronomique et Développement (CIRAD), the Institut Sénégalais de Recherche Agronomique - Centre National de Recherche Forestière (ISRA-CNRF) and the Université Cheikh Anta Diop de Dakar (UCAD), and the FairCarboN - Ferlo-Sine project. The Dundi Ferlo project promotes new approaches for restoring degraded land, in particular by involving local communities in decision-making processes, with the aim of fostering community autonomy in reforestation initiatives.

The aim of this doctoral work is to understand the dynamics associated with these operations to restore degraded land in the Great Green Wall intervention zone in Senegal, and to help local stakeholders to co-construct and debate viable territorial development scenarios. By including stakeholders in the definition of objectives and the design of restoration options, this thesis aims to provide the Great Green Wall accelerator with new approaches to ecosystem restoration, with indicators adapted to local situations, based on community interest, participation and initiative. This thesis is part of a process of post-normal science in which the researcher's problematics are developed according to local concerns. It stands at the intersection of the fields of ecology, human and social sciences and computer modelling. Through the intermediary of the commons approach and companion modelling, it aims to co-construct a locally shared representation of the territorial system for collective management of the commons. The implementation of a companion modelling approach will make it possible to strengthen local ownership and responsibility for initiatives to restore degraded land as part of the Great Green Wall, and to work towards the socio-economic and socio-ecological viability of restoration processes with a view to scaling them up.

Research units: SENS, Selmet, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2022-2025

Assessing the environmental impact of the use of digital technologies in agriculture in the context of agroecological transition

Abstract: Nowadays, digital technologies are involved in the entire agricultural value chain, from production to distribution in all sectors (plant and animal). The current diversity of digital solutions constitutes an opportunity to support the necessary transitions towards value-creating agriculture while reducing its impact on environment and health.

The evaluation of the contributions and the costs and impacts inherent in the use of digital solutions by farmers remains a crucial stake. Technico-economic references must be generated, as well as social and environmental impacts references. This thesis is focused on this last point.

Life Cycle Assessment (LCA) offers a recognised and standardised evaluation framework to quantify the environmental impacts of a product or service. However, the implementation of LCA to assess the environmental impacts of digital technologies in agriculture raises a number of questions (on the objectives, the method, the data, the interpretation or the operational use of the results) that need to be addressed in order to provide solid arguments to users, suppliers or public decision-makers. The thesis aims to address the following two questions:

(i) How to assess the environmental impacts of digital use in agriculture by mobilising the LCA framework in a context of an abundance of services provided by digital solutions and extremely varied and contrasting situations of use (different sectors, production systems, pedoclimatic conditions, socio-economic environment, etc.)?

(ii) How can we prioritise the actions to be implemented to achieve the objectives set by the agro-ecological transition?

Research units: ITAP, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2020-2023

Spatialization methods of crop models and metrics for evaluating spatialized crop model performances in a precision agriculture context

Abstract: Crop models play a key role in simplifying and understanding complex agronomic systems. However, not all practitioners are interested in modeling agronomic variables at the same spatial scale. Changing the spatial scale at which such variables are modeled is therefore a necessary process to meet environmental and societal expectations. Spatialization enables a crop model to be applied at a different spatial scale from its native spatial footprint. More specifically, downscaling spatialization processes are identified as an opportunity to use existing crop models, initially designed at field scale use, at finer modeling scales (within-field scale) without modifying the internal structure of the model. This will permit a more tactical use of crop models for management, compared to their current, mainly strategic use. Particular attention was paid to mechanistic crop models, as they provide a better understanding of the biological, physiological and physical processes associated with the agronomic variables modeled. However, these biophysical crop process equations are generally designed at the field scale, and it is still unclear how a change of spatial resolution will particularly affect mechanistic crop models. This PhD project is based on the assumption that existing crop models are efficient and well recognized by the agronomic community. Thus, using them at finer spatial scales, by rethinking their use, would make it possible to employ these models into precision agriculture without having to use 'true' spatial crop models, which are more complicated to design. This led to the general research issue: is the spatialization of existing crop models, by using downscaling processes, conceivable and relevant for their use at within-field scales? However, the evaluation of the performance of these spatialized crop models at different scales needed to be rethought to take into account both aspatial and spatial pattern errors. These statements have led to the following specific scientific questions: how to perform a relevant evaluation and comparison of spatialized crop model performances across different spatial scales? And, is the spatial calibration of selected crop model parameters an effective method of downscaling existing crop models to permit modeling at within-field scales? Evaluation of the spatialized crop model performances at different spatial scales should be possible with the right metric. However, the metrics currently used are not the most relevant for assessing the performance of such models. A new metric has therefore been proposed: Spatial Balanced Accuracy (SBA). The SBA enables a relevant evaluation of spatialized crop models, taking into account the aspatial and the spatial pattern-based error of the considered variable(s). A spatial calibration approach was also implemented to downscale the spatial scale of two crop models, a simple and a complex model, to the within-field scale. This method proved successful, for both model types, when the modeled variable was strongly spatially structured and when ancillary data correlated with this variable were available. The intention was not to draw general conclusions on the spatialization of crop models, but to formalize this concept in a precision agriculture context and to build a basis for future research on the tactical use of these models at the within-field scale.

Research units: ITAP, MISTEA, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2019-2022

Knowledge representation and reasoning for agro-ecological systems

Abstract: The scientific question addressed by this thesis is the following: how to formally represent complex systems such as agro-ecological systems, to allow an automatic exploitation of this representation based on its semantics?

It is located in computer science in the field of knowledge representation and reasoning, a branch of artificial intelligence, which provides the theoretical and algorithmic foundations for the research to be carried out. This work has an interdisciplinary dimension and will be developed in close collaboration with agricultural researchers studying agro-ecological systems. Indeed, understanding agro-ecological systems poses challenges common to both disciplines: addressing the complexity of agro-ecological processes and their interactions, articulating several types and forms of knowledge, representing and managing dynamic and multi-scale processes.

The results of the thesis will contribute to the creation of a tool (i) for eliciting, formalizing, integrating and sharing data and knowledge on the functioning and management of agroecosystems for the agro-ecological transition of agriculture, and (ii) offering various services based on the semantics of this data and knowledge, including: exploration and query based on domain ontologies, verification of the consistency of the modelling, analysis of the behaviour of the system and explanation of the inferences made, highlighting the consequences of system disturbances (in particular with a view to helping to formulate scientific hypotheses, for example, is the association of a certain type of plant with a crop likely to reduce the risk of pests and diseases?), the evaluation of technical change scenarios that meet specific objectives (e. g. reducing pest attacks).

This thesis will be accompanied by projects in partnership with agricultural development organizations that will assess its products with a view to supporting farmers in an agro-ecological transition process.

Research units: LIRMM, AbSyS, INRIA

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Application of big data methods for the improvement of local PLS algorithms in chemometrics

Main scientific field: Technology and Sciences

Abstract: Near infrared spectrometry can provide huge amounts of data to digital agriculture. The main tool of chemometrics, used to analyze NIR spectra, is Partial Least Squares (PLS) regression. PLS allows building efficient predictive models from a large number of variables even if these variables are highly correlated. The method has proved its relevance for small homogeneous databases. Its extension to medium-sized bases (<10,000 individuals) is the "local-PLS": it determines a neighborhood of the individual to be predicted, and then realizes a usual PLS on this neighborhood. This method combines the power of the k nearest neighbors' method (k-NN) and the PLS. However, it is is not able to process large databases (e.g. >50,000 individuals) or even >1 million of individuals that will appear in the near future to digital agriculture. The current local-PLS algorithms all use sequential k-NN algorithms for which calculation times become unrealistic; other algorithms must be considered. Paradoxically, very little research has been done on this challenge in chemometrics. Our idea is that algorithms of indexation used in big data, integrated in the local-PLS method, could lift this methodological lock. We propose to consider two algorithms of dimension reduction and fast neighborhood searches used by the Zenith Team of Lirmm-Montpellier for processing large data sets of time series (that have a similar data structure as the NIR spectra): the hashing (calculation of sketches) and the iSax (Symbolic Aggregate approXimation). The work will consist in two steps: (1) a "business as usual" integration of the two algorithms in the local-PLS algorithm, (2) an optimisation of the algorithms taking into account the chemometric specificity of the NIR spectra. The new algorithms developed in this thesis will improve the ability to predict physico-chemical variables from large heterogeneous NIRS data bases, and will find direct applications in many domains (plants, feed, soils, etc.).

Research units: ITAP, SELMET, IRSTEA

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Main scientific field: Technology and Sciences

Co-funded PhD – 2017-2020

Adaptative Constrained Optimization for Spatial Sampling in Precision Agriculture

Abstract: The wine industry needs to know the yield of each vine field precisely to optimize quality management and limit the costs of harvest operations. Yield estimation is usually based on random vine sampling. The resulting estimations are often not precise enough because of the high variability within vineyard fields. Recent works showed the interest of using vegetative index (i.e. NDVI, GLCV, etc.) derived from high spatial resolution airborne/satellite images to optimize sampling. These works showed it was possible to improve yield estimation by 15 % depending on the considered vine field and the strength of the correlation between vegetative index and yield components.

Other recent research has proposed a unique original approach, based on the consideration of spatial and operational constraints, to optimize the operation of within-field machine operation in viticulture based on high spatial resolution information derived from airborne images and experts zoning (application to optimize selective harvest).

The originality of the PhD project is to propose an interdisciplinary approach that takes into account both these results to optimize the spatial sampling carried out by an operator. The work will aim at developing a methodology which considers i) high resolution information describing the within-field spatial variability ii) operational as well as spatial constraints (time required to perform an observation, time required to walk from a site of measurement to another, spatial organization of the cultivation like rows etc.) and iii) specificity of the field under consideration (like spatial organization of the variability as well as the strength of the correlation between high resolution data and the agronomic information under study, etc.).

The research will provide with the wine industry an adaptative Constrained Optimization for Spatial Sampling in Precision Agriculture. In the short term, the methods may be embedded in a mobile platform like a smartphone with localization facilities. In the long term, these results will be quite usable to optimize the sampling carried out by mobile platforms such as robots.

Research units: ITAP, MISTEA, Institut Agro

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Main scientific field: Technology and Sciences

Labeled PhD – 2019-2022

Integration and analysis of massive and heterogeneous data for an intelligent observation/monitoring of the territory

Abstract: This thesis project is fully in line with the Smart City approach. It thus aims to develop skills around "intelligent observation of the territory".

Observation from various sources of information (collected, measured, interpreted), intelligent because they do not implement not only innovative technologies but also approaches based on the heterogeneity of sources, knowledge extraction from massive data.

The integration of heterogeneous data by taking into account the "smart city" ecosystem of the Metropolis (labs, start-ups, collectives, etc.) is based on traditional information (demographic, economic, climatic, etc.) but also on information from projects carried out by the Metropolis.

The aim is to show the gain and efficiency of linking data previously managed in silos and organizing the interactions that can result from them.

Research units: TETIS, INRAE

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Main scientific field: Technology and Sciences

Labeled PhD – 2018-2021

Proposal of a grape yield elaboration and forecast model through learning process from heterogeneous data such as time series of observations and historical climatic data.

Abstract: Understanding the key steps of grape yield elaboration and estimating at the intra-plot level are two important issues for the wine industry. The development of precision viticulture is leading to major changes in terms of data generation, thus making it possible to to explore new operational approaches.

In this context, the PhD project proposes to analyse heterogeneous data such as time series of observations and historical data in order to: i) infer knowledge relating to yield elaboration mechanisms specific to the local context since they are determined based on the data, ii) identify the factors which can locally affect the yield throughout the vine cycle, iii) foresee the learning of empirical models which are locally adapted and allow yield estimation throughout the production cycle.

The PhD project therefore focuses on two main issues: how to infer knowledge about grape yield elaboration from heterogeneous data? How can this knowledge be used to develop an empirical yield forecasting model?

Although it does not exclude any approach at the moment, the thesis proposes to use new methods under development such as the Bliss method (Grollemund, 2017) to answer the first question. These are Bayesian functional statistical methods that allow the analysis of the global history of variables evolving over time. Regarding the second issue, the PhD will focus on fuzzy rules logic and inference (Grelier et al., 2007) to process heterogeneous data while taking their imprecision and complex interactions into account.

This approach brings forward important potentialities for the agriculture sector. Indeed, the analysis of the relationships between dated quantitative variables and multi-variate time series is very often necessary to estimate the quality and quantity of production (yield, sugar content, acidity, grain protein content, etc.) as a function of time variables (temperature, water status, radiation, soil moisture, etc.).

Grollemund P., 2017 Régression linéaire bayésienne sur données fonctionnelles. Université de Montpellier.

Grelier M., Guillaume S., Tisseyre B., Scholasch T., 2007. Precision viticulture data analysis using fuzzy inference systems. Journal International des Sciences de la Vigne et du Vin 41 (1), 19-31

Research units: ITAP, Institut Agro

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Main scientific field: Technology and Sciences

Labeled PhD – 2016-2019

Matching between massive and heterogeneous data: application to biodiversity data

Abstract: In scientific literature, few approaches exists for matching heterogeneous data in a generic way. As part of this thesis, propositions will be established in multidisciplinary ways of matching under 3 axes: thematic matching, spatial matching and temporal matching. The identification of pertinent descriptors will be established under these three axes using symbolic, statistic and semantic methods and the use of NLP methods for exploring textual data.

Research units: TETIS, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2016-2019

Pre-processing and zoning within field yield monitor data: Towards site specific nutrient balances

Abstract: Precision Agriculture makes use of geo-referenced information and communication technologies to improve agrosystems' management. Yield datasets stemming from mounted sensors on combine harvesters were the first source of information available in Precision Agriculture. Each year, the highly spatially resolute within-field yield maps generated by these sensors help to characterize the spatial variability of the field technical management's outcome and to make decisions with regard to the monitoring and management of the upcoming crop production. However, these yield data are not widely used by the experts of the agricultural sector because no practical application is proposed to make value of this information. Because of the low expectations coming from the agricultural sector, the yield processing chain has never really been robustified since it was created. Furthermore, yield maps are still not enough presented to the agronomy experts from an operational perspective, i.e. as zones that correspond to reliable and relevant management units, which does not help in making decisions. The thesis will focus on the proposal of methods to define variable rate application maps based on previously filtered yield datasets. The main contribution of this work is to incorporate the available agronomical expertise within the methods. This expertise takes place at two different levels: regarding the method to correct or pre-process the raw yield datasets and concerning the operational constraints related to the application that will be performed (spatial footprint of the machine, machine accuracy levels, etc) that will drive the zoning algorithm. A general methodology will be proposed and dedicated to the generation of within-field nutrient balance maps.

Research units: ITAP, Institut Agro

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Main scientific field: Technology and Sciences

Internship - 2019

Development of a method allowing to mine and analyse huge volumes of simulation results from a crop model

Abstract: With the simultaneous increase in the questions addressed to agriculture, in system knowledge and computing power, simulation models tend to be more and more complex producing increasing volumes of heterogeneous data. These data are generally not fully analysed, due to their huge volume that makes their mining difficult, and to the fact that model users are often just interested in a small part of the data. Futhermore, simulation data are often lost after their valorisation although they could help answering other scientific questions. This suggests a need for a method allowing a storage of simulation data on the long term, as well as an easier mining and analysis of simulation data with the possibility for model users to answer multi-criteria questions. The IRISA-INRIA LACODAM team is developping data mining methods enabling to identify interesting patterns supporting the recommendation of actions. A data warehouse to explore multidimensional simulated data from an agro-hydrological model was recently developed by this team to improve catchment nitrogen management (Bouadi et al., 2017). The objective is to adapt this method for the exploration and analysis of the simulated data from the STICS crop model (Brisson et al., 2003) that were produced in the framework of a French study called « Production, exportation d'azote et risques de lessivage » (Graux et al., 2017). STICS simulates crop production and associated environmental risks and benefits at the plot and crop rotation scales, according to soil and climate conditions and to crop management. The work has already started with the development of a relational database where simulated data can be stored. The first step of the training is to move this database towards a multidimensional data warehouse involving time and spatial dimensions and allowing an easier exploration and interactive analysis of the stored data. Based on this data warehouse, the trainee will be in charge of proposing and developing a method allowing the analysis and retrieval of multidimensional information, based on skyline queries. The latter offer the possibility to use user's preferences to detect and bring out possibly interesting data (i.e. skyline points) and to identify multi-criteria trade-off solutions. The method has also to allow explaining to users the result from a skyline query (Chester et al., 2015) (i.e. why a situation which is a priori not interesting is included in the query's result and conversely, why a situation wihch a priori interesting has been excluded from the query's result). This will enable to put users at the heart of decision-making and to co-develop accepted recommendations.

Research units: LACODAM, INRIA

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Main scientific field: Technology and Sciences

Internship - 2018

Spectral band registration by 3D reconstruction for short range operation of agricultural multispectral imaging sensors

Abstract: Application of UAV to crop monitoring, which is rapidly increasing, relies on the availability of multispectral imaging sensors combining visible and near infrared spectral bands. Nowadays, various commercial devices are proposed (4-bands camera Sequoia (www.parrot.com), 6-bands camera Airphen (www.hiphen-plant.com)), which are all based on the assembly of elementary cameras equipped with their own lens.

This multi-lenses solution is satisfactory for the acquisition of images with a spatial resolution limited to a few centimeters per pixel. However, it is not usable for applications requiring a better resolution, such as weed detection, emerging plant counting, spot disease detection or very close monitoring. Indeed, at short range, the uniform superposition of images corresponding to the different spectral bands is impossible due to parallax effects.

The present proposition addresses the development of a registration method between spectral bands adapted to short range imagery, relying on the 3D reconstruction of the targeted scene.

As a first step, a classical Visual From Motion approach will be used to build a digital surface model (DSM) with one of the available bands, by mosaicing a set of widely overlapping images. This DSM, in association with the geometrical calibration of the sensor, will then allow matching the pixel coordinates in every band with the corresponding coordinates in other bands, and thus finally the exact superposition of spectral data for the complete scene.

The student will have to develop these successive steps, and to assess the obtained performances through field experimentations.

Technical developments will be collectively supervised by Gilles Rabatel (ITAP – Comic team) and by Olivier Strauss and/or Frédéric Comby (LIRMM – Icar team).

The experimental frame will be defined in collaboration with Sébastien Codis (IFV), member of the Ecotech-Viti Technological Unit (UMT) hosted at ITAP. It will consist in testing the acquisition system and its associated algorithms on vineyard crops, in order to provide very high resolution NDVI maps (leaf scale).

These first trials should contribute, in a longer term, to the building of a collaborative project devoted to the short range monitoring of vineyard plants submitted to biotic stress, especially the flavescence dorée.

Research units: ITAP, IRSTEA

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Main scientific field: Technology and Sciences

Internship - 2024

Development of semantic resources for field phenotyping and crop modeling

Abstract: One of the major challenges facing interdisciplinary scientific communities is the effective use and sharing of semantic resources (thesaurus, taxonomies, ontologies). In the context of phenotyping and crop modeling, these semantic resources need to be enriched and adapted to take into account different sources of data in the field, simulation models and, above all, research questions and phenotyping methods that are evolving by proposing new variables to be observed. Standards do exist, but they are not complete in relation to these new research questions and are difficult to evolve. As a result, their use can be an obstacle for researchers. The aim of this proposal is to enable controlled and efficient management of the evolution of semantic resources, while maintaining a link with existing standards. Standards and semantic resources in the field will be enriched, and a solution based on existing environments (AgroPortal) and ontology design patterns will be developed to provide researchers with a user-friendly strategy and tools.

Research units: MISTEA, INRAE

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture

Challenge 1: ICT and the agroecology challenge

Main scientific field: Life and environmental sciences

Funded post-doc – 2024-2025

High-throughput phenotyping of fruit tree genetic diversity for better adaptation to climate change

Abstract: This project aims to characterize the resilience of fruit trees via digital phenotyping of a certain number of traits related to flowering and tree architecture based on the combination of the skills in image analysis (AGAP-PHENOMEN, EMMAH-CAPTE), genetics (GAFL) and architectural analysis (AFEF) of the four teams involved. In addition to methodological developments in stereovision and RGB data processing to assess these traits, this project is interested in the fusion of information generated by these data and the generalization and transferability of these traits and methods between species. Several approaches (machine and deep learning, mathematical morphology, statistics) will be combined. This project is based on the acquisition of datasets in three core collections (peach, apricot, apple) each of them comprising more than 150 different genotypes, thus ensuring a representativeness of the variability of flowering and tree structure by differences in age and contrasting environments. It also aims to establish temporal consistency between past measurements (visual notations) and digital phenotyping.

In terms of expected outputs, we aim to contribute to the phenotyping of complex and integrative traits (improved accuracy and throughput, access to new traits not accessible manually), and to the genetic screening of resilience by determining a typology of trees that can maintain production in the face of environmental perturbations.

Research units: EMMAH, AGAP, INRAE

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Main scientific field: Human and social sciences

Labeled post-doc – 2023-2025

Co-evolution between labour market and agricultural robotics

Abstract: Agricultural robotics is a rapidly structuring sector that has garnered significant interest from both public authorities and private actors. Two promises accompany the development of agricultural robots. The first envisions robots as a means to address the labor shortage affecting the sector. The second promise 2 positions agricultural robots as indispensable innovations for agroecological transition. Agricultural robotics thus holds the promise of a profound transformation of the agricultural sector. However, the current state of knowledge regarding the actual transformations induced by robotic technologies remains limited (Martin et al. 2022, Rose et al. 2021). The labor shortage in the agricultural sector affects numerous European countries. This deficit raises questions about the sector's ability to transition to more labor-intensive practices. The difficulty in finding workers illustrates both the low attractiveness of a sector heavily marked by an outdated productivism model and profound shifts in work within our societies. Hence, agricultural robotics is often highlighted as a solution to fill this labor gap. But what is their actual capacity to replace external labor? Based on existing research, we hypothesize that robots contribute more to a shift in the role of workers than to their replacement (Marinoudi et al. 2019, Martin 2023). Therefore, we aim to characterize the role of robotics in transforming the labor market and the position of migrant workers in robot-equipped agricultural operations.
Reduction and precision in pesticide and fertilizer applications, mechanical weeding, decision support, and animal welfare management are key arguments at the heart of agricultural robotics projects. For many public and private actors, these innovations are deemed essential for implementing more environmentally friendly practices. How do stakeholders in the agricultural robotics sector incorporate agroecological transition as a promotion argument for these innovations? We seek to understand how agricultural robotics actors articulate labor market changes with the challenges of agroecological transition in production systems. This work aims to clarify the coevolution between the labor market, agricultural robotics, and agroecological transition. We hypothesize that robots are deployed under the influence of a dual promise: addressing the labor shortage in the British agricultural sector and the imperative of greening practices. We will seek to compare the actual deployment and its effects on workers and practices with the development of agricultural robotics as promising innovation systems. To achieve this, we will implement a comparative approach between the United Kingdom and France to identify convergences as well as national specificities in terms of public policies, agrarian structure, and labor market organization. The British context provides a particularly rich configuration for studying the development of agricultural robotics and its effects on agricultural workers and the labor market. British farms are highly dependent on migrant labor from Eastern European countries. Since Brexit, the mobility of these workers has been constrained by the new regulatory framework, and robotics is highlighted, especially by the British government, as a means to reduce reliance on foreign workers while maintaining economic dynamism in the sector.

Research units: Innovation, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2023-2026

Semantic and modular representation of crop models

Abstract: The use of crop models to predict the performance and environmental impact of crops is widespread at all levels of the value chain. Their use to reduce the use of inputs, to adapt agriculture to climate change, to diversify agro-systems, to preserve biodiversity, and thus to meet the objectives of the Green Deal, leads to constantly review their formalisms and to model new processes.

We have recently developed the Crop Modelling Meta Language (Crop2ML) model representation and transformation system, which allows the development of model components in accordance with FAIR principles. A current limitation of Crop2ML is the lack of semantics to search for components and facilitate their composition in operational modeling solutions.

The SemCrop project aims to address this limitation. The operational objectives concern the interoperability of the modeling tools and the links with the information systems collecting very large data sets. A modularity of the models at the process level is aimed at allowing a better integration at different scales, facilitating the link with the data, and the feedback between data and models (digital twins).

By proposing a modular modeling system, SemCrop will bring an original contribution to address the challenges of ecological, climate, and digital transitions. It will provide #DigitAg and regional AgTech companies (ITK, SMAG, FruitionSciences,...) with innovative tools to develop digital solutions for agriculture. SemCrop will increase the international scope of #DigitAg's research via its insertion in the AMEI (Agriculture Model Exchange Initiative) initiative coordinated by the supervisors.

Research units: LEPSE, AGAP, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2021-2024

Cooperatives: a way towards the digital transition of agriculture?

Abstract: Digital tools have been developing in agriculture for several years. Some authors see it as a way to support its Agroecological Transition. However, the compatibility between some digital tools and agro¬ecological approaches is still debated. On the other hand, in France, cooperatives represent an important part of the agricultural and agri-food activity. At the national level,75% of farmers (90% in Occitanie) depend on a cooperative, making these structures key players in the digital transition. They are characterized by a great diversity of sizes and structures, despite a trend towards concentration.

The central question of this thesis is the following: which models of agriculture do agricultural cooperatives promote through their digital choices? lt can be divided into two sub-questions: 1) What factors influence the choice of digital tools in agricultural cooperatives: size? sector? governance? Particular focus will be paid to the latter factor. 2) What models of agriculture do these choices promote: agro-ecological? agricultural Intensification ? precision agriculture? labels (HVE, AB …)? From a theoretical point of view, several fields will be mobilized: theories of innovation, governance theories. Thus, the question of the representation of cooperatives actors of the digital transition, intermediaries between the upstream and downstream sectors will be raised, as well as the three dimensions of cooperatives governance. From a methodological point of view, two important regional sectors will be targeted: wine and fruit and vegetables. The characterization of production systems and agricultural practices will be based on the agronomy and agroecology work of the UMR ABSys "Agrosystèmes biodiversifiés".

Research units: MoISA, AbSyS, Institut Agro

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Main scientific field: Technology and sciences

Co-funded PhD – 2021-2024

Combining participatory approaches and constrained modelling to design agroecological systems

Abstract: Addressing the challenges of agriculture in a context of global changes, loss of biodiversity and depletion of fossil resources requires a profound renewal of agricultural systems. Agroecology proposes to base the design of agricultural systems on the enhancement of ecological functionalities. This requires reintroducing biodiversity into agrosystems, adapting practices to the local context and combining knowledge (scientific, expert and operational). Agroecology experiments around the world have shown that increasing the complexity of agrosystems increases their resilience, reduces dependence on synthetic inputs, provides ecosystem services and thus improves their performance. But these experiences have also shown the difficulty of designing these complex agrosystems: agro-ecological design remains a major obstacle for actors in the agro-ecological transition, due to the lack of appropriate tools and approaches. This challenge for agricultural researchers also calls for research in artificial intelligence to design such tools. The objective of this thesis is to articulate concepts and methods from these two disciplinary fields in order to equip this stage of agroecological design with (i) constrained reasoning models to explore the combinatorics of spatio-temporal arrangements of agrosystem elements, and (ii) a participatory design device using models as an intermediate object, making it possible to clarify constraints, combine knowledge and stimulate creativity to co-design agroecological farms. It will be implemented on five situations of market garden orchard design, in collaboration with research and higher education institutes (Institut Agro, INRAE, Ecole du paysage), farmers, associations (GRAB, Domaine du possible), private sector companies (Potagers & compagnie) and local authorities. This diversity of situations will make it possible to increase the genericity of the knowledge produced and will facilitate, with the participatory approach, the transfer of the co-built tools to the actors of the agro-ecological transition.

Research units: AbSyS, MISTEA, Institut Agro

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2021-2024

Modelization of maize architecture: estimating radiation interception, using sensors and 3-D models

Abstract: Optimizing maize crop structure is an important strategy to improve yield. Characterizing the morphological plasticity of maize plants as a response to intra-specific competition is necessary to identify the optimal combination between canopy architecture (crop density and structure) that maximizes crop productivity. In that context, crop architectural and physiological characteristics can be assessed through high-throughput optical observations acquired from plant phenotyping platforms. However, understanding maize morphological plasticity requires the use of 3D plant models, that can integrate architectural parameters derived from optical observations, and can describe canopy light regime.

This project is structured around two main goals:

- To evaluate the consequences of sowing patterns (row width, plant density, orientation) on light interception by the crop and to understand their influence on yield formation.

- To improve the use of sensors (high throughput phenotyping, drones, satellites) in order to obtain a detailed crop architectural description

To achieve both goals this PhD will study the architectural plasticity and the light interception and light use efficiency of a range of maize cultivars, in response to intra-specific competition. These indicators will be related to crop performance. The project addresses 4 objectives:

- Accessing structural crop parameters through optical data obtained in maize plots at early stages. Several techniques will be used to reconstruct 3D descriptions in order to characterize plant and crop architecture

- Estimating canopy light regime (light quantity and quality) using realistic 3D architectural models and ray-tracing algorithms.

- Analyzing and describing plant response (organogenesis, LAI and biomass growth, yield components) using architectural and functional plant modelling.

- Characterizing genotypic plasticity associated to intra-specific competition analyzing the dynamics of canopy light regime and plant architecture.

Research units: Acta / ARVALIS, EMMAH, ACTA

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Main scientific field: Technology and Sciences

Labeled PhD – 2022-2025

Small datasets and prediction in Artificial Intelligence, towards a better cohabitation: Application to the sustainable management of weediness in agricultural systems in La Réunion

Main scientific field: Technology and Sciences

Abstract: Several studies have been conducted on weed management. The Deci-Florsys project determines weed dynamics by simulation using agro-environmental indicators. Another project concerns the recognition of weeds by spectral image analysis. Machine learning algorithms are used to identify and discriminate the different species. However, they do not consider the tropical weed flora and do not try to directly predict weediness. The thesis will apply artificial intelligence to predict the weed flora of agricultural systems in Reunion in a tropical context. We present a non-exhaustive list of some works that will be completed during the thesis. Different scientific issues are identified that impact the performance of prediction algorithms on small observed data sets. Different concepts concern the adaptation of learning algorithms to take into account missing values, their sensitivity in a context of unbalanced data with high bias (fairness), the exploitation of relationships between the variables to be predicted and finally, the heteroscedastic aspect of the data. In the literature, a certain gap is noted between the classical works on prediction and the concepts mentioned above. However, these works have been carried out on specific tasks using complete data sets. This thesis will contribute to enrich the knowledge on these recent concepts in the literature and to apply them on small observed data sets

Research units: Recyclage et Risque, CIRAD

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Main scientific field: Human and social sciences

Labeled PhD – 2022-2024

Environmental performance and choice of investment in digital tools on farms

Abstract: The contemporary period is characterized by an abundant supply of digital equipment intended for the agricultural sector combined with a political will and sectors to support an ecological and digital transition. This context is now leading farmers to reflect on their strategies for investing and acquiring digital tools.

The use of these digital tools should make it possible to better manage operations, improve productivity, ensure better traceability and above all efficient use of resources and in particular energy resources. However, today the levels of equipment of farmers are very heterogeneous, they concern above all large farms and looking for productivity gains and intensification margins (Carillo and Abeni, 2020). In addition, the impact of the use of digital tools on the environmental performance of farms has not yet been fully established (Lioutas and Charatsari, 2020). This is partly explained by the difficulties of defining evaluation indicators.

This thesis has two objectives: i) to assess the effects of the use of digital tools on the economic and environmental performance of farms. For this, it will propose relevant indicators for assessing the impact of the use of new digital technologies on the environmental performance of farms. ii) Understand the place of the environment in the decisions of the farmer, in particular with regard to investments in digital tools. Are investments in digital tools part of a management strategy for a sustainable agricultural system or rather, as some people suggest, are they a continuation of a conventional system?

Research units: LARESS (Laboratoire de recherche en science sociale /ESA), LAMES (Membre associé CEE-M), Agrocampus Rennes Angers

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Main scientific field: Technology and Sciences

Labeled PhD – 2022-2025

Large-scale yield gap estimation and characterization with multisource remote sensing data – Case study of rainfed wheat in Ethiopia

Abstract: In Ethiopia; despite wheat yields improvement observed in recent years, the current wheat yield is only 20% of its potential. To be able to develop sustainable production systems that allow to address food security issue while decreasing environmental pressures, spatially explicit information on yield gap and its determinants are needed. However, spatially explicit yield gap (YG) analysis at large scale has long been a challenging exercise due to the lack of reproducible and robust spatial frameworks. This PhD will address issues related to the improvement of existing methodologies to quantify and characterize the yield gap of rain fed wheat in Ethiopia. We hypothesize that this challenge can be met with the new Earth observation and geospatial technologies combined with field data. The goal of this Ph.D. research study is to assess the yield gap of rain-fed wheat in Ethiopia on a large scale, using a data-driven approach that integrates advanced data science, machine learning, and up-to-date remote sensing from multiple sources, with analysis conducted on the Google Earth Engine cloud computing platform. Specifically, this PhD aims to achieve the following objectives: 1) to develop a methodology for the delineation of agroecological spatial unit (ASU) for scaling up rain-fed wheat crop YG analysis. Under this objective, accurate and reliable rain-fed wheat crop land will be produced, and will serve as a stepping point for ASU delineation and YG analysis. 2) to improve large scale actual rain-fed wheat yield estimation and 3) to spatially deepen the YG analysis through (1) a temporal perspective by disentangling the persistent YG from the transient YG and (2) a structural perspective by decomposing the YG in to technical efficiency, resource and technological YG.

Research units: Aïda, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2022-2025

How to create training databases led by different professional expertise in order to improve agro-environemental variables prediction thanks to remote sensing data. A case study of large scale land occupation classification.

Abstract: Land occupation mapping is a major issue when managing, monitoring and protecting agroecosystems at large scale. Classify land occupation consists in determining the type of physical cover of each location on a specific land. Therefore, land occupation classification is a prerequisite to most agri-environmental studies. Before the years 2000, this was exclusively done by experts on the field, surveying the land and identifying each type of land classification. With the recent emergence of remote sensing images nowadays, this is done thanks to both field sampling and remote sensing images analysis with AI methods (Machine Learning, Deep Learning). These methods require that experts create training dataset so the models learn to recognize land occupation classes and generate results. If todays AI methods are efficient and adapted to many use cases, field sampling of training dataset still lack objective methods. However, creating a quality training dataset is essential in order to ensure an efficient classification. During this PhD work, we will solve this issue by creating new methods allowing experts to create training datasets fully adapted to remote sensing images analysis and in return allow this analysis to help preparing field sampling. Thus, we will answer the two following questions:

- How to direct data sampling considering both field expertise and remote sensing images analysis?

- How to choose relevant images variables considering field expertise introduced in the machine learning model?

Research units: ITAP, Institut Agro

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Main scientific field: Human and social sciences

Labeled PhD – 2022-2025

Agriculture crowdfunding platforms

Abstract: Crowdfunding platforms enable users to raise funds from the general public. Since their creation in 2010, these platforms have played a residual (less than 1%) but growing role in funding projects in the agricultural sector, at a time when agriculture faces radical changes.

The emergence of these platforms raises a number of questions. They present themselves as a driving force for the agro-ecological transition, as an alternative to the traditional banking system that might hinder certain projects. However, they are forging partnerships with these traditional players, including banks. This raises questions about the reality of the transformations induced by platforms.

This sociology thesis, which began in November 2022, aims to understand how platforms are transforming agricultural financing institutions.

To study these platforms, the thesis uses a mixed method of combining qualitative and quantitative approaches. Interviews will be conducted with the main players involved: farmers submitting projects, donors and lenders on the platforms, platform firms, etc. In addition, data will be extracted from the websites of these participative financing platforms (partly using a web scrapping approach). This data will characterize the project (purpose of the funding, agro-ecological dimension, etc.), the farmer behind it, and the economic performance indicators of the farms. The data will be used to establish a typology of the projects financed by the platforms and to compare the financial conditions with those applied in the traditional banking sector. It will then be possible to understand whether the platforms make it possible to bypass certain financing institutions that limit agro-ecological projects, or whether they reinforce them.

Research units: AGIR, INRAE

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Main scientific field: Technology and Sciences

Labeled PhD – 2021-2024

Mixing machine learning and semantic web methods for the optimization and planning of market gardening in agro-ecology

Abstract: The general aim of the thesis is to produce a methodology for processing agricultural data to enrich it semantically (via description or annotation with ontologies or domain repositories (co-produced in the context of D2KAB)), then interconnect and disambiguate it to produce a knowledge graph to be exploited via graph embeddings, a representation learning method. We are particularly interested in recommendations in terms of crop planning, crop location and companionship, i.e. what to plant with. We hypothesize that the semantic enrichment of agricultural data will increase the performance of machine learning methods for the recommendation task more than the exploitation of raw data.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Human and social sciences

Labeled PhD – 2018-2021

Online communities and digital technologies to produce and exchange knowledge for agroecology

Abstract: Agroforestry deals with agroecological systems that are diversified and complex. Such systems include different scales and a variety of compartments. They need to be adapted to local situations, and entail a transformation of knowledge. They require the articulation of generic and localised knowledge, and thus, collaborative learning between various actors. With the digital revolution in agriculture, the increasing use of tools such as forums, videos, and online social media, lead to the constitution of essential spaces in order to share technical experimentations and personal trajectories about innovations. In the agroecological domain, the multiplication of Youtube channels, digital trainings, and dedicated web pages reveals a change into the way knowledge can be shared. This thesis aims to understand how farmers, advisers, trainers etc. appropriate these tools in order to transform their practices. It will especially analyse how these tools can contribute to the emergence of new forms of professional socialisation, and constitute a place where knowledge related to complex and diversified agroecological systems – and especially to agroforestry – can be shared and produced.

Research units: INNOVATION, INRA

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Main scientific field: Human and social sciences

Labeled PhD – 2024-2027

Designing parsimonious metrology to inform farmers about the performance of agroecological practices tested in On-Farm Experiments

Abstract: This thesis addresses the following research question: how can low-cost multifunctional acquisition technologies (high-lowtech) be utilized to streamline the monitoring of agroecological practices in real- world conditions through on-farm experimentation? The aim is to design a parsimonious metrology, characterized by simplicity, affordability, and efficiency, to evaluate agroecological practices within large-scale cropping systems and agroforestry. The proposed digital tools will enable real-time acquisition and analysis of data related to crops (phenotyping) and environmental factors (envirotyping). These technologies will be coupled with advanced statistical and geostatistical methods to produce relevant and reliable indicators, even when dealing with the inherent uncertainties of real-world conditions. Key success factors for agroecological practices include their adaptation to the specific pedoclimatic and economic contexts of each farm, along with the integration of multifunctional sensors to manage spatial and temporal variability. Furthermore, the project will develop descriptive models to elucidate the interactions between agroecological practices and environmental conditions. Case studies in large-scale crops and agroforestry will be carried out to validate these approaches. Ultimately, this research will contribute to the agroecological transition by providing farmers with practical, accessible tools to enhance the management and optimization of their production systems while addressing local constraints.

Research units: ITAP, INRAE

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Main scientific field: Technology and Sciences

Funded post-doc – 2018-2019

OPTI-REUSE (Digital Platform for the optimisation of water and nutrient resources in agriculture, including treated waste water reuse)

Abstract: Depending on the crop and its development stage, nutriment needs are different in quantity (concentration in irrigation water) and also in quality. Mixing water from different stages of the treatment process is a solution to adapt water quality to crop needs and to reduce the use of fresh water. The control of this mixing process must consider all parts of the chain from the raw sewage entering the treatment plant to the crop development: treatment outputs (nutrient concentrations), transport and distribution of water (clogging), crop growing. We propose to develop an integrated software platform that will associate simplified models of the different steps to identify possible solutions, including adaptation of tertiary treatments. Optimizing the solution will integrate yield, cost and environmental burden. The latter will be evaluated through Life Cycle Assessment, addressing the conceptual approach to apply this method to reuse applications.

Research units: ITAP, IRSTEA

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Main scientific field: Technology and Sciences

Co-Funded PhD – 2020-2023

Augmented reality to support agroforestry systems design

Abstract: Agroforestry is recognized as a way of developing sustainable, resilient agriculture and combating climate change. However, the number of species combinations, spatial configurations, tree and crop management options is vast. The choices must be adapted to the pedo-climatic and socio-economic contexts and to the objectives of the farmer, who therefore needs support to design the system. New technologies can facilitate this support and promote the adoption of agroforestry. Augmented reality (AR, the superimposition of digital objects on real-world images) makes it possible to visualize different future scenarios in order to choose the most desirable one, to begin a process of change. Agroforestry is an ideal case study: the introduction of trees profoundly modifies the appearance of plots and landscapes, so visualization tools would be very effective; and tree growth is slow and the consequences of the farmer's choices are only revealed several decades later.

The aim of the thesis is to develop two AR applications, and to evaluate them with farmers, agricultural colleges and agroforestry advisors. The first will improve the design of agroforestry systems by allowing interactive comparison of configurations and visualization of the evolution of vegetation dynamics. This approach will be tested in agroforestry system design workshops. The second will realistically visualize in situ the growth of trees in agricultural plots, allowing the farmer to visit his plots and visualize their appearance 10, 20 or 40 years later. This research work aims to integrate growth models into AR technologies and the participatory approach to meet farmers' needs.

Research units: AbSyS, AMAP, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2020-2023

Semantic Representation and Computation of Mathematical Formulas for Plant Phenomics Data Exploitation

Abstract: Knowledge Graphs (KGs) have become central to managing diverse datasets across fields like agriculture, biomedical, environmental, and social sciences. Semantic Web (SW) technologies excel at representing taxonomic knowledge in these KGs. However, scenarios involving numerical relationships with algebraic operations or unit conversions are less addressed, yet hold potential to enhance KG data.

For instance, consider the Body Mass Index (BMI) computation, which relies on weight and height properties. This can enrich a KG with derived data. Similarly, deriving the Vapour Pressure Deficit (VPD) from air temperature and relative humidity is valuable. While experts understand these formulas, they are often implemented in ad-hoc programming languages, limiting reuse and reproducibility.

This thesis explores Semantic Web approaches to represent and compute these numerical relationships. We identify current limitations in representation, computational methods, and expressivity. To tackle these challenges, we propose a Semantic Web-based framework with the following goals: (i) Represent mathematical formulas in line with Linked Open Data (LOD) and FAIR principles, to enhance adoption and reproducibility. (ii) Enable on-demand execution of numerical relationships, recognising that materialising results is infeasible for large and diverse KGs. (iii) Express mathematical formulas using KG data in the form of quantity values, leveraging semantic resources and metadata like unit ontologies. (iv) Facilitate aggregations within mathematical formulas, acknowledging that much of this numerical data operates on multiple scales. We evaluate this framework on KGs from the agriculture and plant phenomics domain, the focus of this thesis, as well as on more established Semantic Web KGs like DBpedia.

Research units: MISTEA, LEPSE, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2019-2022

Modelling the performance of annual intercrops: an approach coupling functional ecology and data science

Abstract: In order to contextualise this research, this doctoral research project has focused on the potential of a time-series of Sentinel-2 satellite images for monitoring vineyards at the regional scale across the Occitanie region (France). This spatio-temporal Sentinel-2 dataset presents unique characteristics in terms of revisit time, spatial resolution, attribute information provided and cost. Moreover, the choice of spatial coverage is interesting in itself, as the Languedoc-Roussillon wine region represents a great diversity of agri-environmental conditions resulting in a large number of different grape varieties being cultivated as well as a large diversity in the management practices of the wine growers. Collectively these factors introduce additional levels of variability into the analysis of regional-scale viticulture data. This PhD work is based on the assumption that assessing the temporal variability in the satellite imagery, in addition to spectral variations, would allow a more complete analysis to derive new and relevant information about production variability of individual vineyards at the regional scale. With this in mind, the principal objective of this thesis is to integrate temporal analyses, as an additional descriptor of vineyard variability, in order to take into account, in a better and more holistic way, all the specific dimensions of remote sensing data (spectral, temporal and spatial). Different supervised and unsupervised multi-way analysis methods, derived from the field of chemometrics, were used, capable of generating information at the regional scale from time series of multispectral images. Unsupervised approaches demonstrated the possibility of extracting agronomic knowledge over time (e.g. different vegetative dynamics) without a priori knowledge. The supervised methods allowed, firstly, the spectral, temporal and spatial assessment of an extreme climatic event (e.g. a heat wave) and, secondly, the selection of multidimensional (spectral-temporal) variables to deepen the agronomic understanding of the impact of an extreme climatic event on grapevines at a regional scale.

Research units: AGIR, MISTEA, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2019-2022

Potential of multispectral satellite image time series for the characterisation and dynamic monitoring of a crop: application to vines on a regional scale

Abstract: Information sources based on remote sensing have particularly interesting characteristics for dynamic crop monitoring, from the plot scale to the regional scale. Imagery from sensing platforms is capable of being used for operational decision support (for expertise or as model input) for crop monitoring at different scales. Despite the demonstration of this capability in previous studies, the development of these new sources of information (platforms and sensors) is progressing more rapidly than the development of new information technologies adapted to the management of this vast quantity of data. Indeed, the information that characterises this type of data is not only large (multidimensional), but also very heterogeneous, which remains a challenge for data processing and agronomic interpretations.

Research units: ITAP, AbSyS, Institut Agro

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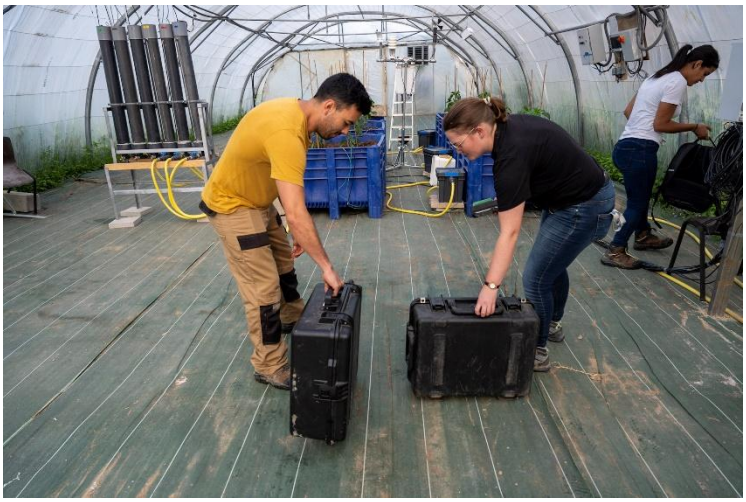

https://theses.hal.science/tel-04047025/

Main scientific field: Human and social sciences

Co-funded PhD – 2018-2022

The Innovation System of Digital Agriculture facing the ecological transition

Abstract: The thesis, which is positioned in the multidisciplinary field of Innovation Studies (Economics, Management and Sociology of innovation), mobilizes the approach of innovation systems, in order to analyze the development of digital agriculture and its possible effects on the ecological transition in the French agriculture. The thesis will thus study the modalities of adoption of digital innovations by two forms of agriculture that seek to contribute to this transition, either by "optimization of conventional practices" or by "breaking through organic farming". The research combines i) a national mapping of the innovation system of digital agriculture (census of institutions, firms, networks contributing to these innovations) with ii) the analysis of local dynamics of innovation in 3 sectors marked by both the development of digital agriculture and the coexistence of the two models which aim at contributing to the greening of agriculture: milk, cereal crops and wine (survey on a sample of farms). Digital agriculture has never been analyzed by Innovation Studies as a global movement, transforming agricultural sectors, its institutions, communities of knowledge and practices: This is a major scientific issue in research on innovation in agriculture. The thesis will contribute directly to the DigitAg convergence institute (axis 1), to the priorities of INRA (# 3Perf) and to the research on innovation network on 'Innovation (RNI).

Research units: INNOVATION, AGIR, INRA

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Main scientific field: Technology and Sciences

Co-funded PhD – 2017-2020

Modelling and viewing relations between agrienvironmental time courses and product quality using a parcimonious Bayesian approach

Abstract: Traditional knowledge plays an important role in agricultural practices. For instance, in the vine and wine food chain, decisions taken in vineyards mainly rely on expert knowledge-based approaches. Confronted with new challenges, stakeholders in agricultural production chains need advanced quantitative-based decision support tools. The aims of this PhD are i) to propose a knowledge discovery method to deal with big data from time courses, ii) to explain and predict product quality. Data integration should deal with high resolution data from sensors or agronomic models, low resolution observations and expert knowledge. It requires taking into account the reliability of all sources and data uncertainties. This calls for a coupling between informatics and data analysis, and constitutes the core of the PhD. The main application concerns the vine and wine food chain, in close relation with industrial partners (consulting professionals: ITK, Fruition Sciences, technical institute IFV) and public research laboratories (Joint Units LEPSE and SPO)

Research units: MISTEA, LEPSE, INRA

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Main scientific field: Life and environmental sciences

Labeled PhD – 2019-2022

Analysis and modelling of effects of dynamic shading on grapevine development and berry ripening and quality

Abstract: Dynamic agrivoltaic systems combine agricultural production with the supply of energy by mobile photovoltaic panels on the same surface. They can resolve land use conflicts and offer new ways to manage the microclimate of crops, particularly in the face of climate change. These systems appear as interesting for grapevine, often established in areas threatened by this change, but their success depends on maintaining or even improving the yield and / or the quality of the harvest. Specifically, an "intelligent" control of panels' orientation above the crop must be designed according to how sensitive to radiation are the various processes involved in the development of the yield. Plant growth requires radiation, but excess can be detrimental. Some species acclimate in the shade and make better use of radiation. However, no data exist on the acclimation of the vine under intermittent shade such as that created by panels. The work will consist of evaluating the consequences of such shading on the physiological behavior of the vine and its production in terms of quantity and quality on an annual and multi-annual scale. A first axis will consist in analyzing and modeling the radiation use efficiency under different shading regimes and at different stages of plant development, taking into account the architectural changes of the canopy and its consequences on intercepted radiation. A second axis will be dedicated to the analysis and modeling of the grape ripening under these same conditions. A third axis will consist in coupling these 2 groups of results in a global model. The final objective is to use the model to identify the dynamic shading practices that would be the most favorable in terms of yield and / or quality in an agrivoltaic system.

Research units: LEPSE, INRAE

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Main scientific field: Technology and Sciences

Internship - 2023

Navigating the multidimensional implications of agroecology for animal and plant health decision-making

Abstract: For a farmer, deciding on a practice requires considering those already in place to avoid disturbing the balance of the system through the introduction of new interactions. He therefore has to know the diversity of available practices. In the case of crop protection, for example, the literature presents various plant-based solutions (in aqueous or essential oil form) to control the infestation by a pest. For example, choosing a solution that repels a pest population may result in the population moving to a neighboring crop, which is usually not attacked.

The Knomana database [Silvie et al., 2021], with over 48,000 descriptions of pesticidal and antibiotic plant use, can enable this choice. The RCAviz [Muller et al., 2022] and RCAvizIR software platforms can be used to navigate through this knowledge base, whose knowledge has been previously classified using Relational Concept Analysis. In order to accurately represent the data of various dimension and to facilitate their interpretation by the farmer, a promising solution is to express them in the form of multidimensional implication rules, a new method derived from Formal Concept Analysis. For a ternary relation (3-D data) relating pests, plants, and protected crop, this method makes it possible, for example, to express knowledge in the form "when Pest1 is controlled by plant1 on crop1, then Pest1 is also controlled by plant2 on crop1, and by plant3 on crop2". This method can be applied to relations of dimension greater than 3.

The objective of the internship is to develop a software prototype for visualizing knowledge, expressed in the form of multidimensional implication rules. These rules are produced by an algorithm implemented in Python. We will also develop a strategy so that the rules are presented to the user according to his interests and according to the semantics of the rules' content.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Technology and Sciences

Internship - 2023

Automatic normalization of variables from agroecology databases

Abstract: Agro-ecological studies generate many heterogeneous databases in terms of structure and content. They are difficult to exploit and require curation to be used in statistical or modeling approaches. Curation consists in selecting the most relevant data and enriching them with the metadata necessary to understand them, in order to make them accessible, shareable and reusable. To annotate the data and increase the precision of the terms used, an interdisciplinary group of CIRAD researchers has built a dictionary of variables. A variable consists of semantic terms derived from expert knowledge and reference ontologies. A list of usual variables has been defined to facilitate data comparison and analysis, and links with crop models.

The objective of this internship is to automate the labelling of variables from agro-ecology databases from the list of usual variables.

The intern will use data from agro-ecological trials set up in Reunion by CIRAD and its partners (eRcane and CTIS).

Several methods will be mobilized and combined to propose the dictionary variables that are most in line with the database variables:

- lexical proximities measures,

- contextual proximity methods based on the description of the variables given by the experts,

- contextual proximity methods based on corpora. Contexts will be constituted from textual corpora and word embedding methods from deep learning methods.

Beyond an extension of the method by proposing original text mining methods, an important objective of this internship is to propose a generic approach to label data and facilitate the interoperability of databases in agroecology

Research units: Aïda, CIRAD

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Main scientific field: Engineering sciences

Internship - 2023

Internship IT development for agroforestry

Abstract: Agroforestry systems provide many ecological benefits (biodiversity, protection against climate change, etc.) but are complex to design and therefore to implement. To help agricultural advisors and farmers to design such systems, tools are being created. A first prototype, intended for interactive design, makes it possible to represent the plant elements defining the agroforestry system above a model. A second prototype uses the description of the designed scenes and is intended to represent the future trees at real size as well as their evolution over time in the targeted real plot. The project involves researchers from three well-known Montpellier research units: the ICAR team of the LIRMM, the AMAP unit (a pioneer in 3D plants and image-based plant identification), and the ABSys unit (INRAE), which is known for its work in agroforestry.

Research units: AbSyS, INRAE

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Main scientific field: Technology and Sciences

Internship - 2023

Evaluating the potential of neural networks for spatial remote sensing

Abstract: The objective of this study is to identify indicators helping the characterization of coffee landscape vulnerability to pest and disease (P&D), based on remote sensing images at very high spatial resolution (Pleiades, WV2) combined with exogenic data (soil, climate…). We thus propose to test the Swin Transformer Neural Network approach. The attended deliverables are (1) a map of the level of resistance to P&D spread, (2) a typology formalizing the P&D resistance in terms of landscape structure components.

The student's main mission will be to build an image processing algorithm adapted to this problem. His.her work will rely on reference data priorly collected in the fields in Uganda during the DESIRA Robust project, thanks to its large pluri-disciplinary research team (ex: UMR PHIM). This context will allow to produce a large and accurate data base, geographically extended, and with a good representativity, such factors being a common limit for the network's approaches.

A large number of plots (>50 per type) will thus be identified in the fields, being characteristic and representative of the coffee plantation structure and density diversity (shading type, diversity, organisation...), and showing various degrees of P&D vulnerability. These reference plots will be divided in three datasets: first to train and fine-tune a neural network priorly trained on standard remote sensing data, second to test and improve the quality of training results while avoiding overtraining effects, and third to map the whole study zone and evaluate the final result.

Various input combinations will be studied to determine the most performing networks depending on the scale of results: recognition and typology at the coffee orchard scale, and then at lower levels (intraplot structure), with adaptation of the input data resolutions. The most significative parameters will then be yielded for each working scale.

Research units: AMAP, CIRAD

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Main scientific field: Engineering sciences

Internship - 2023

Influence of dairy cow posture on variations in morphological measurements in a 3D imaging-based data capture system

Abstract: The phenotypic monitoring of dairy cattle is essential for both genetic selection and herd management in livestock farming. This practice is time-consuming and presents risks of stress and accident for animals, and humans. Phenotyping devices based on three-dimensional (3D) imaging are thus of interest and has been developed in recent years. However, many of them require immobilization of the animal during image acquisition, since a device used without constraint usually results in variations of the animal's posture on 3D images. Using a constraint free system called Deffilait3D, the present study aims to determine the influence of head position on morphological measurements, and the possibility of correcting these measurements according to cow's position. Two datasets including 3D images of four and ten cows with different head position were used, for a total of 24 and 106 3D images respectively. From these images, the height at the withers (HG), the height at the sacrum (HS), and the average height at the hips (HH) were determined. The results confirm the position of the head has a significant influence on the measurement of height at the withers, while the measurements at the back of the animal remain stable, regardless of the position of the head. Thus, when cows lower their head, the height at the withers decreases, increasing the error of this morphological measurement on average by about 3% when the head reaches ground level, with a maximum error of 4.8%. Three approaches were tested to correct shoulder height for head position: prediction of height at the withers from hip height measurement; application of a fixed percentage correction for head position; and correction based on predicting the measurement error based on head position. The last two approaches showed similar results to correct the measurement of height at the withers, with measurement error lower than 0.80% and 0.10% respectively. These results indicate that the posture of cattle in a phenotyping system based on 3D images may lead to variations in morphological measurements, which can be determined and corrected.

Research units: PEGASE, INRAE

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Main scientific field: Technology and Sciences

Internship - 2022

Automatic segmentation of aerial images of agroforestry systems to characterize their structure

Abstract: This work demonstrates that analysis methods exploiting temporal and spectral signatures to extract information on regional-scale variations in vegetative growth offer valuable information for assessing individual crop performance. Taking into account the high dimensionality of the data, which includes the temporal dimension, the needs as well as the limitations of time series analysis are explored in the context of providing relevant information to aid large-scale knowledge of a crop, such as grapevines.

Research units: AMAP, CIRAD

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Main scientific field: Human and social sciences

Internship - 2022

Digital tools in the design of agroforestry systems. State of the art of practices and needs

Abstract: The design of agroforestry systems, and in particular the design of agroforestry systems, is a complex issue involving multiple stakeholders with different points of view and both implicit and explicit knowledge and experience. Moreover, the effects of the decisions made will only be perceptible in the long term. The research work of the last decade shows that co-design workshops are a relevant way to reach operational solutions. In these workshops, the use of digital technology remains limited but is a promising approach. The development of generalist tools is hampered by the variety of workshop practices and the limited availability of literature on the subject.

This internship aims at analyzing the current practices of agroforestry system co-design workshops in order to identify how digital tools can improve this design. Semi-directive interviews will be conducted with various actors who have had experience in facilitating and participating in co-design workshops to identify the characteristics of the systems that are the focus of the design, the different steps of co-design workshops, the tools currently used and the characteristics expected from a design support tool. The analysis of the needs and means that would allow the development of digital applications in agroforestry system co-design workshops will allow us to answer key questions that are important in the development of digital tools that contribute to system design:

- What visualizations of ecosystem services are most needed?

- What gaps in current tools/methods are most felt by stakeholders?

- Is it necessary, and if so, how should the spatial and temporal dimension of systems be represented?

Research units: AGIR, INRAE

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Main scientific field: Technology and Sciences

Internship - 2021

Deep Learning for detection, delineation, and differentiation of mango trees and mango-based orchards from very high spatial resolution images

Abstract: In West Africa, information acquisition in fruit sector is hampered by the lack of adapted methods and tools for the characterization of fruit tree based systems, often complex (e.g. agroforestry systems). In this context, PixFruit project (UPR HortSys) aims at aquiring data on mango production at both scales of tree and orchard, respectively, for the calibration of regional production models dedicated to provide accurate and reliable analytical statistics to the actors of the sector. In order to extrapolate to the scale of a region the mango production from data collected in the field by PixFruit tools (PixFruit smartapp), it is necessary to delimit and classify the trees and orchards to provide additional input data (cultivated area, planting density, cultivar composition, etc.) to regional models.

We thus propose to explore and evaluate the potential of deep learning in neuronal classification and segmentation methods for the production of this information from multispectral satellite imagery data at very high spatial resolution (Pleiades).

Our first objective is to develop, on the basis of this innovative methodology, tools making it possible to detect, identify and delineate orchards in a production region, and then to discriminate those containing mango trees. Our second objective is to identify and delineate the mango trees themselves, as individual trees, whether isolated or in orchards. It will therefore be necessary to obtain better results in segmentation (orchard circumscription, individual tree cut out) and classification (orchard recognition according to its majority species, orchard classification according to structure and cultivar composition, tree by tree species identification) than with the tools more conventionally used in remote sensing (SVM, RF). In this work, we will evaluate the potential of the two mostly used types of neural networks, on several data architectures, to delimit and classify orchards: convolutional networks (CNN) on two Pleiades images acquired in March and July 2017, and recurrent networks (RNN) on the association of these Pleiades images and a Sentinel-2 time series. Finally, we will analyze the performance of the Mask-RCNN (Regional Convolutional Neural Network) to correctly identify and segment trees.

The study area will be the Niayes in Senegal (503 km2), relevant for its cropping systems diversity comprising different levels of complexity and density (fruit monocultures, extensive systems and agroforestry systems) and the presence of many cultivated species (e.g. mango, citrus, cashew, neem, etc.). In addition, this area benefits from a large field database (11,300 mango trees and 12,211 orchards, resulting from Julien Sarron's #DigitAg thesis) and the agronomic expertise got within the framework of the PixFruit project, which will allow the technical achievement of this study.

Research units: TETIS, CIRAD

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Main scientific field: Technology and Sciences

Internship - 2021

Visualisation and Navigation in agro-environmental spatio-temporal data classified by relational concept analysis

Abstract: With the rise of digital technology, agricultural research has produced numerous datasets on agriculture and on the environment to be mobilized to develop decision-making tools for populations from the North and the South. Among these datasets, there is one on the watercourses of two French watersheds developed by the Fresqueau project (http://dataqual.engees.unistra.fr/fresqueau_presentation_gb) which is spatio-temporal and another one on the uses of plants with pesticidal and antibiotic effect developed by the Knomana project (https://agris.fao.org/agris-search/search.do?recordID=FR2019109314) for animal, plant, human and public health whose data model has a ternary structure.

To develop the decision support tool, the classification method used by these projects, to model temporality and ternary relationship, is Relational Concepts Analysis (RCA). Using logical quantifiers, RCA groups and classifies sets of entities sharing common properties and relationships, supporting for example reasoning by exploring properties and similarities, reasoning by abduction to create hypotheses, and the search for alternative solutions by neighborhood with known solutions. To avoid calculating the complete classification to navigate and explore the dataset step by step, an on-demand calculation method has been developed. The problem faced by the team carrying out these projects, i.e. LIRMM, UPR AIDA, UMR IPME and ENGEES, is to have a tool for visualizing and navigating through the data classified by RCA.

Furthermore, the LIRMM conducts research in analytical visualization (Keim et al. 2008). This field focuses on the study of interactive visual interfaces enabling the exploration of complex and heterogeneous datasets in order to facilitate analytical reasoning on the data and thus derive knowledge from them (see for example (Accorsi et al. 2014) developed within the Fresqueau project).

The objective of this internship is to develop a software prototype for the visualization of data sets, including spatial and/or temporal data, classified by RCA. More precisely, the trainee will carry out an interactive visualization allowing to pilot the calculations on request of RCA and to display the results in an incremental way. Several visual approaches will be combined in order to give the user an overview of the extracted knowledge space and, as requested by the user, a detailed view of subsets of the classification calculated on the fly. Different interaction methods (Munzner 2014, chapters 11-14) and different graph visualization techniques (Tamassia 2013) will be used. The trainee will follow the design steps described by Sedlmair et al. 2012: i.e. literature review, definition of the need expressed as visual problem, proposal of a model, development, deployment, validation.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Technology and Sciences

Internship - 2021

Distributed plant simulations: Application to agroecology.

Abstract: To meet societal demands for a more sustainable and ecological agriculture, plant models simulating their growth and functioning (FSPM) are being developed by the scientific community. In the framework of the OpenAlea modeling platform, we have been developing for several years, different simulation formalisms (Pradal et al., 2008; Boudon et al., 2012). In particular, formal grammars, such as L-systems, allowing the efficient rewriting of trees or methods for rewriting multi-scale graphs (MTG) are available and have been used to model a wide variety of plants (apple, mango, palm, maize, sorghum, etc.).

FSPM models allow the study and analysis of plant-plant interactions in complex canopies in association (Gaudio et al., 2019, Braghiere et al., 2020). They allow to simulate aerial and root phenotypic plasticity by taking into account the competition for light and resources acquisition in a mechanistic way. For this, it is however necessary to simulate, at the organ scale and in 3D, the development and functioning of a large number of interacting plants within the same canopy. To do this in a reasonable time, it would be necessary to distribute the simulation calculations over large computing infrastructures (cluster, cloud). However, currently, there is neither formalism nor technology to automatically distribute the 3D simulation of interacting heterogeneous plants.

The challenge we are trying to address is therefore to efficiently simulate a set of plants in spatial (competition for resources acquisition) and temporal (feedback between structure and function) interaction. The objective of this project is to analyze different parallelization strategies to simulate in 3D the growth and functioning of plants and stands on shared memory architectures and in distributed environments (Pradal et al., 2017; Heidsieck et al., 2020). One of the challenges is to define design patterns for distributed computations at different granularities (parallel simulation of an isolated plant, distributed computation of a large number of interacting plants) using current technologies (OpenMP, Spark, Dask). An important issue is to take into account the dependencies between the computations made on the structures when they are rewritten according to the strategies used (in place or by copy).

One application of this work will be the simulation of an agroforestry system mixing palm trees and rice for which pre-existing models (VPalm and Cereals projects) will be reused.

The student's work will consist of:

- Definition of a protocol for spatial information exchange and synchronization between simulators.

- Formalization of a strategy for distributing simulations on several machines or clusters.

- Application to the creation of a Palm-Rice agroforestry system model with characterization of the dynamics of light distribution during a growth cycle.

Research units: AGAP, CIRAD

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 1: ICT and the Agroecology challenge

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Main scientific field: Technology and Sciences

Internship - 2021

Collecte et analyse de données issues des ruches connectées des apiculteurs

Abstract: Beekeeping has faced many challenges in recent decades, the causes and consequences of which have plunged beekeepers and the economy of the sector into a situation that is still uncertain. In response to the decline of bees, the decline in French honey production and strong environmental constraints, beekeepers are increasingly expressing the need for technical support and to base their strategies on references and tools for decision aids.

One proposal is to study the behavior of honey bee colonies, their dynamics over a period and in a given territory and their performance in terms of honey production. For this, beekeepers have been using electronic and connected scales for the past fifteen years, measuring the weight of the hives in real time. With a few thousand scales now in operation with beekeepers and hourly information being reported, this constitutes a mass of data that is still undervalued to this day. In addition, the ability of a colony to exploit nectar resources is influenced by biotic (colony development status, floral resources) and abiotic (meteorology) factors which may be considered depending on the availability of these data. By crossing these different data sources and implementing data science methods, this offers great potential for building the prediction services of tomorrow.

A thesis led by ITSAP in collaboration with INRIA on this topic was accepted by DigitAg in 2018, but its implementation was thwarted by the onset of a financial crisis at ITSAP. The financial stability of the Institute is now secure, and the subject is still as important for the beekeeping sector, we wish to relaunch this scientific dynamic in 2021 through this internship subject. A new submission of a thesis subject as a continuation of this internship will also be made.

In addition, this internship will be based on the dynamics of the Occitanum Apiculture open lab which also provides for actions on these connected balance technologies to develop decision support tools for beekeepers.

The intern's work will aim to

- Approach beekeepers in order to obtain their consent to collect digital data from the scales (a minimum of one hundred) and complete the contextual data essential to the interpretation of the evolution of the weight curves generated by the scales (i.e. geolocation, change and date of places during transhumance of beehives, activity / honey targeted by the beekeeper). This task will be carried out directly by the trainee or he will support advisers from beekeeping development associations in charge of ensuring this data collection.

- Validate the quality of the data collected according to the specifications of the format required for the "MIELLEES Computer System" database, already operational and developed by INRAE Genphyse and ITSAP-Institut de l'Abeille in 2019-2020.

- Apply a routine of "cleaning" of the numerical data of the evolution of the weight from an R programming acquired and tested on a set of experimental data restricted in 2020 (identification of the type of data, validation of the time step, management missing data, validation of the variation in weight, correction of weights, possibly segmentation).

- Identify subsets of consistent data from apidological criteria (honey production basin, period, target honey flow, density of scales identified per unit area, etc.).

- Develop and test the temporal dynamics of the weight of a hive (variable of interest) to predict the colony's ability to exploit the nectar resources available within a given foraging radius and in relation to climatic factors. Different methods of machine learning will be tested.

- Offer operational, simple and educational outputs for beekeepers of the results obtained from coherent data subsets: visualization and mapping of productions, average of the evolution of weights, positioning of the activity of a colony in relation to other colonies, identification of favorable days for foraging according to the meteorology.

Research units: ACTA

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Main scientific field: Human and social sciences

Internship - 2021

Cooperatives: driving the digital transition in agriculture?

Abstract: In France, cooperatives account for a significant proportion of agricultural and agrifood activity. The 2,300 agricultural cooperatives generate sales of 85.3 billion euros, or 40% of the French agri-food industry, and employ 190,000 people, including subsidiaries (La Coopération Agricole, 2019). Upstream, 75% of farmers in France depend on a cooperative. In the Occitanie region, there are 361 cooperatives, employing 15,000 people, generating sales of 6 million euros. 9 out of 10 farmers here belong to a cooperative. At the same time, cooperatives are characterized by a wide diversity of sizes and structures, despite an underlying trend towards concentration. Their weight in the agricultural world makes them a key player in the digital transition of agriculture. A study on cooperatives and digital has already been carried out by PWC in 2016. However, it only covered 11 large French and foreign cooperatives, even though 93% of them are SMEs. An ecosystem around the digital issue has been set up (training, certification...).

This master's internship will explore three questions:

1) Take stock of the role of French agricultural cooperatives in the digital transition of agriculture. While initiatives such as that of InVivo and its "digital factory" are particularly high-profile, what about smaller cooperatives in different sectors? Do they play a purely advisory role, supplying digital solutions? Are they involved in designing digital tools and guiding research? Beyond the size of these cooperatives, is there a link with their modes of governance? In this regard, we will draw on the work of Saisset (2014), the INNOGOUV project and Boris Biao's thesis.

2) What models of agriculture do these cooperatives promote through their digital tools: sustainability? intensification? agro-ecology?

3) In terms of theoretical approaches, several avenues can be explored. There is little literature on innovation in cooperatives, beyond that on social innovation. In the field of innovation, many approaches to innovation focus on the characteristics of the "innovator". In the case of cooperatives, this approach is not relevant, given their special status and positioning in value chains.

In summary, this dissertation is expected to:

- An initial theoretical framework on technological innovation in agricultural cooperatives,

- An initial typology of the role of cooperatives in the digital transition, according to size, sector(s) of activity, mode of governance: their role in global innovation processes (design, distribution, consulting, etc.), their role in the models of agriculture being promoted. As part of this Master's program, we plan to conduct exploratory interviews with at least 10 to 15 cooperatives (the exact number will be determined by the saturation principle). Two major regional sectors are targeted: viticulture on the one hand, and fruit and vegetables on the other, which, in addition to their economic importance, will enable us to benefit from synergies with two other projects (Innogouv, led by Louis-Antoine Saïsset, on the link between innovation,

governance and sustainable performance in winegrowing cooperatives, and the RMT Filarmoni, in which Leïla Temri participates, on the fruit and vegetable sector). The cooperatives will be selected to represent

the widest possible range of sizes, modes of governance and, in the case of F&V, types of production. The interview guide will focus on the role of cooperatives in the choice of digital tools (distributor, advisor, designer, etc.), their links with research and development, and their criteria for choosing the tools they promote. For each cooperative, a few farmers will also be interviewed to assess the impact of these tools on their production system.

We will also call on the skills of specialists in digital farming to help us understand the characteristics of the tools, and agronomists to characterize the farming models promoted. Léo Garcia, agronomist, will support us in the construction of this interview guide.

Research units: MoISA, Institut Agro

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Main scientific field: Technology and Sciences

Internship - 2021

Building the decision to optimise weed control

Abstract: Weeds are a major constraint on tropical agricultural production, leading to crop yield losses of 30-80%. Optimizing weed control practices in crop management requires a good knowledge of their behaviour. This course is part of a collaborative research initiative that proposes to combine approaches related to data science and field knowledge from experimental trials in agroecology. The aim of the course is to build a decision support tool for farmers, enabling them to optimize weed management practices according to pedoclimatic factors, technical itineraries and knowledge of the life cycle of species on Reunion Island. This work will be based on a large volume of data (floristic surveys, environmental factors, taxonomy, and phaenology of weed species) that has been published on the CIRAD Dataverse in the form of files that are standardized from a syntactic, semantic and structural point of view.The construction of the decision-support tool will be based on three steps:

1. Predicting the influence of agronomic and ecological factors on the presence and abundance of species.

Based on the 1,341 surveys carried out on the Reunion Island and the 300 taxa observed, a machine learning method will be developed to predict the probability of the presence and abundance of the various weed species. The abundance of species in a plot will be predicted according to factors that can be easily informed by farmers, such as field location, soil type, altitude, season of intervention and the technical itinerary of the crop.

2. Predict the aggressiveness of weeds by taking into account their phenology.

Based on the expertise of CIRAD weed scientists, the abundance predictions of stage 1 will be combined with aggressiveness indices for each species to estimate the potential harmfulness of weeds in the plot under consideration. In addition, by integrating the observations made on the phenology of the species (emergence, flowering), which are themselves linked to the previous pedoclimatic factors, an optimal range of intervention will be defined and technical choices of intervention will be recommended for the implementation of weed management practices.

3. Advise the most appropriate means of control

Taking into account the predicted abundance of species, the range of intervention and the technical itinerary, as well as the expertise of local researchers, an expert decision system will be built to propose the most appropriate control methods (alternative methods to herbicides or optimized application of herbicides) to the agro-ecological context and according to the technical possibilities of the farmer.

This decision-support tool will be developed in the Reunionese context and for sugarcane crop, but in a sufficiently generic way to allow re-configuration for other cropping systems, other territories and other climates. Thus, it will be possible to propose adapted weeding practices according to a type of weed infestation prediction, in a given location, at a given date, for a given cropping system.

Research units: Aïda, CIRAD

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Main scientific field: Human and social sciences

Internship - 2021

Implementation of a methodology for monitoring and evaluation of digital innovations for agro-ecological transition

Abstract: "Digital innovations are often cited as a means of accelerating the agro-ecological transition. However, digital innovations are struggling to spread in agriculture, for various reasons. Some devices can be designed to facilitate the dissemination of digital innovations. Livings labs, for instance, designed to encourage open innovation and the appropriation of stakeholders, are one of them. This is how the Occitanum living lab (https://occitanum.fr/), launched in 2020, was built, with the aim of promting the development of agro-ecology by mobilizing digital technologies. The objective of the internship is to contribute to the design of the adaptive management system of the living lab Occitanum to promote, thanks to digital tools, the transition of agriculture (agro-ecological transition in the broad sense). Three stages of work are planned:

1. Conduct a literature review on the processes of diffusion of innovations and on the tools of adaptive management of digital innovations, by specifically analyzing the stakes of the digital and the agro-ecological transition.

2. Propose a generic piloting and evaluation strategy to promote the introduction of digital innovations for the agro-ecological transition.

3. Refine in co-construction with one or two Open-labs of the Occitanum living lab the methodological proposal for piloting and evaluation."

Research units: TETIS, INRAE

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Main scientific field: Technology and Sciences

Internship - 2021

Characterize the natural environments grazed by remote sensing to assess the sustainability of pastoral livestock in the PACA region.

Abstract: Interactions between pastoral livestock farming and "natural environments" are an important component of the resilience of socio-ecological systems in the hinterland of the Provence-Alpes-Côte-D'azur region. These spaces occupy more than 30% of the land area and livestock farming contributes to the ecological and social dynamics. This activity is strongly intertwined with the multiple use of the spaces with other activities that jointly define the identity of the territories. But the spatial inscription of grazing as well as its relations to the dynamics of land use, contrary to other agricultural practices (ploughing, mowing), is difficult to determine with precision.

However, the intersection between land use and grazing is at the center of concerns both in terms of the capacity to adapt to and mitigate climate change, the control of ecological dynamics with regard to the preservation of biodiversity and the prevention of forest fires. The sustainability of livestock farming itself is directly questioned by the "closure" of pastoral environments that grazing practices are struggling to curb. The medium-term renewal of the fodder resource for grazing herds is threatened as well as the maintenance of these areas in the eligibility criteria for support under the first pillar of the CAP. The characterization of the land use of these environments and their ecological dynamics are thus at the heart of the analysis of the sustainability of the region's pastoral livestock activity.

The available land-use maps (such as corine land cover ...) do not allow to operate in a satisfactory way these crossings. Therefore, we have undertaken a work on:

- On the one hand, a detailed characterization of the uses of pastoral areas based on the data from the pastoral survey carried out by the actors of livestock farming on the scale of the Alps and on farmers' declarations to the CAP's graphical parcel register.

- On the other hand, the characterization of land use in these areas using a supervised classification (Bayes) of five environmental closure classes based on SPOT 6 images and multi-resolution segmentation (Baatzshape).

The proposed training course aims at adapting this land use characterization methodology to the whole region. This work will produce an easily updatable map allowing the identification of particularly exposed areas and the decision support of the actors of the livestock industry within the framework of public actions aiming at reinforcing the future of the activity.

Research units: SELMET, INRAE

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Main scientific field: Maths and its applications

Internship - 2021

Extending the Graal software with numerical reasoning

Abstract: This internship accompanies a thesis funded by #DigitAg (Elie Najm) on the design of agroecological systems. Within the framework of this thesis, the reasoning techniques developed require (1) access to heterogeneous data sources and (2) the integration of various numerical calculations with logical rules. We rely on the Graal software tool (https://graphik-team.github.io/Graal/) developed in Java by the GraphIK team, dedicated to querying knowledge bases described by rules in rst-order logic. Graal allows to access various data sources and to perform logical reasoning, but it does not allow to integrate numerical calculations, potentially complex. For example, the case study currently considered in Elie Najm's thesis exploits a database of plant functional traits and, based on knowledge of ecology and agronomy described by logical rules, seeks to determine which bouquet of agrosystemic services can be rendered (more or less well) by various plant species. This requires aggregating functional trait values and associating a reliability value to the calculations, which is currently not possible with Graal. The current thesis work combines the use of Graal with that of an Answer Set Programming tool (Clingo, which allows functions to be called in Python), which is not, however, satisfactory for the targeted functionalities.

The aim of this internship is to extend Graal with numerical processing.

Research units: Lirmm, INRIA

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Main scientific field: Technology and Sciences

Internship - 2021

Prediction of sets of species by adaptive thresholding of categorical predictive models

Abstract: Deep species distribution models have recently shown superior predictive capabilities to classical methods used in ecology, especially when trained on very large volumes of occurrence data. In the framework of Benjamin Deneu's thesis, we are developing such models [1,2] with two main application objectives: (i) to measure the impact of the structure of the agricultural landscape on biodiversity, (ii) to predict the presence of weeds and crop beneficials as a function of the environment and the agricultural landscape. The models developed so far allow to predict the probability of a species conditional to an observation but they do not allow to predict species assemblages, in particular weeds or crop protection agents. In this internship, we will try to overcome this limitation by developing a method of adaptive thresholding of categorical predictions of the model whose objective will be to predict more relevant assemblages than naive methods such as absolute thresholding or the k most probable species. We will rely on statistical tests to reject a null hypothesis obtained either via a randomly initialized neural network or via random input data.

Research units: ZENITH, AMAP, INRIA

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Main scientific field: Life and environmental sciences

Internship - 2021

Hormone-free breeding management in dairy ewes: Management modifications and performance evaluation

Abstract: Context

The evolution of French livestock farming systems is accompanied by increasingly high socio-economic performance requirements while meeting the challenges of agro-ecology. This implies good control of reproduction, particularly in seasonal species such as sheep and goats, capable of adapting to the technical, economic, social, political and legislative context without compromising the viability of the production system.

Thus, in small ruminant dairy farms, the sector is looking for alternatives to the use of hormonal programs implemented in the context of animal insemination. Solutions are emerging both from research and from the farms themselves. These alternative solutions bring into play changes in practices that are by nature radical, involving in particular the use of the male effect and/or individualized detection of heat.

General objective

This internship is part of a research project on the design of hormone-free dairy small ruminant breeding systems, and aims to characterize hormone-free breeding practices and to measure the performance of the breeding systems implementing them.

Related research questions

What are the impacts of the introduction of new hormone-free reproductive management practices on the functioning of conventional and organic small ruminant farms?

How does this introduction change existing behaviour?

What are the assessed performances for a diversity of dairy farming systems?

Research units: SELMET, INRAE

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Main scientific field: Technology and Sciences

Internship - 2020

Assimilation of proximal and remote sensing data to improve the forecast capacity of the crop growth model SiriusQuality

Abstract: Crop models simulate the interaction between plants and the environment to estimate yield, harvest quality and the environmental impact of the crop. They represent the daily crop growth as a function of meteorological conditions, water and nitrogen availability and varietal characteristics. Crop models can be used to optimize (strategical and tactical decisions) or to drive (operational decisions) crop management practices, to maximize crop yield and quality and minimize unwanted nitrogen losses (e.g. leaching, N2O emissions).

Data assimilation improves the forecast capacity of models and reduces uncertainty of simulations. By collecting spatial information for large areas at low resolution (>10 m), remote sensing provides the means of monitoring agricultural systems at intra-plot to regional scale, to evaluate the effect of different management strategies on yields and the environment. Proximal remote sensing methods (terrestrial or aerial) provide complementary information with higher temporal and spatial resolution. In addition to crop management, proximal remote sensing methods are developed for high throughput phenotyping for varietal selection. Assimilation of fast phenotyping data allows to determine genotype x environment interactions in multi environment experiments, or to analyze the genetic variability of not or punctually measurable characters.

The objective of this Master project is to evaluate data assimilation methods to be coupled with a crop model (Sirius Quality; http://www1.clermont.Inrae.fr/siriusquality/). The student will use leaf area index, soil moisture and chlorophyll concentration data from different sources (Sentinel 2, drone, Phenomobile), and will evaluate a hybrid data assimilation method that combines parameter and initial conditions estimation and an original particle filter method (Chen, Trevezas, Cournede, 2014 ; doi.10.1137/1.9781611973273.10) developed in the framework of a collaboration with the Cybeletech agricultural start up. This will contribute to improve the representation of crop growth and reduce uncertainty. The student will be involved in the choice of the parameter and initial condition estimation method, and in the coupling with the data assimilation method. He/She will implement and test the methods for the Sirius Quality model. At the end the developed method will be validated for two additional crop models (STICS and Monica) and will be integrated in the decision support tool developed by Cybeletech.

Research units: LEPSE, INRAE

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Main scientific field: Human and social sciences

Internship - 2020

Adoption of digital technologies in the wine cooperatives: what impact on the agroecological transition?

Abstract: The use of digital technologies on farms is becoming more and more frequent, but the exact nature of these uses remains little known, as are their real impacts on the greening of farming practices. This question is particularly important in the wine sector, which is at the same time integrating many technological innovations, and facing increasing environmental challenges. The strong growth of organic viticulture illustrates this trend, which also depends on the cooperative cellars strategies that can have a major influence on the use of digital and the change of practices on the farms members.

The Master's internship refers to the field of Innovation Studies. It aims i) to characterize the digital uses of grape growers that are members of cooperative cellar in Occitanie, ii) to highlight the links between these uses and commitment to organic viticulture and iii) to specify the conditions that influences the adoption of these technologies and in particular the role of the cooperative. The work will therefore focus on the entire process of adoption and use of digital in a sector, including its conditions and impacts. Several hypotheses can be tested, such as the role of the cooperative's strategy or the viticulturist's personal trajectory.

The internship will consist in the realization of about thirty surveys with grape growers in the Occitanie region, starting from a selection of a reasoned sample of organic, non-organic and mixed cooperatives, then by a selection of 3 or 4 members per cooperative. The work will help i) Identify the digital technologies used and build a typology of their usage patterns; ii) specify their possible links with the agronomic practices implemented on the farm, in particular those involved in the agroecological transition; (iii) Identify the factors affecting the adoption and use of these technologies; iv) Identify the links between farms and cooperative in the use of digital. These results will not be sufficient for a thorough quantitative analysis, but it will bring very rich qualitative information around a study cases analysis.

The originality of this work is to propose a characterization of digital usage profiles and to examine their relation with the organic or non-organic nature of farms, in a context of cooperatives. It may lead to the production of a scientific article. The internship participates in a research program built around Eléonore Schnebelin's thesis on the links between digital and organic farming in several agricultural sectors, including viticulture. It will be carried out in conjunction with UMR Innovation and UMR AGIR, and in partnership with Coop de France Occitanie.

Research units: INNOVATION, INRA

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Main scientific field: Life and environmental sciences

Internship - 2020

Exploring the possibilities of augmented reality to support agroforestry systems design

Abstract: Agroforestry is recognized nationally and internationally as a way of developing a sustainable agriculture that is both resilient to and mitigates climate change. However, its adoption by farmers in developed countries remains low. Beyond the technical issues (technical feasibility, lack of skills in tree management) and economic issues (lack of economic references on the costs and benefits associated with agroforestry), a major obstacle to the adoption of this practice is the necessary shift in the temporal scale: farmers are used to make decisions on an annual time step or over a few years, not over the several decades of tree growth. In addition, because of the complexity of these systems, the number of combinations of species, spatial configurations, tree and crop management options is huge and the choice of a particular system must be specific to each farm, depending on its pedo-climatic constraints, the local value chains and the objectives of the farmer.

Farmers therefore need support for the design of their system, in the form of system design workshops or individual coaching. New technologies can facilitate this process and thus promote the adoption of agroforestry. In particular, augmented reality (superimposition of digital objects on real world images) offers the possibility of visualizing different options and thus to immerse oneself in different scenarios in order to choose the most desirable one and to initiate a process of change. Agroforestry is an ideal case study for augmented reality. First, the introduction of trees profoundly changes the appearance of the plots and landscapes, so visualization tools would be very effective. Second, the growth of trees is slow and the consequences of the choices farmers make now will only be felt several decades later, hence the utility of accelerated-time visualization tools.

This internship will define the methodology and technical environment allowing building virtual agroforestry systems, describing them and visualising them in situ. We intend to explore two complementary uses of augmented reality (AR): marker-based AR to enhance user experience during design workshops (e.g. after placing markers on a map of the farm, one could visualize the growth of trees on a digital elevation model superimposed on the map) and geolocation-based AR (following the design of his/her agroforestry system, the farmer could visit the real fields and visualize their appearance in 10, 20 or 40 years). The applications will be first developed for temperate agroforestry systems, for which 3D models of tree growth already exist within AMAP unit (e.g. walnut, poplar, wild cherry…), and then, tropical agroforestry systems (there is an on-going PhD thesis on the architecture of forest trees associated with coffee plantations in Côte d'Ivoire).

Research units: AbSyS, INRA

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Main scientific field: Human and social sciences

Internship - 2020

Uses of digital artefacts for agroecological transition in Benin

Abstract: Context – Agroecological transition requires creating, acquiring, exchanging information and knowledge. Digital tools take an even greater role to support this transition through the emergence of communities of practice. The digital transition is, in Benin, spurred by massive investment (for instance $100 million by the world bank in rural areas). Digital artefacts are now seen as a necessary condition for rural areas to adapt. Both transitions generate inequalities and deep structural and cognitive changes: tacit knowledge, access, financial means, available time, capacity in technology use. Users are various – farmers, technicians, extension services. Technologies and uses are multiple – information exchange (eg: WhatsApp groups, forums), building knowledge commons (eg: wiki), collective norm making (eg: specifications), decision aid tools (eg: remote sensing tools, online training videos).

Research question and objectives – What changes could emerge from such infrastructure building paving the way to larger bandwith in rural areas in Benin? What are the current uses of digital artefacts? What do they allow, how frustating are they? How practices would evolve? What are the pros and cons of digital artifacts compared to more traditional ways of information/knowledge exchange? This internship aims at exploring such questions with both a critical and open to surprises approach set in empirical grounds. We expect a typology of uses and users, a description of pros and cons of digital compared to face-to-face as a result. This preliminary investigation could lay the foundations for a thesis on the subject on the uses of digital artefacts to favor the agroecological transition.

Methods – State of the art on intellectual commons, social-ecological systems and existing collaborative tools. Field study investigation in Benin with actors who use or are willing to use digital tools. The specific focus will evolve depending on the intern interests and field observations. The internship will start by investigating small and identified communities inclined towards agroecological practices which use digital tools: a participatory guarantee system (https://amapbenin.com/2017/08/17/certification/), the Organic and Ecologic Agriculture Platform (PABE - https://www.pabebenin.org/?p=169) or other profesional organisations such as niébé based products.

Research units: INNOVATION, CIRAD

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Main scientific field: Technology and Sciences

Internship - 2020

Building the “Coffe Health Diagnosis” application

Abstract: The coffee farmer looks at a diseased tree and wonders if he should treat his coffee trees. He takes his smartphone, activates the ChDiag application "Coffee health diagnosis", and reports the damage to a virtual coffee tree. ChDiag indicates other coffee trees to sample and then provides him with an estimate of the level of damage on the plot. He can make a decision.

Thus, the objective of this project is to create a tool to diagnose the severity of pest attacks on a plant and on a plot scale. The project aims to contribute to the reduction of chemical inputs in crop protection. Indeed, Liebig et al (2016) find that many producers trust the effectiveness of chemical treatments while other types of treatments, such as cultural methods, exist. In their study, producers using chemical treatments have no better results than those using alternative methods. ChDiag will also allow a more accurate assessment of attacks: Ribeyre & Cilas (1998) showed that, in the case of the coffee berry borer, the "random" sampling of visible damage resulted in a significant overestimation of the damage.

Diagnosis on smartphones will be carried out via guided damage entry. A damage scale will be represented on a typical plant with variable numbers of branches and fruits. The user will choose the type of plant that most closely resembles the actual plant and report the observed damage in situ. A sequential sampling plan will guide the producer in the choice of plants to be sampled and will stop it when the required precision is reached. ChDiag will then provide an estimate of the damage to the plot.

This tool intended for coffee producers in areas where the pest infestation occurs will be specialized for damage caused by leaf disease, rust and a bark beetle, the black twig borer (branch attacks). According to the assessment of the level of damage caused, ChDiag will recommend that the producer switch to farming methods when infestations are below the epidemic threshold. ChDiag will therefore help to limit the use of chemical treatments. A procedure for control sampling, spaced over time, will be recommended.

This smartphone tool will integrate 1) a statistical sampling procedure based on literature, past or acquired experimental data, and validated by partnerships (coffee growers' associations) established as part of ongoing projects (including SWITCH Africa Green / EuropAid in Uganda and PROCAGICA UE in Costa Rica); 2) a geo-located data entry interface; 3) action advice based on the literature.

A tool for predicting the impact of damage on production (coupling a bio-aggressor model with the FSPM GreenLab model) is planned to be integrated later.

Research units: AMAP, CIRAD

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Main scientific field: Life and environmental sciences

Internship - 2019

Operationalization of an optimization model to the re-use of treated waste water for crop fertigation in Mediterranean conditions

Abstract: Re-use of treated waste water is a strategic opportunity to save water but also for crop nutrients (mainly nitrogen and phosphorus). Implementing this principle reveals optimisation and applicability issues. The optimisation concerns 2 points. The first one is to adapt waste water treatment to fit with plant needs in a dynamic way. The second one is to drive the outflows to fulfill plant needs while avoiding nutrients storage in the soil (and leaching). To reach this objective, a model platform is currently developed in a #Digitag post-doc project (opti-reuse). This platform is based on the principle of double modelling: basic processes models (bio-reactor, transport, crop-soil climate system) are simplified in their domain of use and feed an optimisation model to drive stages of the treatment process and inputs to the crops.

The objective of this master project is to bring answers to the applicability and the impact evaluation issues building on two case studies: the pilot site of Murviel-lesMontpellier (34), identified in the opti-reuse project and the pilot site of Saint Martin de Castillon (84). Both sites are equiped for the reuse or treated waste water for crop fertigation: olive and vines in Murviel les Montpellier, durum wheat and melons in Saint Martin de Castillon. In the first site water is treated through lagooning and tertiary treatment with a membrane bio-reactor. In the second site, treatment is made with a bacterian bed supplemented with a sand filter and UV beam for the tertiary treatment. Then both sites are complementary considering the treatment process and also the irrigated cropping systems.

This master projects will be structured around the following steps:

1. To participate to the identification of scenarios for the calibration of the models in both sites (one per site)

2. For these scenarios, to proceed with a sensibility analysis to identify predominant parameters

3. To identify measurements to be made for the calibration: element to be measured, sampling, calendar, experimental designs

4. To identify and characterize the errors of the simplified models and to propose improvements

5. To provide accurate inventory data for the impact evaluation of the two scenarios

6. To define a methodology for the calibration and the implementation of the platform for future scenarios or case studies.

Research units: ITAP, Institut Agro

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Main scientific field: Technology and Sciences

Internship - 2019

Knowledge representation and reasoning for the design of agroecological cropping systems

Abstract: Meeting the agro-ecological challenge leads to design very innovative cropping systems. Achieving this ambition requires both genericity (of the processes) and specificity (of the many possible technical combinations), which implies sharing and integrating various kinds of knowledge to adapt each system to its context (soil, climate, landscape, exploitation). Current agricultural system design methods are based on workshop sessions with experts of multiple domains and skills and rely on the construction of conceptual models (Lamanda et al., 2012) used as an interactive basis to formalize and integrate scientific and empirical knowledge.

This master internship fits into an emerging collaboration and is expected to be continued by a PhD thesis, whose final objective will be the construction of a tool (i) dedicated to the elicitation, formalization, integration and sharing of data and knowledge on the functioning and management of agro-systems in the context of the agro-ecological transition of agriculture, and (ii) offering several services that will rely on the semantics of these data and knowledge: exploration and query answering, checking the consistency of the modeling, identifying the elements of a process as well as the relationships between these elements, bringing out the consequences of some changes in the system, etc. This will be a tool for aiding the conception sessions, which will allow the participants to have a global and systemic view of how the studied agro-system operates. This tool will also help to formulate scientific hypotheses, to verify them, and to identify « gaps » in expert knowledge.

The aim of the master internship is to carry out the first steps of this project:

1. Start from a small set of conceptual models which describe the agro-ecological functioning of a vineyard plot or an orchard (designed within the ongoing AgroEcoPérennes Casdar project, 2017-2020). These models are about the functioning of perennial plant cultivation systems, centered on the description of processes, specifically concerning diseases and pests. The intern will have to understand, and possibly specify, these conceptual models with the help of agronomists, and study which knowledge representation and reasoning languages (beginning with standard languages from the semantic web) are best suited for their formalization.

2. Formalize the associated agro-ecological issues and identify generic reasoning problems: exploration / query answering / consistency checking / identification of key elements of a process, computation of the consequences of changes in the system.

3. Make a proof of concept based on the selected conceptual models.

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Research units: GRAPHIK, INRIA

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Main scientific field: Technology and Sciences

Internship - 2019

Integration of statistical analysis and visualization tools for the global agroecology information system AEGIS

Abstract: AEGIS (Agro-Ecological Global Information System) is positioned as an information system that supports digital agriculture and the successful transition to agroecology. This tool offers functionalities that are useful not only for researchers and students but also for industries, technical institutes and farmers, whether in Northern or Southern countries.

AEGIS' priorities are: rationalizing the observation function, sharing and standardizing the data collected. The aim is to strengthen and perpetuate observation systems for agro-ecological resources and their uses. AEGIS must be able to produce homogeneous data at different scales of observations by meeting industrial quality standards, to develop its tools and diversify the indicators and strive to meet the expectations of both research and experts but also environmental policies, and this, through: (i) the development of generic statistical analysis tools, (ii) the implementation of ex-ante and ex-post data processing methodologies, (iii) the provision of data sets for simulation and (iv) the development of complex visualization tools to facilitate the interpretation of data and to highlight indicators, patterns, trends and correlations inaccessible from raw data.

By aiming at the integration, through dashboards, of different data analysis, processing, simulation and visualization tools, aegis aims to be a complete steering and decision support tool in the context of agroecosystems.

The objective of the course is to create a set of statistical treatments allowing a first approach exploration and visualization of the data contained in AEGIS. Initially, a needs study will be conducted in interaction with a panel of agricultural researchers from CIRAD, as well as its public and private partners (INRA, IRD, IRSTEA, SupAgro, SASRI, CGIAR, etc.) whose project data are already in AEGIS, in order to establish a list of statistical treatments to meet most of the needs expressed. In a second step, the associated R scripts will be created. Finally, it will be necessary to integrate these scripts into the AEGIS framework. These last phases will be realized using shiny (https://shiny.rstudio.com/ - Shiny is an R package that facilitates the creation of interactive Web applications directly from R).

This course will take place in a heterogeneous and interdisciplinary scientific environment. It requires a good knowledge of R language and shiny. Some notions on relational databases and on the MVC architecture widely used for web applications would be appreciated.

Research units: Aïda, CIRAD

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Main scientific field: Life and environmental sciences

Funded PhD – 2023-2026

Co-design, adaptation and dissemination of high-low-techs to understand and support water management in the agro-ecological transition

Abstract: Agroecology is emerging worldwide as an alternative to meet the challenges of agricultural sustainability, notably with regard to water resources, subject to strong anthropic and climatic pressures. The transition from conventional production systems to agroecological systems faces various obstacles, particularly because of the increased complexity of agroecosystems that it may involve. Recent advances in mass information technologies (on-board electronics, IoT, wireless sensor networks) offer opportunities for the development of new measurement systems, more technically and economically accessible to the agricultural sector. However, the use and adoption of such tools remain conditioned by the agricultural contexts in which they are implemented. We believe that the co-design of new low-cost digital technologies can improve the understanding of water flows and support their management within agroecological cropping systems. The objectives of the project are to i) assess the constraints and needs of producers regarding water management, specific to different agroecological contexts, ii) adapt existing technologies (or develop them if necessary) through a participatory method involving farmers to meet the challenges of the systems studied, and iii) facilitate the adoption and dissemination of digital innovations by supporting the stakeholder networks established (monitoring, consulting, training). Two study sites, in Occitanie and California, representing different agricultural contexts (socio-economic environments and means of production), cropping systems (annual, perennial, agro-ecological practices) and contrasted levels of hydric constraint, will enable these methods to gain in genericity and robustness for the production of references to support the agroecological transition

Research units: AbSyS, G-eau, Institut Agro

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Main scientific field: Engineering sciences

Internship - 2024

A decision support to correct anomalies in multidimensional and multirelational data on agroecology for animal and plant health

Abstract: To ensure the success of the agroecological transition, farmers need to have access to knowledge about alternatives to conventional farming techniques. However, before a knowledge base (KB) can be used by farmers and scientific experts, it needs to be corrected of its anomalies. The context of this internship is the Knomana KB [Silvie et al., 2021], which brings together 48,000 descriptions of pesticidal and antibiotic uses of plants, and aims to propose plant-based preparations to replace synthetic chemicals. Dictionaries are already available to correct values for its 31 data types. But, verifying data correction and consistency is too complex to be carried out manually. For example, an inconsistency between the pesticide plant, the protected system (e.g. corn crop), the bio-aggressor (e.g. insect) and the geographical location is enough to mislead a farmer. The methad named Attribute Exploration (EA), developed by Formal Concept Analysis, can be used to detect and correct these anomalies [Saab et al., 2022]. EA expresses each piece of knowledge in the form of an implication rule, and identifies generalizations at different levels (e.g. all insects of genus X are controlled by plants of Family Y). The rules are presented to the experts, who validate or invalidate them in order to bring the BC into a coherent state.

The objective of the internship is to develop a software prototype for detecting and correcting anomalies in multidimensional and multirelational data. This prototype will enable to manipulate data and data types, then interact with the FCA4J library, for rule computation, and the RCAvizIR software, developed with the support of #Digitag (Master internships in 2022 and 2023) to present them in an order that facilitates correction work by experts.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Life and environmental sciences

Internship - 2024

Better understanding of water use in agro-ecological farms in Occitania: evaluation of existing low-tech sensors and application to monitoring irrigation practices

Abstract: In Occitania, water is a critical resource for agriculture. Climate change reinforces this fact. By allowing to reduce the water stress for crops, irrigation is part of the possible means of adaptation and can constitute an important lever of agroecological transition. On farms already committed to agroecology, a better knowledge of water and irrigation management at the farm level is necessary. The TAI-OC project aims to characterize the irrigated agroecological systems of Occitania, to understand the factors of the agroecological transition and to accompany this transition. To understand these systems, particularly in terms of water use, we wish to rely on the developments, initiated within the framework of a European project (www.prima-hubis.org), of a set of technical solutions based on low-tech and low cost sensors. These solutions allow a better understanding of the irrigation management within the farms.

The trainee's objective will be to evaluate the interest of sensors of this type for the monitoring and control of irrigation in agroecological farms. For this, several sub-objectives are defined:

1/ to take stock of the low-cost low-tech sensors available on the market, concerning the capacities of measurement of the volume of irrigation and pressure in irrigated systems (conduits, canals).

2/ to evaluate their usability (on economic and end-user criteria: cost, availability, ease of use but also technical: reliability in terms of measurements and uncertainties, number and type of failures, possibility of construction and repair).

3/ to analyze the interest and the operationality of their use in agroecological farms (positioning, number to be used, etc.) thanks to the modeling of irrigation networks.

Research units: G-eau, Institut Agro

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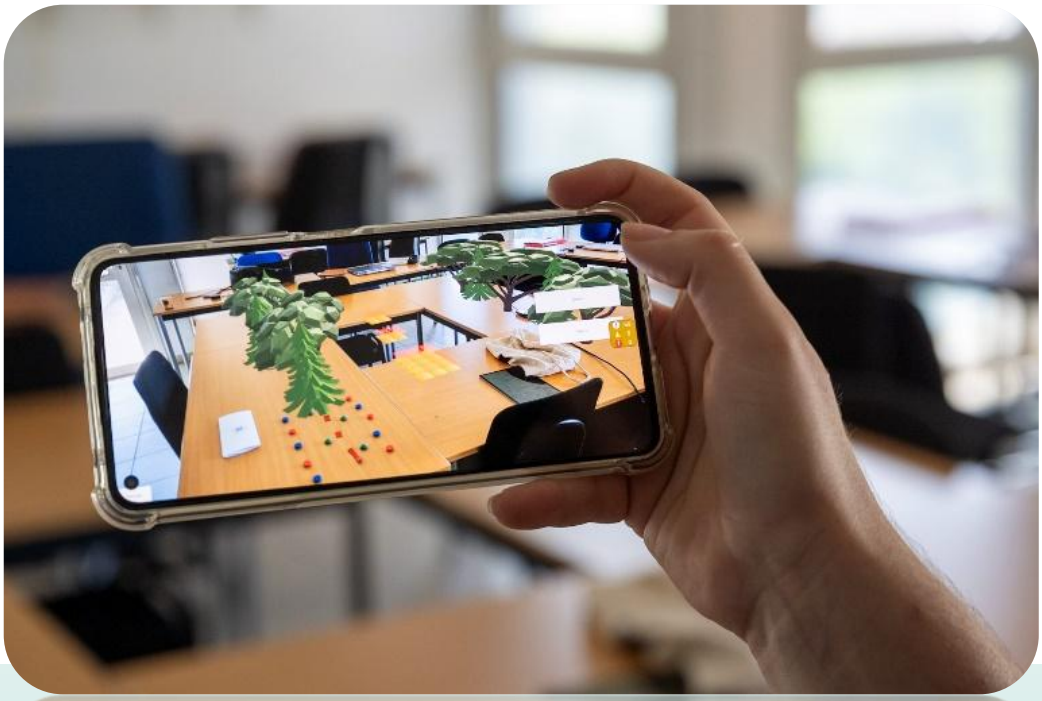
Stake 1 – Agricultural production improvement using ICT-enabled agriculture

Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets



Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets

Main scientific field: Life and environmental sciences

Funded post-doc – 2024-2025

High-throughput phenotyping of fruit tree genetic diversity for better adaptation to climate change

Abstract: This project aims to characterize the resilience of fruit trees via digital phenotyping of a certain number of traits related to flowering and tree architecture based on the combination of the skills in image analysis (AGAP-PHENOMEN, EMMAH-CAPTE), genetics (GAFL) and architectural analysis (AFEF) of the four teams involved. In addition to methodological developments in stereovision and RGB data processing to assess these traits, this project is interested in the fusion of information generated by these data and the generalization and transferability of these traits and methods between species. Several approaches (machine and deep learning, mathematical morphology, statistics) will be combined. This project is based on the acquisition of datasets in three core collections (peach, apricot, apple) each of them comprising more than 150 different genotypes, thus ensuring a representativeness of the variability of flowering and tree structure by differences in age and contrasting environments. It also aims to establish temporal consistency between past measurements (visual notations) and digital phenotyping.

In terms of expected outputs, we aim to contribute to the phenotyping of complex and integrative traits (improved accuracy and throughput, access to new traits not accessible manually), and to the genetic screening of resilience by determining a typology of trees that can maintain production in the face of environmental perturbations.

Research units: EMMAH / AGAP, INRAE

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Main scientific field: Maths and its applications

Funded post-doc – 2024-2025

Use of temporal series of hyperspectral images for early assessment of septoria symptoms in wheat.

Abstract: There is a growing interest in phenotyping plant resistance to leaf diseases using optical methods in order, on the one hand, to specify the status of the plant with respect to the pathogen (in a range from susceptible to resistant) and, on the other hand, to have robust methods characterising these interactions in a wide range of environmental situations.

In order to investigate the capacities of hyperspectral imaging (HSI) to characterise the symptoms of a fungal disease (septoria in wheat), a thesis was carried out (2020-2023) within a group of researchers bringing together specialists in HSI, infrared spectra processing and phytopathology (UMRs ITAP, PHIM and AGAP Institut). This work focused on the processing of HSI time series and led to the development of a method (based on Moving Window Principal Component Analysis, MWPCA) that clearly distinguishes the average kinetics of healthy and diseased leaves using visible and near-infrared spectra. The perspectives produced during this thesis open up two lines of research: (i) characterising the pĥenomenon at the individual scale (and not just a group average), (ii) achieving earlier detection of the disease and (iii) taking into account spatial dimension of the image.

Therefore, the first objective of this postdoctoral research project is to explore these two lines of research by applying alternative data processing algorithms to the dataset generated during the thesis, in order to improve the sensitivity and earliness of the measurement of disease establishment. To this end, a second and more operational objective is to improve the overall methodology developed in the thesis by proposing a more robust and parsimonious methodology, to assess the potential of a tool that could be deployed in the field.

Research units: Agap, ITAP, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2021-2024

Study and implementation of an original optical approach combining diffuse polarization spectrometry and Mueller's method for plant monitoring with the identification of specific phenotypic traits: application to vine water stress.

Abstract: In a fast-changing global environment, the ability to produce plant material adapted to diverse, changing and sometimes extreme agronomic conditions is an absolute priority. In particular, agriculture must consider possible ways of adapting and managing water resources to maintain sustainable agricultural production. To do this, one of the levers identified is the creation of new varieties that are more tolerant to abiotic stresses. While genotyping capacities have exploded in recent years, identifying the mechanisms involved through phenotyping remains very complex. Thus, the ability to produce relevant phenotyping information remains the limiting factor for the progress of varietal selection. However, instrumental optics, and in particular measurement systems based on visible and near-infrared spectrometry, have demonstrated in recent years that they offer undeniable potential for addressing these demands. But while some gene expression parameters are now accessible, there are other, crucial parameters that are not yet directly measurable. In particular, the measurement of some characteristics of the plant's response to water stress. The aim of this thesis will be to study, implement and evaluate a new and original optical approach that combines polarized light spectroscopy and the Mueller matrix. This technique, which is precise and more targeted, will make it possible to better decrypt the spectra in order to extract and select the main traits and indicators that characterize the varieties and their resistance to hydric stress. This method will be tested on different varieties of grape varieties subjected to different types of hydric stress with measurements taken at the leaf level to avoid the first level of spectral disturbance linked to the plant cover.

Research units: ITAP, LEPSE, Institut Agro

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets

Main scientific field: Life and environmental sciences

Labeled PhD – 2024-2027

STAR - Feeding and reproduction strategies evaluated by modelling to optimize the production and reproduction performance of dairy cows as well as their welfare

Abstract: This thesis is part of the flagship project "InSiliCow" (DIGIT-BIO metaprogram) which aims to develop and demonstrate the value of an operational digital twinning tool based on a dairy cow herd management simulator. Having a virtual farm (an exact copy of the characteristics of the farm studied) simulated by computer would be a useful decision-making tool for managing a real farm. The thesis aims to propose feeding and reproduction strategies adapted to the characteristics of dairy cows and to the technologies available on each farm in order to optimize production and reproduction performances, as well as cow health. This thesis is divided into 3 stages: 1) mobilization of the experimental farm databases of the InSiliCow project partners and appropriation of the simulator; 2) evaluation from these data of the effects of different factors (dietary characteristics, animal characteristics, level of lactation persistence, etc.) on cow performance and welfare (here integrating the health and behavior of the animal via the study of its physical activity and feeding behavior). These factors can then be integrated into the InSiliCow simulation model in order to improve the realism of the simulations. Finally, the last stage of this thesis will allow the use of the simulator to identify optimized reproduction and feeding strategies (in terms of performance and welfare) according to the individual characteristics and other factors listed above.

Research units: PEGASE, INRAE

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets

Main scientific field: Engineering sciences

Internship - 2025

High-throughput spatiotemporal reconstruction of root system architecture from frugal images using topological tracking and deep learning.

Abstract: Plants expand their root system to meet their needs for water and nutrients, from germination to harvest. The architecture of the root system, its growth dynamics and its plasticity determine the plant's production and its ability to withstand adverse growing conditions (flooding, drought). Root traits are difficult to measure in the field. Destructive observation (shovelomics) does not allow to study large GxE panels or to observe root growth dynamics.

High-throughput phenotyping platforms have been developed with automated analysis pipelines based on convolutional neural networks [1][2]. These pipelines segment simple architectures. However, they are not reliable for more complex architectures. Until recently, these methods have never been evaluated for dynamic feature estimation. We studied this aspect in [3] with a spatiotemporal reconstruction algorithm. Its reliability for topology and dynamic feature estimation has been demonstrated.

These modern phenotyping techniques have been developed for laboratories (Petri dishes, blotters, model species, imaging robots). There is a need to extend their capabilities in order to apply them to agronomic crops grown under conditions close to the field (Rhizotron) and observed using frugal techniques (simple camera). During this internship, we will study the limitations of reconstruction algorithms [3] and deep learning techniques [1][2] on these data in order to combine these approaches and extend their scope. We will work on the formal constraints of the algorithms to integrate more variate topologies and on the conditions (topological cost function [4], network architecture) to be met for a neural network to contribute to the reconstruction of topologically valid spatiotemporal architectures.

Research units: AGAP, INRAE

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Main scientific field: Maths and its applications

Internship - 2024

Improvement of an event detection tool (reproductive, sanitary, malfunction) in a herd of dairy cows and several groups of sows

Abstract: Precision farming tools combined with the breeder's observations, allow individual and automated tracking of dairy cows and sows contributing to an earlier detection of events (calving, health problems, malfunction). From water consumption data, an analysis method made it possible to detect disturbances related to health, reproduction or technical dysfunction events. This method is more than 95% specific for cows and sows, however its sensitivity is at best around 70% for cows and remains lower for sows (<50%).

The objective of this internship is to improve this method of identifying disturbances. The main hypothesis of this internship is that certain variables are dependent on each other (eg amount of water consumption and amount of feed ingested for cows) and that the structure of dependence between these variables will change during a disturbance event. The combined study of the dependent variables should make it possible to improve the sensitivity of our method of identifying disturbances.

This internship will be carried out at INRAE UMR PEGASE, Saint-Gilles, in collaboration with UMR GenPhySE from INRAE and will be co-supervised by a nutritionist researcher in cattle breeding (Anne Boudon, PEGASE), a nutritionist-modeler researcher in pig breeding (Charlotte Gaillard, PEGASE) and a statistician researcher (Tom Rohmer, GenPhySE). A follow-up committee of the internship will bring together researchers competent in the physiological regulations of water consumption and in the processing of dynamic data in livestock.

At the beginning of the internship, the databases will be available as well as a first version of an event detection program based on a differential smoothing method. The first step of the internship will consist in determining pairs of dependent variables specific to each species. The second step will consist of improving the event detection process by applying it to these pairs.

Research units: PEGASE, INRAE

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Main scientific field: Maths and its applications

Funded post-doc – 2020-2021

Time series analysis of hyperspectral images for early diagnosis of septoria symptoms in durum wheat

Abstract: The development and implementation of new technologies among various agricultural stakeholders aim to promote innovation and establish reliable, fast, simple, and cost-effective methods. In my postdoctoral research, I will use visible-near infrared hyperspectral imaging and various chemometric methods to identify markers of wheat STB disease. The spatial and spectral dimensions will be analyzed daily to reveal the specific signatures of the disease over time. Classification and prediction methods will be developed, applied, and compared on the dataset to diagnose the early onset of STB symptoms on durum wheat leaves. Additionally, variable selection methods will be studied to identify the wavelengths of interest associated with the disease, potentially leading to the development of simplified sensors.

Research units: AGAP, INRAE

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets

Main scientific field: Life and environmental sciences

Labeled post-doc – 2020-2021

Detection of vine water stress by optical instrument

Abstract: The postdoctorate position is part of the VINIoT project of Interreg Sudoe. The objective of this project is to propose a new precision viticulture service based on an IoT (Internet Of Things) sensor network. This service will enable SMEs in the wine sector in the SUDOE area to monitor their vineyards in real time, remotely and at different precision scales (grape, plant, plot and vineyard). The aim is to accurately assess the state of the vine, from the maturity of the berries to the early detection of the appearance of diseases or water stress. The first year is dedicated to the study on the leaf scale with a precise monitoring of the potted vine. The other years are devoted to the application on the scale of the agricultural field.

The Research Team 'optical sensors for complex media' (COMIC) of the research unit UMR ITAP is in charge of proposing optical instrument solutions for vine monitoring in a water stress context. The objective of the COMIC team is to study the detection limits of optical instruments to monitor the state of the vine.

Experiments will be carried out during the three years of the project in partnership with other INRAE teams (UMR LEPSE, UE Pech-Rouge). The first step will consist of studying whether the detection of water stress in grapevines is possible with tools usually used in the laboratory, in particular hyperspectral imaging. The second step will then be to consider less expensive sensor solutions adapted to field constraints for the use of IoT objects. The COMIC team will also provide the necessary scientific support to the collaborators from a data analysis point of view and on the discussions of technological choices.

The post-doctoral student will coordinate the scientific aspects of the part of the project concerning the COMIC team.

The missions will be:

- To manage the experiments (organization, planning the needs of material and human resources).

- To conceive experimental designs and to establish protocols for hyperspectral image acquisition, NIR spectroscopy and other phenotyping tools

- To analyze data from different experiments.

- To valorize results through the writing of scientific articles.

- To participate in the meetings between the different collaborators of the project: AIMEN (Spain), Agacal (Spain), ADVID (Portugal), IFV (France), AGAMELARIOJA (Gobierno de la Rioja), FEUGA (Spain).

Research units: ITAP, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2020-2023

Combining T-LiDAR, deep-learning methods and functional-structural plant models for the quantification of architectural and functional traits in fruit trees.

Abstract: With the effects of climate change, a growing human population, and the need to ensure food security, understanding the development of plants is a crucial part of the possible solutions. To undertake such a study, it is necessary to explore how genetic variability gives rise to specific sets of architectural traits. Understanding these architectural variations facilitates the regulation, prediction and assurance of fruit production. It will also allow management strategies to be proposed to maintain the health of the tree and optimize its productivity.

Fruit trees typically consist of two components: the upper part, including the trunk, branches, and other organs above ground, and the underground part encompassing the entire root system. In both cases, studying the architecture raises various questions concerning tree geometry, the genes involved in tree development and variation, and the successive states of the tree. By addressing these questions, understanding the architecture of fruit trees can contribute to the improvement of varieties and their production.

Hence, several techniques have been developed to measure tree organs and model their architecture and shape. Initially, this task required a group of human operators to physically measure these objects directly in the field. However, this approach is time-consuming and demands extensive observation. Over the past few decades, the advent of new sensors such as cameras and LiDAR (Light Detection and Ranging) has facilitated the acquisition of digital representations of trees, opening up new possibilities for study.

The objective of this thesis is to obtain architectural metrics that provide an overall perspective of the tree's geometry, followed by a more precise approximation at the organ level. These metrics were based on the processing of point clouds obtained from terrestrial and aerial LiDAR in an apple orchard including a collection of genotypes. The point clouds were processed by developing two pipelines utilizing various filtering, machine learning, and deep learning algorithms.

The first chapter will present a comparison of architectural indices obtained from aerial LiDAR and terrestrial LiDAR. In the second chapter, the focus will be on the application of deep learning for organ segmentation (fruit, leaves, and branches). Lastly, the third chapter will introduce an approach to develop a GAN (Generative Adversarial Network) model with the aim of generating fully annotated synthetic apple trees. This will facilitate more efficient training of other deep learning models.

Research units: AGAP, LIRMM, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Semantic and modular representation of crop models using a declarative meta-language

Abstract: Over the past two decades, the emergence of modeling platforms in agriculture has greatly increased the use of crop models in research, as well as their applications for production system management or scenario analysis. Despite the advances they represent, these platforms have impacted the models by causing a loss of transparency for the modelers, which has hampered the development of new formalisms, in particular for new uses related to phenotyping. There is thus a growing discrepancy between the representation of biological processes in crop models and our knowledge in plant ecophysiology. Here, we propose to design and implement a high level language, allowing the expression of each model and its composition independently of the programming languages and the formalisms of each modeling platform. This metalanguage will be based on the declarative languages developed in the international initiative COMBINE ('COmputational Modeling in BIology' Network; http://co.mbine.org/), which wi be extended to consider the specificities of agricultural models. The operational objectives concern the interoperability of the modeling tools and the links with the information systems collecting the data. Modularity of the models at the process level is aimed at allowing a better integration of knowledge on biological processes and facilitating the link with the data.

Research units: LEPSE, MIAT, INRAE

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Main scientific field: Technology and Sciences

Co-Funded PhD – 2017-2020

Distributed Management of Scientific Workflows for High-Throughput Plant Phenotyping

Abstract: High-throughput plant phenotyping aims at capturing the genetic variability of plant responses to environmental factor for thousands of plants, in order to identify heritable traits for genomic selection and predict the genetic values of allelic combinations in different environments. This implies the automation of the measurement of a large number of traits (to characterize plant growth, plant development and plant functioning), which can now be performed using phenotyping platforms (such as the seven facilities of the French plant phenotyping network Phenome). These platforms produce massive data sets (plant imaging, climatic information, from 150 to 200 Terabytes of data per year in Phénome) that must be analyzed to understand interactions between genes and environment (GxE) and possibly predict crop performance.

Thus, it has become critical to couple the design of flexible, adaptable, and dynamic evolving plant response models with these massive data sets. The challenge lies in efficiently analyzing huge and complex datasets while keeping such in-silico experiments reproducible. To deal with massive data sets, we need to exploit powerful computing environments in a way that is easy for the users, without requiring them high-technical knowledge. The goal of this thesis is to address two critical issues in the management of plant phenotyping experiments: (i) schedule distributed computation while considering many constraints and (ii) allow reuse and reproducibility of experiments by biologists. These methodological developments will be applied to scientific workflows for 3D shoot architecture reconstruction, implemented in the OpenAlea platform, and used in the Phénome project.

Research units: ZENITH, LIRMM, INRIA

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Main scientific field: Life and environmental sciences

Labeled PhD – 2019-2022

Connecting the dots between high-throughput phenotyping platforms and crop models

Abstract: Global agriculture has two requirements: to be productive to meet demand and efficient in terms of land use. This dual requirement is formulated in a context of both climate change and moderation of the use of irrigation and chemical fertilizers. To arrive at these results, the architecture of the root system appears as a target to be favored. This has been rather neglected in the selection schemes while arguments accumulate to demonstrate its role in optimizing the harvesting of water resources and minerals especially in situations of low inputs. To enable the world of selection to direct its choices towards efficient root architectures, it is necessary to develop and then assemble at least two elements: crop models integrating a more or less explicit description of the root architecture and its response to soil heterogeneities and a high throughput pipeline to parameterize these models for a wide variety of genotypes. However, currently, the main models of culture embody a very frustrating representation of the root system and do not take into account its plasticity in the face of the underground environment. In addition, although high-throughput phenotyping platforms for root architecture have recently been developed, they are still too little connected to models. The thesis project aims to fill this double void (i) To improve the representation of root system architecture and functioning in crop models, to better understand their potential benefits in different environmental scenarios including drought and low-N; (ii) To connect data from high-throughput phenotyping platforms to the parameters of root architecture model (RAMs); (iii) To explore the value of root plasticity traits to improve plant responses to spatially and temporally variable water and nitrogen supply under defined environmental scenarios. Simulations of the impact of contrasting root architectures will be conducted at the end of the thesis in order to identify the ideotypes in targeted environmental conditions. This will take place in the framework of the H2020 SOLACE project, in which platform experiments have already been conducted using two panels of 200 genotypes of common wheat and durum wheat, including those with nitrogen and water deficiency.

Note that the thesis will be held in close collaboration with the teams of UMR Agroecology Dijon (C Salon) and the Catholic University of Louvain-la-Neuve. In addition, all developments in modeling will be based on existing standards consisting of the RSML language and the OpenAlea platform (http://openalea.gforge.inria.fr).

Research units: LEPSE, INRAE

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Main scientific field: Life and environmental sciences

Labeled PhD – 2018-2021

Continuous monitoring of crop development from IoT sensors fixed in the field

Abstract: The recent development of field sensors and high-throughput platforms offers new opportunities to acquire near-real time, and valuable information on plant dynamics. These new systems have an enormous potential as instruments for decision support systems in agriculture.

In this context, the objective of this thesis is to propose a methodological framework that permits to exploit a new prototype of a field system named IoTA –Internet of Things for Agriculture– developed by Bosch Inc. with the contribution of CAPTE in the domains of precision agriculture and high-throughput phenotyping.

To achieve that goal, the thesis will first investigate how the raw data provided by the IoTA devices –a RGB camera, two PAR sensors to measure transmitted light by the canopy, and a multi-spectral radiometer– can be exploited to provide reliable information of highly valuable physiological traits. These traits include the dynamics of vegetation structure (e.g. the green fraction or leaf area index), the detection of key phenological stages (e.g. heading date), the density and size of reproductive organs, and the presence of diseases. Several algorithms such as deterministic models and deep learning approaches will be validated against ground data to identify a set of algorithms that can be suitable for their use in an operational context.

Secondly, the sampling strategy that will permit network of IoTAs to acquire representative observations of crop canopies at different spatial scales will be also investigated. The footprint of the IoTA sensors is few square meters, and their operational use on phenotyping experiments (thousands of microplots of 20 m2), commercial fields (several hectares), or over a territory requires an optimal strategy to distribute the systems. That will permit to develop empirical transfer functions that could support observations with wide spatial coverage given by UAV or a high-resolution satellite (e.g. Sentinel 2).

Research units: EMMAH, INRA

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Main scientific field: Technology and Sciences

Labeled PhD – 2016-2019

Metamodelling and robust optimization - application to ideotype design under climatic uncertainty

Abstract: Using complex numerical models for prediction, risk assessment or design has become an essential tool in numerous fields, including engineering, economy or in natural sciences. Often, the modeled systems depend on uncertain environments that greatly influence the quantities of interest: typically in agronomy an annual yield or environmental impact depend on the climatic conditions. It is necessary to design methods that account for uncertain environments, in particular by integrating risk-aversion concepts.

Metamodel-based optimization under uncertainty has retained a growing attention over the past few years, following the emergence of complex simulators that depend on stochastic processes. However, if several solutions have been proposed when average performances are optimized, solutions are scarce as soon as risk-aversion strategies are sought.

The objective of this PhD is first to propose new metamodeling approaches allowing to consider either several risk levels at once, or the entire distribution of the quantity of interest. Among possible starting points, the student may focus on vectorial prediction for several risk indices (co-kriging), or functional predictors. Secondly, sampling strategies based on these metamodels may be developped to achieve optimization. Those approaches could either be heuristic or based on recent convergence results. The approaches developped may be validated on an agronomical problem: the ideotype design of sunflower crops, based on the SUNFLO model.

Research units: MIAT, INRA

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Main scientific field: Technology and Sciences

Labeled PhD – 2016-2019

Potential of Visible and Near infrared spectroscopy aerial acquisition with high spectral/low spatial resolution for plant phenotyping

Abstract: The operational objective of this thesis is to study the opportunities offered by the VIS/NIR spectrometry couple with an aerial acquisition system to address the needs of new tools for high-throughput phenotyping. The underlying application is to identify and describe new genotypes with better behavioural response under water-stress. From a technological point of view, it also represents a potential way to have access to the high spectral resolution of vegetal cover. However, the spectral information must be relevant and exploitable for phenotyping, and therefore, processing will be optimised by developing:

• Methods for extracting appropriate parameters for breeding genotype

• Methods that will improve in spectral/spatial resolution of signals

Maintaining a high degree of spectral resolution is the key factor to produce models.

In this context, it would provide answers to this following scientific question:

How can a low spatial/high spectral resolution sensor be coupled with a mobile vector in order to produce high spatial /high spectral resolution information allowing to describe vegetal response under stress?

Thus, the research objectives are:

• To test the hypothesis that with a total spectral signature of vegetation, the crop monitoring or the extraction of phenotyping traits are more robustness and more sensitive with a small variation of genotype response under stress.

• To define acquisition protocols and to develop processing methods of these spectral information to guarantee enough spectral and spatial resolution for phenotyping

• To approve methodology for identification and precise characterisation of different corn cultivars under water stress.

Research units: ITAP, IRSTEA

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 2: Digital solutions to optimize the genotype in changing production systems and markets

Main scientific field: Technology and Sciences

Internship - 2021

Phenotyping mixed crops by proxidetection sensors

Abstract: Mixed crops have many agronomic advantages: better use of resources, better tolerance to stress. However, to be beneficial, they require adequate cultivation, adapted to local pedo-climatic conditions.

In order to better help producers choose the species and manage their crops, measurements are taken during the season in order to monitor the development of the main crop and associated cover. These data are classically obtained from visual field observations and destructive measurements. However, these methods are complex, tedious and often not very repeatable because very heterogeneous spatially. Therefore, their automation by sensors is a major challenge for accelerating acquisitions and improving their repeatability.

In 2021, a field trial comparing different modalities of associated crops will be set up in Oraison (04). It will be monitored by classical methods (visual, destructive) and by a set of largely automated phenotyping techniques (drones, portable system). Support activity with the technical team will be necessary to ensure the smooth running of the season. Once acquired and structured, this dataset will be used for the development of methods for characterizing the mixed covers as well as for their validation, in connection with experts from UMT CAPTE. Several approaches will be implemented and evaluated: quantification of coverage fractions by deep learning (semantic segmentation), characterization of the crops' structure by depth image analysis (stereovision). Finally, a comparison of the performance of the different methods and tools will be established.

Integrated within the INRAE - ARVALIS team in Avignon, the intern oversees a complete data project: from data acquisition to analysis in the experiments set up. The main steps are as follows:

• Participate in the field acquisition of sensor measurements and reference data (March -> June) with sensors developed by CAPTE

• Develop and compare different algorithms, in conjunction with the CAPTE team. The robustness of the methods is an essential point.

• Evaluate the quality of the estimates by the system, according to the conditions of use and the methods

• Write the internship report and preparation for the defense.

ARVALIS – Institut du végétal is a leading applied research organization in the analysis of sensor data for agriculture. Within the UMT CAPTE, in cooperation with INRAE of Avignon and the company HIPHEN, we develop tools and methods using sensors (lidars, cameras, spectrometers, etc.) integrated on different systems (robots, drones, sensors wireless, …)

Research units: ACTA

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Main scientific field: Technology and Sciences

Internship - 2021

High-throughput phenotyping of developmental heterogeneity of berries in grape clusters

Abstract: In order to adapt Mediterranean viticulture to climate change, high expectations are weighing on the creation of varieties and the design of new viticultural practices. This questions the genetic and physiological bases of the vine's response to fluctuations in the environment. In particular, ongoing research within the UMR LEPSE in collaboration with UMR AGAP highlights the need to take into account the developmental heterogeneity of berries in the cluster both to improve the accuracy of phenotypic characterizations but also because this heterogeneity of development is often increased in response to abiotic stresses and strongly impacts the quality of the harvest. Unfortunately, the implementation of such characterizations faces the heaviness of phenotyping methodologies while genotyping today benefits from very high speed technologies. The UMR LEPSE is piloting large national projects to advance these methodologies by focusing more particularly on automated devices in a controlled environment.

The objective of the proposed internship is to evolve the automatisms dedicated to image acquisition and pretreatment in the PhénoArch phenotyping platform to analyze the developmental heterogeneity of berries in the cluster. The project will rely on the equipment and mechanisms in place in the platform that allow: positioning the plant in an imaging cabin with respect to the cameras shooting side and zenith; to position a side camera (as regards height and distance to the object) with respect to the plant; pretreat the image to retrocontrol if necessary the positioning of the plant and the lateral camera. The project will use robotics and machine learning methods. It will develop an automation algorithm for the placement of the camera and the plant that allows to optimize (quality and speed) image capture of the cluster and identification of a maximum number of berries in the cluster from the set of views taken by different cameras. The trainee will be able to rely on a similar project that has made it possible to automate the detection and measurement of early ear development on maize plants in the same platform (Brichet et al., 2017. Plant Methods 13: 96). He will benefit from the expertise of the head of the platform (access to code and knowledge of robotics), an engineer specialized in pattern recognition in plant images and possibly LIRMM colleagues who have contributed to the success from the previous project on the ear of maize. Potted vine plants of various genotypes will be prepared in the greenhouse in the winter of 2019-2020 to be available for the development of the method.

Research units: LEPSE, INRAE

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Main scientific field: Life and environmental sciences

Internship - 2021

Effect of housing parameters (enrichment and light) on the behaviour and nutritional requirements of gestating sows

Abstract: Precision feeding is developing in pig farms, with the aim of reducing environmental losses and feed cost without affecting the animal's production or reproduction performance. Housing parameters such as the level of enrichment or the continuous presence of light can influence the behaviour of gestating sows and consequently their nutritional requirements. These parameters must therefore be integrated into the nutritional models to better adjust rations to individual requirements. Thanks to the development of new technologies, it is now possible to continuously monitor the behaviour of each animal (i.e. activity sensor, video analysis, frequency of visits to the feeder). In the long term, these behavioural data coupled with production data (ingestion, weight and backfat thickness) should enable real-time assessment of each animal's nutritional requirements and anticipate well-being problems (i.e. health) in a non-invasive manner.

The objective of this internship is to quantify the effects of the level of enrichment of a gestating pen and the continuous presence of light on the behaviour of gestating sows and their nutritional requirements.

First, a database under construction will be completed through monitoring of experiments (February to March) and video analysis. In a second phase, a data search associated with statistical analyses will be carried out to determine the effect of enrichment and light on sow behaviour (social interactions, visits and time spent at automatons, activity) and production variables (weight, backfat thickness, feed and water ingestion). The results will be valued in a summary for a French conference (JRP or 3R) with a poster presentation.

This internship will be carried out at INRAE UMR PEGASE in Saint-Gilles. It is part of a 4-year project aimed at integrating real-time environmental and well-being indicators (behaviour and health) of pregnant sows into nutritional models used for precision feeding (SOWELL project). The experiments followed during the internship are part of a thesis in progress financed by #DIGITAG - INRAE and in collaboration with INRIA. The trainee will benefit from this collaboration with INRIA, in particular for the data search section and the development of analysis methods.

Research units: PEGASE, INRAE

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Main scientific field: Life and environmental sciences

Internship - 2021

Construction of an event detection tool (reproductive, sanitary, malfunction) using data from automatic water trough in a herd of dairy cows and several groups of sows

Abstract: Precision farming tools now allow individual and automated tracking of dairy cows and sows. This follow-up, combined with the breeder's observations, can lead to an earlier detection of a large number of events in which a breeder's response is required (calving, health problems, malfunction of equipment). The UMR PEGASE validated, both on dairy cows and on pregnant sows, an individualized monitoring device for drinking behavior, consisting of connected water troughs able to record individual water consumption and drinking behavior.

The main hypothesis of this project is that large variations in water consumption can indicate health, reproduction or equipment dysfunction events. Two databases collected at UMR PEGASE will allow this hypothesis to be tested. The database of dairy cows consists of 2 years of data collection (water consumption, milk production, breeding and sanitary events) on a herd of 162 cows. The database of gestating sows contains data about water consumption, ingestion, and health events collected on 60 sows during various induced technical malfunctions events (i.e. closure of one of the feeder on the two in a room, variation of the room temperature).

This internship will be carried out at UMR PEGASE of INRAE, with a double supervision by a researcher nutritionist (Anne Boudon) and a researcher modeler (Charlotte Gaillard). This internship will also be an opportunity of exchange with researchers from UMR MoSAR. Thus, the internship monitoring committee will bring together researchers who are competent on the physiological regulations of water consumption and on the processing of dynamic data in livestock for the detection of events.

At the start of the internship, the databases described above will be available as well as a first draft of the R event detection program. The first step of the internship will be to verify and structure the data, as well as to explore and describe the variability of the data. The second step will consist of building an event detection process. The planned approach is to use a differential smoothing method, already implemented by UMR MoSAR, to detect disturbances in the dynamics of watering signals. These disturbances will then be compared to the dynamics of events induced in sows and to recorded events in dairy cows. This disturbance detection method has the a priori advantage of its adaptability to the two very different contexts treated (lactating cows and pregnant sows). This internship should also be an opportunity to explorate other possible approaches, in particular through an exchange with the Locadam unit of IRISA.

Research units: PEGASE, INRAE

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Main scientific field: Technology and Sciences

Internship - 2020

Comparison of shallow and Deep Learning methods to estimate the vegetation green fraction from RGB imagery. Impact of the spatial resolution.

Abstract: High-throughput phenotyping is developing rapidly for plant breeding and smart farming applications. The green fraction, i.e. the fraction of green pixels in an image, is one of the most useful trait to monitor vegetation development that can be extracted from high resolution imagery taken from a range of systems including UAVs, ground robotic rovers and fixed cameras for continuous crop monitoring.

When the spatial resolution is fine enough to minimize the fraction of mixed pixels, segmentation techniques appear very efficient to estimate the green fraction. They include either pixel based methods such as random-forest classification, and deep-learning approaches such as the Unet model. However, when the spatial resolution degrades, mixed pixels represent a significant fraction of the image. In these conditions the segmentation techniques have difficulties to segment the mixed pixels. The application of super-resolution techniques based on generative adversarial networks (GAN) could recover the spatial resolution so that the previous segmentation techniques can be still performing. However, when the resolution is too degraded, segmentation and super-resolution techniques failed. In these cases, other approaches either based on vegetation indices or on deep-learning models could be developed to yield estimates of the green fraction.

The objectives of the proposed study are to evaluate the performances of the three types of approaches described above as a function of the image resolution relative to the size of the vegetation elements. For this purpose, a collection of annotated high resolution RGB imagery (resolution better than 0.5 mm) taken over wheat crops will be used as a reference. The spatial resolution of these images will be degraded by binning adjacent pixels up to the point where the image texture disappeared (resolution of few cm). The performances of the three approaches described above (1: segmentation, 2: super-resolution + segmentation, 3: vegetation index or deep-learning) will be evaluated over this range of spatial resolutions for the reference images. The techniques may be adapted to better suit the actual spatial resolution using independent datasets for the training.

The fellowship will be under the supervision of F. Baret, INRA, at UMT-CAPTE in Avignon. The student will work closely with S. Liu, E. David and K. Velumani who are experienced in image processing and deep-learning approaches. The work should result in an article that will be published in an international peer reviewed journal.

Research units: EMMAH, INRA

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Main scientific field: Technology and Sciences

Internship - 2018

Trajectory mining in phenotyping data

Abstract: In a context of water scarcity and global climate changes, the researches at the LEPSE aim at analyzing and modelling the responses of plants to drought and high temperatures as well as their genetic variability at the intra- and inter-specific levels. They analyse in models that embark genetic and environmental variability in order to predict the response of genotypes and species to current and future climate scenarios.

The objective of this Master's internship is to consider phenotyping data directly through data mining approaches. The main interest is that these approaches do not consider any a priori and allow to extract knowledge to make classification, prediction, etc. The models obtained can thus be compared with the models used by the LEPSE in order to compare them, improve them and make them evolve, but also help to propose new ones.

More specifically, during this internship, we will focus on data mining approaches based on trajectories. Initially, these approaches dedicated to spatio-temporal data, i.e. objects having a spatial component followed over time, aim at capturing the notion of common behavior, called trajectory, between moving objects. They identify groups of moving objects for which there is a strong relationship within a spatial region and over a given period of time. Many patterns with different properties can thus be extracted: flocks, moving clusters, convoys, swarm, group patterns, convergent and divergent patterns, and so on.

Consider, for example, the tracking of bird trajectories. The convoys will serve to highlight the fact that during a certain period of time the birds fly together, that they separate and then regroup in the same place. The moving clusters will focus on the proportion of birds that follow the same behavior. Finally, the convergent / divergent patterns will higlihth that the birds will all converge in time to the same area and then separate.

Recently the LIRMM team proposed an efficient and unified approach to extract all of these patterns. It also showed that the spatial constraint could be suppressed and that, in the end, the search for a trajectory consist in following the evolution of clusters (grouping of objects) over time. This principle has been applied in particular to data from DNA chips and has given rise to new knowledge. The aim of this internship is to adapt it to phenotyping data in order to propose new models and to compare them with existing models. In addition, a visualization component will be proposed in order to better understand the extracted patterns.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Engineering sciences

Internship - 2024

High-throughput spatiotemporal reconstruction of root system architecture from frugal images using topological tracking and deep learning.

Abstract: Plants expand their root system to meet their needs for water and nutrients, from germination to harvest. The architecture of the root system, its growth dynamics and its plasticity determine the plant's production and its ability to withstand adverse growing conditions (flooding, drought). Root traits are difficult to measure in the field. Destructive observation (shovelomics) does not allow to study large GxE panels or to observe root growth dynamics.

High-throughput phenotyping platforms have been developed with automated analysis pipelines based on convolutional neural networks [1][2]. These pipelines segment simple architectures. However, they are not reliable for more complex architectures. Until recently, these methods have never been evaluated for dynamic feature estimation. We studied this aspect in [3] with a spatiotemporal reconstruction algorithm. Its reliability for topology and dynamic feature estimation has been demonstrated.

These modern phenotyping techniques have been developed for laboratories (Petri dishes, blotters, model species, imaging robots). There is a need to extend their capabilities in order to apply them to agronomic crops grown under conditions close to the field (Rhizotron) and observed using frugal techniques (simple camera). During this internship, we will study the limitations of reconstruction algorithms [3] and deep learning techniques [1][2] on these data in order to combine these approaches and extend their scope. We will work on the formal constraints of the algorithms to integrate more variate topologies and on the conditions (topological cost function [4], network architecture) to be met for a neural network to contribute to the reconstruction of topologically valid spatiotemporal architectures.

Research units: AGAP, CIRAD

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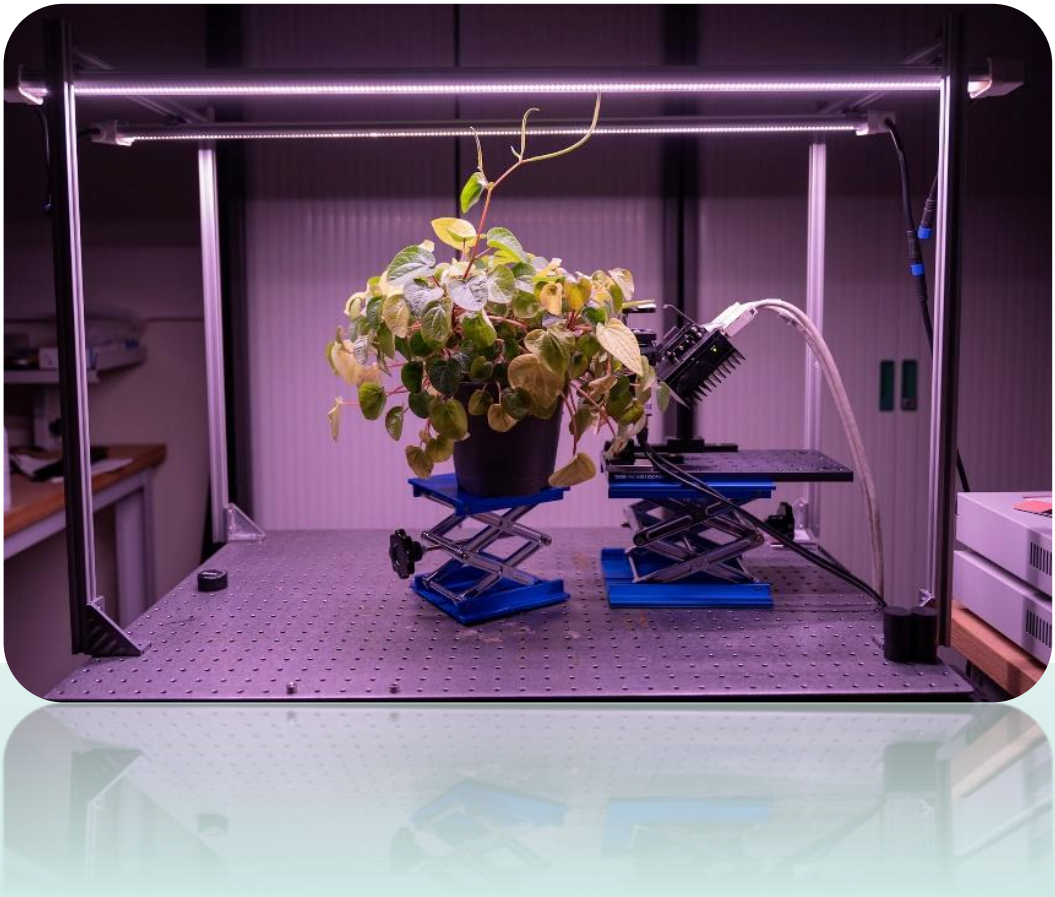
Stake 1 – Agricultural production improvement using ICT-enabled agriculture

Challenge 3: ICT and crop protection



Main scientific field: Human and social sciences

Labeled post-doc – 2023-2025

Communicating risk in digital decision tools for pest control in farming

Abstract: Nowadays there are many decision support tools (DST) based on solid scientific knowledge and made available to farmers in order to reduce significantly the use of pesticides. However, they are underutilized by farmers. Our hypothesis is that they do not respond sufficiently to farmers' perceptions and attitudes towards risk, particularly in the way in which recommendations and the margin of uncertainty associated to the information leading to these recommendations are communicated. Hence, our question is: how new information provided by digital technology can help farmers to commit to reducing the use of pesticides by responding to biases induced by the perceptions and attitudes of farmers towards risks?

Research units: CEE-M, INRAE

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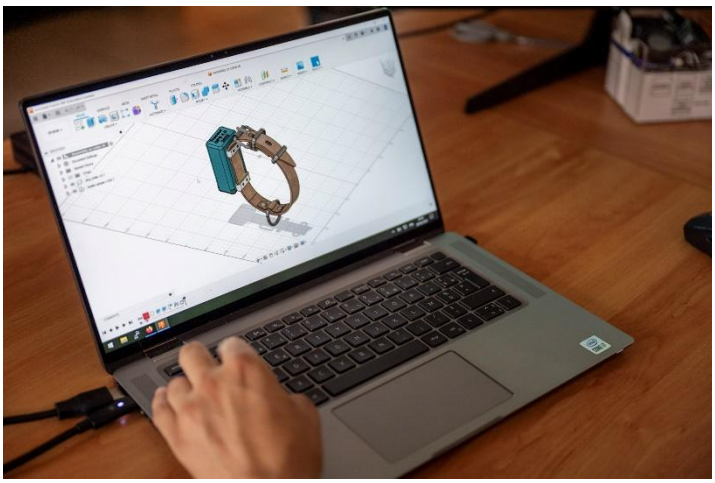

Main scientific field: Technology and Sciences

Co-funded PhD – 2023-2026

Integration and normalization of experimental databases in agroecology: text mining approaches guided by semantic information

Abstract: One of the challenges to improve modelling methods in agroecology and their reproducibility is to link and standardize expert variables and model variables by integrating the semantic information they carry. In this context, the textual data associated with the variables (scientific publications, technical reports, blogs, etc.) and semantic resources such as "ontologies" can provide crucial semantic information to contextualize the variables. The objective of this PhD is to propose a generic approach to automate the labeling of variables created by experts and their linkage with model variables, using text mining methods driven by semantic information.

Research units: Aïda, TETIS, CIRAD

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture
Challenge 3: ICT and crop protection

Main scientific field: Technology and Sciences

Co-funded PhD – 2021-2023

Learning of hybrid rules for the analysis of the dynamics of plant diseases and pests according to climatic conditions

Abstract: As the list of different phytosanitary problems on various crops is very long, agricultural Research & Development services cannot devote enough efforts to develop decision support tools (DST) for effective crop protection in all cases. One of the goals of such tools is to limit the use of phytosanitary products in crops. Given the plethora of existing data on the dynamics of diseases and the usage of phytosanitary products in crops, such a goal requires us to exploit data science techniques in order to accelerate our understanding on the dynamics of diseases as well as to automate the processes for decision support.

This thesis aims at assisting crop protection experts by automating the discovery of working hypotheses underlying future DST on plant disease behaviour, using learning techniques based on the mass of data collected in epidemiological surveillance networks. We will mobilize original machine learning methods. It will consist in finding "hybrid rules": they predict a numerical variable (e. g. the incidence of downy mildew disease) by taking into account the interactions between categorical variables (e. g. the phenological stage of the plant) and statistical models on numerical variables. This original approach seems to us to be a promising way of reconciling predictive modelling and "local" configuration in line with the great diversity of agronomic situations to be considered.

Exchanges with experts in diseases and pests on this work will make it possible to build new decision-making tools to better understand plant protection treatments. This work can also help to improve the effectiveness of plant health monitoring systems by making better use of the observed data collected in this context.

Research units: LACODAM, ACTA

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Main scientific field: Human and social sciences

Labeled PhD – 2023-2026

Role of behavioral factors in the adoption and diffusion of digital innovations among farmers

Abstract: The agro-ecological transition presents major challenges in how to incentivize farmers to adopt innovations. The literature reports a variety of factors explaining the adoption of innovations by farmers. Still, the gap between the availability of an innovation and its widespread diffusion among farmers has received less attention. This question is all the more complex as agroecology, relying on complex nature-based processes, involves a set of innovations which are context-dependent, linked to the specificities of the farmer, the farm and the local environment. We will focus on these specificities and particularly in the heterogeneity of behavioral factors such as the willingness to innovate, resistance to change, mimicry and risk attitudes and loss aversion. We will identify and model the mechanisms by which innovation diffuses in the population of farmers by borrowing from the literature in marketing (Rogers curve), in economics (learning models, network theory), and in psychology. The objective is to design public policies targeting the mechanisms for spreading innovation among farmers in order to accelerate the diffusion of innovation. To evaluate these policies, we will use laboratory experiments, large-scale surveys, and a randomized experiment with farmers.

Research units: CEE-M, INRAE

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Main scientific field: Technology and Sciences

Labeled PhD – 2022-2024

Interactions between pest attacks and plant growth using a model approach applied to robusta coffee in Uganda. Effects on production

Abstract: One of the difficulties facing coffee producers is the attack of pests. In Uganda, coffee production is heavily affected by fungi (rust, tracheomycosis) and pests (BTB, bark beetle). For example, the outbreak of tracheomycosis greatly reduced the production and number of coffee trees in Uganda in the 1990s and 2000s, resulting in heavy economic losses. About 20% of the population depends on coffee production for their livelihoods, and pest control is expensive.

In this context, it is important to know how to assess the yield losses that a pest will cause in order to decide whether or not to treat it. This thesis is a contribution to answer this question.

The objective of this thesis is to develop a method for coupling attack models of different pests with a plant growth model. The practical aim is to establish the basis of a tool for predicting the short- and long-term impacts of rust and BTB on coffee production.

The construction of this coupled model will make it possible to integrate the interactions between the pest and the plant. These are important to understand their respective evolutions. A pest has direct and indirect effects on organs (e.g. on fruit production) and also repercussions on the subsequent phenology and growth of the plant (feedback), which are spread out over time. Conversely, the dynamics of the pest over time may depend on the growth and phenology of the plant. The integration of these feedbacks, which are often neglected, into the models will make it possible to predict the long-term evolution of production in relation to the climate and the presence of the pest.

This approach will be applied to coffee in the framework of a European DeSIRA project in Uganda with local partners.

Research units: AMAP, PHIM, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2020-2023

Territorial approach to pest management to reduce the use of insecticides in cotton growing in Benin

Abstract: Benin, like many West African countries, has an economy mainly based on agriculture. In this sector represents the main export crop of the country. However, this culture encounters enormous difficulties which mean that cotton farmers are not remunerated for the efforts made. Among these difficulties is parasitism. To resolve this situation, a chemical control program has been developed and popularized. Thi was the source of various environmental (water pollution) and social (food poisoning) problems and the appearance of generations of resistant insects. This thesis aims to develop to develop, with the actors of the territories concerned, multi-scale strategies of agroecological management of cotton pests, by the development of space and agricultural practices. The approach of Bonni et al. (2018) and Sané et al. (2018) will be mobilized to follow pest populations and to assess their pressure on a terroir. Multi-agent modeling implemented with the NetLogo platform will be used to identify innovative agroecological options for pest control. Finally, a post-ante evaluation will be carried out on a regional scale of agroecological practices on the pressure and behavior of the main pests in order to identify the most effective in control. At the end of this thesis, i) the proposal of innovative agroecological practices for the control of cotton pests and soil recycling is expected ii) the profitability of agroecological practices in the fight against cotton pests.

Research units: Aïda, CIRAD

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Main scientific field: Life and environmental sciences

Cofinanced PhD – 2024 -

Towards a prototype for on-farm experimentation of biocontrol products on wheat, using a digital model approach

Abstract: Validating the effectiveness of biocontrol/biostimulation products is difficult in the field, which partly explains the lack of solutions or their low level of acceptance by the profession. As the factors influencing crop response and efficacity of biosolutions are numerous and interact with each other, it seems unrealistic to make a complete multifactorial experimentation even in the field. A digital model is a tool to manage creation and analysis of experimentation in an open system to evaluate the impact of biosolutions. The digital model will simulate reference or expected values and compare them with actual data. Several existing projects provide data that will be used to shape and test this numerical model.

The core of the thesis involves formulating an initial theoretical model and adapting it to a more open system (in the field). This will involve 1) Establishing an initial mathematical model based on laboratory data 2) Proposing a numerical model (Combining machine learning and mathematical model) 3) Prefiguring a protocol for validating the effects of bio-solutions in a multi-plot 'On Farm' system.

The thesis benefits from collaboration between the UMRs MISTEA and PHIM and a a partnership with the Avalis technical institute, the Vegenov technological resource centre (biosolutions experimenters), the Frayssinet company (biosolutions producer) and the BeStim network, to work towards rapid transfer of the numerical model to the profession and farmers.

Research units: Mistea, Institut Agro Montpellier

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Main scientific field: Technology and Sciences

Funded post-doc – 2018-2019

PLANT HEALTH (Plant disease monitoring in crowdsourced image streams)

Abstract: One of the major difficulty encountered in plant disease epidemiology is the lack of occurrence data. Large-scale and sustainable monitoring efforts are penalized by the lack of experts and the difficulty of diagnosing plant diseases for non-experts. In this context, crowdsourcing plant observation tools (such as Pl@ntNet) could serve as a brave new monitoring methodology. Even if non-healthy plants remain a relatively rare event in such high-throughput image data stream, the number of occurrences might be sufficiently high for several monitoring scenarios. Now, automatically recognizing plant diseases in such crowdsourced image streams is a challenging computer vision problem because of the scarcity of the training data, the low inter-class variability and the rarity of the events. The original approach that we propose to solve these issues is to rely on transfer learning and pro-active learning solutions as a way to set up an innovative and participatory citizen sciences program.

Research units: AMAP, INRA

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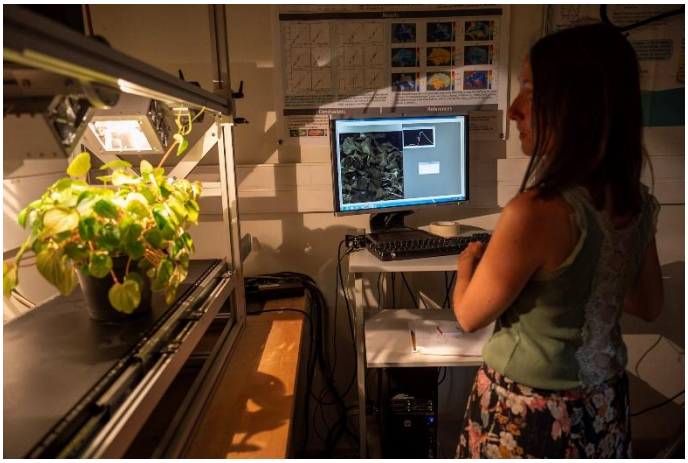

Main scientific field: Life and environmental sciences

Co-Funded PhD – 2020-2023

Reconstruction and interpretation of pseudo-hyperspectral images resulting from sensors pairing imagers and spectrometers: a method for the in-situ evaluation of orchards sanitary status

Abstract: Epidemiological surveillance is a crucial issue for food security, health safety and environmental protection. Perennial arboreal crops, such as apple and pear, are notably sensitive to phytopathologies, in particular “apple scab” and “fire blight”. Therefore, these issues are heightened in orchards where the substantial use of phytopharmaceutical inputs, the frequent exposure of operators and the vicinity with residents are sources of raising concerns or even conflicts.

In this context, Hyperspectral imaging (HIS), especially in proximal sensing, proves to be a relevant solution to describe and discriminate complex physiological phenomena involved in the diagnosis of phytopathologies. However, HIS is in practice difficult to implement for large-scale surveillance purposes. Indeed, numerous operating limits regarding instrumentation costs and more importantly regarding the measurements kinetic make HIS unpractical for industrial use. In order to sort these constraints, most of farm applications proceed by degrading the spectral resolution and then process simpler multi-spectral images (MSI). This strategy, although very functional in field, lacks of the spectral richness necessary to characterise phytopathologies (Nouri, 2018; Al Saddik, 2019; Albetis, 2019, Mahlein et al. 2018).

The purpose of this thesis is to propose a strategy aiming at characterising in-situ the sanitary status of orchards at a local scale. This strategy is an alternative to MSI approaches consisting in estimating HIS from data acquired with more frugal sensors. A new solution, consisting in paring imagers and spectrometers proved to be an efficient solution for issues such as high-throughput in-field phenotyping ("AirStrip" project; Ryckewaert, 2019 [http://www.theses.fr/s191946]). Driven from the conclusion of this work, it is proposed to determine a robust method to reconstruct and analyse pseudo-HSI from AirStrip-type instrumentations. It is inteded to exploit the whole richness of spectral data jointly with structural information contained in images. This work is also the occasion to determine the essential properties of reconstructed images for the problem of pathology detection.

Research units: ITAP, ACTA

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Main scientific field: Technology and Sciences

Co-funded PhD – 2019-2022

Hyperspectral imaging and omic methods to characterize variability of plant responses to combined stresses. Application to wheat crop

Abstract: The development of new agricultural practices based on principles of agroecology needs to analyze complex interactions between plants and their biotic and abiotic environments. Our ability to analyze and to decipher these multiple stresses requires, on the one hand, adopting a new conceptual framework such as phytobiome or extended phenotype, and on the other hand, coupling methodologies that make it possible to analyze the whole plant phenotype - or targeted organs - at different scales (metabolome, cell, composition and tissue structure). In this work, we propose to combine innovative approaches based on light-matter interactions with more classical 'omics' approaches to assess the variability of durum wheat response to multiple stresses: biotic (Septoria, Brown rust) and abiotic (water stress).

Research units: ITAP, AGAP, INRAE

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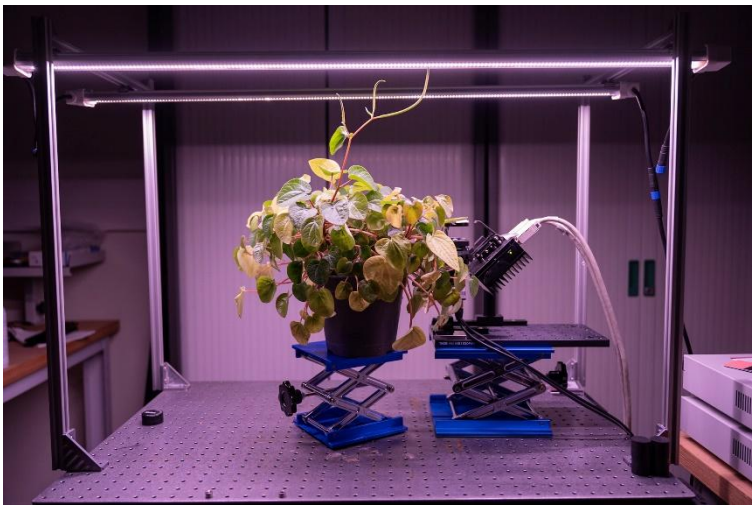

https://theses.hal.science/tel-04449399v1

Main scientific field: Life and environmental sciences

Co-funded PhD – 2018-2021

Quantification of pest regulation by generalist predators by analysis of image sequence to determine and quantify network of interactions, case of the banana weevil

Abstract: In the context of sustainable development in agriculture, it is crucial to define integrated pest management methods. Among these, pest regulation by natural enemies represents a promising way. However, to date, there is no method (i) to identify with certitude the generalist predators that are involved in the biocontrol of pests and (ii) to quantify the effect of this biocontrol on the population dynamics of the pests (i.e. the effectiveness of biocontrol in the field). These knowledges are crucial for the development and the transfer of effective agroecological management practices.

We propose the use of in natura mesocosms coupled with a non-perturbing video measurement method of interaction networks to quantify regulation and predation. These mesocosms will correspond to existing banana production situations in Martinique, the study area of the GECO unit, and will cover a large range of plant biodiversity (planned or not). In each of these mesocosms, the population dynamics of the banana weevil Cosmopolites sordidus will be followed by capture-mark-recapture method in order to determine the magnitude of the regulation by the natural enemies that occurs. In each selected situation, we will establish a control corresponding to a plot where natural enemies are excluded. The video method will allow to know the identity of the predators involved in the regulations and to quantify the links of trophic and non-trophic interactions existing in the animal community (frequency, duration and type of interactions). To this end, methods of automated digital image analysis will be developed (e.g. automatic recognition of a pest, count of individuals), including machine learning and in particular convolutional neural network methods that are developed by the ICAR team (LIRMM unit). These methods should revolutionize our understanding of the functioning of agrosystems and, because of their genericity, can be applied to the study of most cultivated systems.

Research units: GECO, LIRMM, CIRAD

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https://theses.hal.science/tel-04068854v1

Main scientific field: Technology and Sciences

Co-funded PhD – 2017-2020

Optical sensors for the characterization of a spray deposition

Abstract: The spray quality is a crucial issue for our society. A major concern with pesticide application today is related to off-target movement of spray particles (i.e., spray drift). To date, there have been many in field test procedures performed to measure the spray deposition. One of the most common methods includes using water sensitive paper (WSP) and traditional optical techniques that involve analyzing images. However these systems can be time consuming, expensive, and lack sufficient accuracy. Manufacturers and researchers desire a fast and accurate measurement for characterizing spray deposition. The goal objective of this thesis is to develop new optical tools for the characterization of the deposit. This thesis will focus on the potential of the optical sensor to replace the traditional methods based WSP and thus provide an operational solution.

Research units: ITAP, IES, IRSTEA

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Main scientific field: Maths and its applications

Internship - 2022

Development of a rape winter stem weevil flights predictive tool, based on the « Vigiculture » database

Abstract: Ceuthorynchus picitarsis larvae can destroy the terminal bud of rapeseed. The management relies on the use of insecticides which target the adults before the beginning of egg laying. This insect can only be observed in the field thanks to the use of yellow traps which attract them to a certain extent. The optimal date of treatments is based on the precise detection of the arrival of the insects in the fields. The ability to predict flights is therefore essential to optimise the use of insecticides in terms of positioning and avoidance of useless treatments. The « Vigiculture » database agregate field observations since 2008. It is used to edit the « Bulletin de Santé du Végétal » (a weekly report about crop sanitary state) that helps farmers in their decisions. Nonetheless, those data are scarcely used to build predictive tools. The database contains more than 52000 observations over 10000 fields between 2008 and 2020 regarding C. picitarsis.

The goal of this project is to build a predictive model based on those data. Several metrics will be considered (date of first flight, daily flight probability, cumulative sum of trapped insects). Observations in the database are geolocalized. It it thus possible to cross the dataset with external sources of information (particularly meteorological ones) that could explains part of the observed variation. The performances of several machine learning algorithms will be compared. The analysis of the best models will provide informations about interpretability that can be compared to field expert observations. New methods currently developed by Olivier GAURIAU for his DigitAg funded PhD thesis will be tested. Their aim is to find the best compromise between prediction performances and interpretability.

As a perspective of this internship, the best model, if it is precise enough will be freely available to users on the Terres Inovia website and could be integrated in future decision support tool

Research units: ACTA / Terres Inovia, ACTA

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Main scientific field: Technology and Sciences

Internship - 2022

Development of an optical sensor for the monitoring of leaf biochemical content: contribution to decision making for the monitoring of the physiological state & early detection of plant pathologies.

Abstract: Climate change has a direct influence on crops, due to its impact on temperatures and water cycle. Monitoring of foliar chemical composition is relevant to study plant physiology, phenology and to identify pathogens in the context of climate change.

Recent advances in both fields of physical modeling of vegetation at the leaf scale, and in optical instrumentation, now make it possible to accurately measure leaf chemical content using portable and low cost sensors. The PROSPECT model allows precisely estimating the main leaf chemical constituents including chlorophyll, carotenoids, anthocyanins, water and dry matter content. The monitoring of this biochemical signature then makes it possible to diagnose the state of the cultures, to detect the stress and the possible presence of certain pathogens at an early stage. Mapping leaf chlorophyll content in the field using image analysis from remote sensing data (drone, airplane, satellites) is used operationally for several years in order to support decision-making tools dedicated to help farmer's technical itinerary and in and to forecast crop production.

Recent research results show that it is possible to achieve a fine quantification of foliar chemistry using modeling tools and by acquiring parsimonious foliar optical properties in the optical domain. This opens perspectives for the development of a portable leaf-clip sensor using multispectral light emission based on laser diodes and a synchronous detection multi-carrier (patented technology by INRAE).

The objective of this internship is to participate in the development of a prototype to quantify the foliar chemistry. During the first stage of the internship, the student will have to understand the different optical phenomena involved in the interactions between light and leaf material; he/she will also learn to use the modeling tools. He/she will then determine the combination of wavelengths allowing to optimally estimating foliar chemistry, combining simulated and already available experimental databases. Finally, based on these results, he/she will work on the development of a laboratory prototype. This system will be characterized and validated with experimental data from different crop types. This work will allow enhancing the research results of the TETIS and ITAP joint research units, and may lead to a patent application.

Research units: TETIS, INRAE

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Main scientific field: Technology and Sciences

Internship - 2018

Building predictive tools for wheat and vine diseases using data mining techniques, based on national disease monitoring databases

Abstract: It is a national priority to significantly reduce the use of phytosanitary products (ECOPHYTO V2 plan). A better handling of phytosanitary treatment contributes to this reduction by exploiting tools for monitory plant health. Since 2009, the Plant Health Bulletin (BSV) contributes to deliver information at the regional scale to help farmers take decisions, using a network of disease monitoring. Large volumes of data have been collected and exploited in near real time to make these bulletins. However, with for example more than a million data points for the wheat, this data is still under-exploited, especially for building predictive tools.

Up to now, some statistical studies on specific questions have been undertaken (specific diseases of wheat and vine). However data mining techniques have never been used in a more global approach to exploit this data and discover new practical knowledge.

This internship aims at initiating work on data mining on disease monitoring data, especially by analyzing the complete set of diseases and pests. Joining with other data sources could explaining partially disease dynamics, for example using weather data.

Data mining techniques envisioned are: pattern mining (detecting regularities in categorical/discretized data), subgroup discovery/exceptional model mining (discovering sub-groups in numerical data), clustering (partitioning data in homogenous subgroups).

The proposition is to work on wheat culture at the national scale (data from vigicultures – Arvalis) and vineyards from the Ouest of France (data from Epicure - IFV).

Research units: LACODAM, INRIA

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Main scientific field: Maths and its applications

Co-funded PhD – 2024-2027

Towards a prototype for on-farm experimentation of biocontrol products on wheat, using a digital model approach

Abstract: Validating the effectiveness of biocontrol/biostimulation products is difficult in the field, which partly explains the lack of solutions or their low level of acceptance by the profession. As the factors influencing crop response and efficacity of biosolutions are numerous and interact with each other, it seems unrealistic to make a complete multifactorial experimentation even in the field. A digital model is a tool to manage creation and analysis of experimentation in an open system to evaluate the impact of biosolutions. The digital model will simulate reference or expected values and compare them with actual data. Several existing projects provide data that will be used to shape and test this numerical model.

The core of the thesis involves formulating an initial theoretical model and adapting it to a more open system (in the field). This will involve 1) Establishing an initial mathematical model based on laboratory data 2) Proposing a numerical model (Combining machine learning and mathematical model) 3) Prefiguring a protocol for validating the effects of bio-solutions in a multi-plot 'On Farm' system.

The thesis benefits from collaboration between the UMRs MISTEA and PHIM and a a partnership with the Avalis technical institute, the Vegenov technological resource centre (biosolutions experimenters), the Frayssinet company (biosolutions producer) and the BeStim network, to work towards rapid transfer of the numerical model to the profession and farmers.

Research units: MISTEA, PHIM, Institut Agro

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Stake 1 – Agricultural production improvement using ICT-enabled agriculture

Challenge 4: ICT and sustainable animal production

Main scientific field: Technology and Sciences

Co-funded post-doc – 2022-2024

Co-design of participatory simulations of MAS models for multi-actor decision support

Abstract: Simulation models are increasingly used to help better understand the functioning of territories, to project their probable futures, to explore multiple sustainable management options and their possible impacts, and this according to a variety of perspectives carried by a variety of actors. Currently, most models are black boxes with parameters as inputs that describe both the functioning of the territory and the possible options, and time series of indicators as outputs, possibly spatialized, that allow visualizing the impact over time of the options taken. Moreover, the models are often limited to a small part of the functioning of the territory (plot, farm management, supply chain/sector) because integration at the scale of the territory implies hundreds of parameters and indicators, which brings a complexity that is difficult to manage. The use of simulation models is therefore confronted with the requirement of transparency so that the non-scientific actors understand the hypotheses made in the models, their functioning and the interactions between the different processes that take place in them, and with the requirement of usability in a multi-actor context, i.e. that each actor is provided with a view adapted to his objectives in terms of the options and indicators at his disposal. The objective of this project is therefore to design the methods and the technical means to surround existing models at the scale of the territory with computer tools and graphical interfaces allowing a variety of actors to understand their functioning and to have the means to explore a variety of scenarios (possible futures) and options (possible decisions) and to evaluate their impacts. This implies upstream the identification of the different actors concerned, their stakes and objectives and the knowledge they need, and downstream the implementation of tools for the manipulation and visualization of models adapted to their needs. The methods and tools developed will be involved in the governance platforms of territories in the North as well as in the South and will serve as a support for discussions between stakeholders on the future of their territories.

Research units: SELMET, SENS, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2021-2024

Development of a mathematical method based on proximity data sensors for the early detection of pathologies in farm animals

Abstract: Animal production is one of the agricultural sectors with a heterogeneous operational deployment of ICTs. Ruminant breeding is a good example of this contrast with sectors such as dairy cattle, which are well supplied, and sectors with a more modest level of commercial digital equipment, such as suckling sheep. While there is no lack of sensors and associated tools, it is more a question of the relevance and reliability of the information that is derived from them, thanks to sufficiently precise and predictive algorithms that still need to be developed. The use of these new sensors creates the need for new methodologies, such as the modeling of social interactions from spatio-temporal data including advanced statistical inferences, to produce more accurate predictive information in real time. We propose to work on an interdisciplinary approach, using mathematical modeling, inferential statistics and the study of social behaviors.

The aim of the thesis is to adapt these approaches to ruminant (cattle and sheep) movement data, in order to identify breaks in the social structure of a group of farm animals that could be early indicators of individual pathologies. For this purpose, the PhD student will set up new non-parametric statistical estimators for a new model of diffusion process interactions (based on existing models) that will allow the production of specific algorithms for clustering and/or detection of disruptions.

Research units: MISTEA, SELMET, INRAE

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Main scientific field: Life and environmental sciences

Labeled PhD – 2023-2026

What adaptation strategies can agro-ecological Mediterranean agropastoral farming systems use to cope with climate change?

Abstract: In view of the challenges facing livestock farming today, Mediterranean agropastoral systems based on available pastoral resources appear to be interesting agroecological models, but are particularly affected by climate change (CC). With the dual aim of adapting to CC and making the agro-ecological transition, we need to examine the consequences of adaptation strategies on the performance of these farms. The aim of the thesis is to understand the antagonisms and synergies between the agroecological properties of pastoral sheep systems and their ability to adapt to climate change while mitigating its impact, in order to design resilient and efficient agropastoral sheep systems. The proposed research system is based on a co-design mechanism combining workshops involving experts in the farming systems under study and the use of a simulator as a modelling tool to support co-design and evaluation. This system will be applied to two case studies (suckler sheep and dairy), and adaptation strategies will be designed and calibrated for simulation and evaluation in order to identify the compromises inherent in the proposed strategies.

Research units: SELMET, INRAE

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Main scientific field: Life and environmental sciences

Labeled PhD – 2023-2026

Development of a decision-making tool to optimize grazing of spontaneous vegetation based on a functional classification of pastoral resources

Abstract: The grazing of spontaneous vegetation is at the crossroads of many issues (agroecology, climate change, biodiversity, etc.) and mobilizes a diversity of stakeholders. The aim of this thesis is to lay the foundations for a decision-support tool to characterize the pastoral resource available in a given context, in order to optimize grazing management and reconcile several ecosystem services. To achieve this, a number of technologies will be combined: (1) initially, SPIR on fresh samples coupled with observations of feeding behavior will enable us to build up a database of grazed feedstuffs and classify them according to their function in the diet; (2) this classification will be compared with the representations of breeders and shepherds, to harmonize scientific and local knowledge as far as possible; (3) these two types of knowledge will be used to develop a decision-making tool offering a simple, shared representation of the pastoral resource, which can be used as a basis for discussion and decision-making by the diversity of stakeholders involved in pastoralism.

Research units: SELMET, AgroParisTech

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Main scientific field: Technology and Sciences

Co-funded PhD – 2019-2022

Definition, Design and Evaluation of a decision support system for pastoralism

Abstract: Pastoral systems are widely recognized for their social, environmental and cultural value. They also represent a type of livestock farming system consistent with agroecology. Their sustainability depends on their ability to cope with wide spatio-temporal variations in the availability of pastoral resources. Thus, both animals and farmers need to constantly adapt their strategies to the changing context.

Decision making and diagnosis in pastoral systems rely on the analysis of heterogeneous data from various sources (local and scientific knowledge, direct observations and technical references, embarked sensors such as GPS). Such heterogeneous data is more or less available to the farmer or technical advisor, and its comprehensive analysis is carried out on an informal basis and with varying success.

The digital age offers the opportunity to link data that could not be previously correlated. What are the methodological solutions in Computer Science to manipulate and link such data? How to evaluate and measure the interest and the impact of this information for farmers and technical advisors?

The proposed work aims at addressing these issues by (1) defining a data warehouse model allowing the analysis and cross-referencing of heterogeneous data (digital platform offering new services to farmers according to spatial dimensions, temporal and thematic); and (2) carrying out an analysis of the contribution of these new types of information in terms of lever for innovation for pastoral livestock farming systems, at several levels and with a suitable multicriteria analysis.

Research units: TETIS, SELMET, AgroParisTech

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2019-2022

Co-design and sustainability of innovative breeding systems using alternative methods to hormonal treatments in the management of the reproduction of small dairy ruminants

Abstract: The management of hormone-free reproduction in small dairy ruminant farming is a lever to be mobilized to respond to the challenges of agro-ecology and the evolution of societal demands. The Alpha-D® automated heat detector system remains to this day the only operational tool in sheep farms that allows artificial insemination without the use of hormonal synchronization. The introduction of such new tools implies change processes for the farms concerned. These changes may include biotechnical processes, at the herd level and/or surface management level. The objective of this thesis is double. On the one hand, it is a question of characterizing the processes by which conventional and organic farmers integrate the Alpha-D® device into their system and the implementation methods, taking into account changes in associated practices. On the other hand, the work aims to assess the sustainability of a diversity of systems (conventional and organic) that no longer use hormone treatments in their reproductive management. The comparison the simulation results with the actors will make it possible to validate the most appropriate scenarios for implementing hormone-free reproduction according to the sectors and breeding systems tested within the Rayon of Roquefort area.

Research units: SELMET, MIAT, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Selecting pesticidal plants for animal and plant health in Africa using exploratory conceptual navigation

Abstract: Cirad develops several knowledge bases, including PPAf (project Knomana 2017-2018, métaprogramme Glofoods) which gathers usages of plants for animal and vegetal health. The gathered knowledge is useful for identifying alternatives to chemical pesticides and to chemical antibiotics for culture and breeding. As many different knowledge kinds are involved (taxonomy, geography, reliability of information sources, etc.), the knowledge visualization and exploration by end users (farmers, scientists, decision-makers, etc.) is complex. The thesis aims to elaborate a general methodology, theoretical tools and a prototype tool to answer the following questions: – Which is the best support for integrating and representing PPAf knowledge? – Which data mining techniques will be adapted to analyze the existing knowledge (decision trees, association rules, formal concept analysis)? – Which human-machine interaction method would allow different users with different profiles to express queries and analyze knowledge on-the-fly according the navigation context?

Research units: LIRMM, AIDA, CIRAD

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Integrating metabolomic data by quantification of high throughput data. Application to perinatal mortality in pigs

Abstract: Metabolomics data are an affordable way to access fine phenotyping information. They can be acquired from simple blood (plasma), amniotic fluid or urine samples using NMR (Nuclear Magnetic Resonance) high throughput technic. However, due to a lack of method to properly link acquired spectra to metabolite quantification, they are largely underexploited. This PhD proposes to develop a new fast and efficient approach to use metabolomics NMR spectra for metabolite quantification. The results will be validated with direct quantification of metabolites from the ANR project PORCINET ANR-09-GENM-005. This project addresses the issue of perinatal mortality in pigs and the numerous datasets acquired during the project provide a rich framework to prove the efficiency of our approach for precision farming. In particular, metabolite quantification will be integrated with various phenotypes (morphology, allometry, and physiology), proteomic and transcriptomic data obtained in a complex experimental design (4 genotypes x 2 late gestational stages) in order to better understand the biological processes involved in perinatal survival of pigs.

The output of this PhD will be twofold: first, we intent to develop state-of-the-art method for metabolite quantification from NMR spectra. The method will be released for public use in the form of an R package and a Galaxy module. Second, on a biological point of view, we will provide biomarkers explaining biological processes involved in piglet survival. These biomarkers will permit the selection of pig phenotypes to decrease the early death of piglets that will improve pig production competitiveness and sustainability. Because of the easy and cheap acquisition of metabolic data, our approach has great potentials for selection and will be generic enough to adapt to other types of problems.

Research units: MIAT, PEGASE, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2017-2020

Using data mining techniques for improving dairy management

Abstract: The use and analysis of data acquired in dairy farming is a challenge both for data science and for animal science. Its goal is to improve farming conditions (health, welfare and environment) as well as farmers' income. Nowadays, animals are monitored by multiple sensors giving a wealth of heterogeneous data (ex. temperature, weight, milk composition). Current techniques used by animal scientists focus mostly on mono-sensor approaches. The dynamic combination of several sensors could provide new services and information useful for dairy farming. In order to study such combination of several sensors, this PhD will be based on machine learning and pattern mining algorithms. The challenge is to design new algorithms taking into account such data heterogeneity, both from their nature and time scales, and to produce patterns that are actually useful for dairy management. This thesis will be an original and important contribution to the new challenge of the IoT and will interest domain actors to find new added value to a global data analysis. The PhD will take place in an interdisciplinary setting between computer scientists of INRIA and animal scientists of INRA, both located in Rennes.

Research units: LACODAM, PEGASE, INRIA

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2017-2020

Modeling of nutrient utilization and precision feeding of lactating sows

Abstract: Because of the variability in sows milk production and appetite, the nutritional requirements differ largely between farms, between animals from the same farrowing batch, between successive batches due to seasonal variations, and between successive days during lactation, whereas in practice the same diet is generally fed to all sows in a herd. The availability of new technologies for high throughput phenotyping of individual sows and of their environment offers new opportunities for a renewed practical implementation of prediction models of nutritional requirements and performance. The integration of these prediction models in decision support tools incorporated in feeding equipment is thus an important issue for pig farmers and for the companies that develop this equipment. The objective of this thesis is to produce the knowledge required for a more integrated and dynamic approach of feeding lactating sows, by considering all the information available when deciding the optimal composition and amount of feed to be fed to each sow, each day, the ration being prepared by an automatic feeder. The scientific issues consist in a change of paradigm resulting from the possible access to real-time data specific to each animal and their environment as well as to historic data relative to the animal itself (e.g., previous lactation) to similar animals from the same farm or from similar farms. The research question deals with the real-time determination of nutritional requirements of lactating sows and its implementation in practice: "How can we decide in real-time the optimal composition and amount of feed to be fed to a lactating sow using in all the available information at this time?"

Research units: PEGASE, LACODAM, INRA

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Main scientific field: Life and environmental sciences

Labeled PhD – 2019-2022

High-speed phenotyping of body and carcass composition of the growing cattle by 3D imaging and dual energy X-ray absorptiometry (DXA) coupled with machine learning.

Abstract: This French-Swiss thesis project aims to develop innovative methods for estimating the body and carcass compositions of growing cattle. These methods are based on high-speed acquisition and processing i) 3-dimensional images of the external conformation of the vigilant animal and ii) dual energy X-ray absorptiometry data (DXA) of the tissue composition on carcass. Information from these images and from post mortem chemical analyzes will be used to develop predictive models of composition of living animals. This project is based on the mobilization of modern imaging technologies that allow the acquisition of large data sets of morphological traits and chemical composition. Machine learning methods will be used to analyze efficiently these data sets, and continuously improve models. In comparison with existing in vivo approaches, the 3D imaging methods are unequaled in terms of precision / cost / acquisition time / non-invasiveness ratio. This technological breakthrough will improve the fine phenotyping of the body composition of growing animals, for application both in research and in breeding to i) adapt their diet to their individual needs, while reducing their emissions releases, and ii) determine the completion of the fattening phase.

Research units: PEGASE, Agrocampus Rennes Angers

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Main scientific field: Life and environmental sciences

Labeled PhD – 2019-2022

Genetic modeling of animal's robustness using high-throughput numerical data

Abstract: Robustness of an animal corresponds to its ability to maintain performances in different environments. A robust animal is thus less sensitive to environmental variations which is important in the context of climate change and for animal welfare. Thanks to the development of electronic identification and electronic devices in farm, it becomes possible to record individually and repeatedly over time numerous phenotypes. The analysis of such longitudinal data offers the possibility to measure robustness of animals and its 2 components: resistance and resilience. Different methods have been proposed in the literature to extract robustness criteria from such analysis but have never been used in the context and under the constraints of genetic studies.

Our aim is to test such approaches in the context of genetic selection: 1/ apply the different modeling on a large dataset in order to estimate heritability of the different criteria extracted from the different types of analysis 2/ estimate the genetic correlation with traits under selection in order to propose new criteria for genetic selection of robustness. Daily feed intake records from 7500 large white pigs will be used to test the different methods. This dataset, provided by the French pig industry, meets the constraints that the modeling will have to face with to be useful for genetic selection: large dataset, field data, heterogeneous, numerous and unknown environmental challenges.

Research units: GENPHYSE, INRA

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Main scientific field: Technology and Sciences

Labeled PhD – 2017-2020

Extraction and aggregation of information from multi-source data for international monitoring of infectious animal diseases

Abstract: Monitoring animal health worldwide, especially the early detection of outbreaks of emerging and exotic pathogens, is one of the means of preventing the introduction of infectious diseases in France. In that context, the French epidemic intelligence team for international monitoring of animal health has created a tool dedicated to automatic surveillance of electronic media. This tool is based on a text mining approach, which detects, collects, classifies and extracts information from non-structured textual data available in the media reports on the Web. In addition to methodological improvements (spatial uncertainty, automatic classification), the thesis will focus on identification, combination and qualification of information and indicators from multi-sources data to detect the emergence of animal diseases.

Research units: TETIS, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2016-2019

Mathematical modeling of pig growth in perturbed environmental situations

Abstract: To ensure a sustainable production, it is essential to better understand the adaptation potential of the animal when facing to environmental challenges, which changes the physiology and performance of the animal. Several experimental studies have been conducted to investigate the influence of environment on the performance of farm animals (Campos et al, 2014;. Renaudeau et al 2013; Labussière et al. 2015).

The progress of technology and the current context of precision farming, make it possible to obtain measurements of the animal, such as feed intake and body weight, with a very high frequency. We assume that the animal in a stable environment follows a certain phenotypic trajectory. In reality, this environment is not stable and the animal can be affected by variation in ambient temperature, health stressors, etc. These perturbations, for which the origin cannot always be identified, result in deviations from the ideal phenotypic trajectory of animal.

The core of this PhD project is to analyze deviations from the ideal phenotypic trajectory, and characterize these in terms of intensity and duration and, when possible, identify the origin, and put these in relation with the capacity of the animal to return to its ideal trajectory by mechanisms of resistance, resilience and adaptation potential. Given the complexity of the response of the animal, a multidisciplinary approach based on systemic modeling will be used to investigate the adaptive response of the animal. The main objective of this work is therefore to analyze different accessible traits measured as affected by environmental challenges and develop a model of adaptive responses using systemic approach with particular attention to the resistance then resilience periods.

This model applied to the data from precision farming will allow an early detection of deviations from the ideal trajectory of animal's performance (related to the identified or non-identified perturbation of the environment), and propose management strategies to regain it.

Research units: PEGASE, INRA

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Main scientific field: Life and environmental sciences

Internship - 2022

UAV as an intermediate step for the mapping of vegetation at National level.

Abstract: Savannas are ecosystems with a strong spatial heterogeneity for both herbaceous and woody vegetation. The quantification of this vegetation (biomass) is a key point in these arid zones for pastoral livestock for example. Field measurements allow to measure biomass over small areas. But how do you get this information over a larger area? Indeed, the pastoral with the high mobility of the animal used the vegetation on large area. Studies show the possibility to establish relationships between field data and open access of medium-resolution satellite images covering the whole country.

In order to perform calibrations between field data and these open access medium-resolution satellite images, it is necessary to perform intense measurements in the field to take this heterogeneity into account.

One possibility is to use very high spatial resolution (VHRS) images as an intermediate step. The calibration of the field data with these VHRS images would allow to:

- produce vegetation maps considering the heterogeneity of the vegetation

- then make a link between these maps and images with lower spatial resolutions.

The UAV is a tool for obtaining THRS images. For 3 years, work has been carried out in Senegal showing the possibility of calibrating drone outputs with measurements of herbaceous and woody savannas.

The objective of this internship is to use this UAV data as an intermediate step between the terrain and satellite images, then to compare the maps produced with current work based on laborious terrain measurement protocols.

This internship will be supervised by Simon Taugourdeau (CIRAD UMR SELMET) and Audrey Jolivot (CIRAD UMR TETIS).

Research units: SELMET, Institut Agro

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Main scientific field: Life and environmental sciences

Internship - 2022

Assessment of the potential of the Pl@ntNet platform for the identification of pasture species in support of pastoralist management strategies

Abstract: The participatory science platform Pl@ntNet offers various web services to help identify plant species from the automated visual analysis of plant photos. The validated data it generates is used for training automated visual classification models, allowing species identification from photos of leaves, flowers, fruits or stems.

Although pastures represent the agricultural ecosystems with the greatest plant diversity, no Pl@ntNet assessment has been conducted on these agroecosystems, which constitute an interesting study model. The species most represented in the pastures, in particular those of the Poaceae family, are not very numerous in the Pl@ntNet learning base. For illustration, it should be noted that less than 100,000 occurrences of Poaceae are visible on the 10 million Pl@nNet observations published on the GBIF site. In addition, pasture plants are most often seen in the vegetative stage making identification all the more difficult.

The first objective of this internship will be to assess the relevance of Pl@ntNet in its current form, for the identification of pasture species. The constitution of a test data set covering around ten species. In a second step, the enrichment of the Pl@ntNet learning base will be carried out with additional data to evaluate the typology and the volume of relevant images for a significant improvement of performances in the studied context, and to allow a level of precision in line with the expectations of the breeders., an evaluation will be carried out in a third step in order to measure the potential of a quadrat approach. Photos of quadrats at a distance from the ground and fixed focal length will be produced, cropped and submitted to the Pl@ntNet identification service.

The intership is supervise by researcher from SELMET and Amap

Research units: SELMET, INRAE

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Main scientific field: Technology and Sciences

Internship - 2021

Intrabody and submarine communication for sensor network implantable in fish – benchmarking of communication techniques regarding power efficiency

Abstract: This work is part of a long-term project aiming at developing the first implantable sensor network for holistic monitoring of fish state of health. This approach relies on the need for measuring several physiological parameters to gather useful information about various biological processes. For instance, a Ph or temperature sensor in stomach for feeding event identification, a sensor in fat storage to estimate the amount of available energy for a fasting period, a sensor in gonads to monitor oocyte cycle are interesting and useful solutions that should be set in a sensor network to provide useful dataset on the fish.

Setting an implantable sensor network is of interest for every exploited animal species. Studying fishes in the context of aquaculture or fishing, is the targeted application. In the context of fishes living in salted water, a major issue for the deployment of such a sensor network is the wireless communication needed for data gathering. At first biological tissue is a very contraining environment for communicaiton. In addition, salted water strongly attenuates electromagnetic signals, which limits the range of communications usually used for sensor networks.

The objective of this internship is to set-up and test several intrabody communication techniques in order to evaluate their potential deployment in marine context. Intrabody communication techniques are mainly classified in two categories

- Galvanic coupling, the biological tissue is used as a medium of the communication

- RF transmission, the biological tissue is considered as the environment of the communication

Preliminary results have shown that it is possible to setup an intrabody communication through immersed fishes using LoRa protocol with a range of at least 1m.

As the application framework is the deployment in potentially small fishes for a long time (6 month – 1 year), the main criteria are the volume and the battery life. As a consequence, the design of the prototypes will focus on reducing the volume especially considering antenna and battery. The test objectives will be:

- Validate the communication through fishes

- Estimate the range limits according to the application environment.

- Measure the systems consumption

- Calculate a figure of merit relying on the power efficiency of the system under test in order to benchmark the different communication techniques and identify the one that will enable the longer battery life.

Research units: LIRMM, Université de Montpellier

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Main scientific field: Technology and Sciences

Internship - 2020

Subgroup discovery for time series in precision agriculture

Abstract: Dairy cows are increasingly equipped with inexpensive data acquisition sensors that allow to get in real time their temperature and activity level. Analyzing the data provided by these sensors can help for reproduction and health issues. For instance, the Lacodam team published this year a method that significantly outperforms the state of the art for oestrus detection by using ensemble classification methods on these time series [1]. A recent and exciting challenge is to exploit data coming from these sensors for improving animal wellbeing in farms. In the long run, comparing the data from numerous farms would allow to determine conditions and practices that are benefic for animal well being, and those that are detrimental. Adequate recommendations could then be made to farmers in order to help them improve the wellbeing of their herd. In that regard, when given sensor data from cows labelled as "happy" or "unhappy", a first step is to discover understandable patterns that differentiate the two populations. A general solution to this problem is the mining of emerging patterns [2, 3], which is designed to discover understandable (symbolic) patterns in data annotated with class labels. Subgroup discovery [4] is an especially expressive instance of emerging pattern mining: it allows discovering regions of the data that are characteristic of a class, in data that can be symbolic or numeric (most emerging pattern mining methods deal with categorical data). In practice, a subgroup is a set of conditions over attributes of the data that define a region. Subgroup discovery methods focus on regions that satisfy statistical properties guaranteeing that they are more characteristic of a given class. Up to now, subgroup discovery methods have been limited to tabular data. In this internship, we want to extend these approaches to the analysis of time series data [5]. This requires to determine the features of time series that are the most relevant to determine interesting regions of the data, while remaining understandable by an analyst: one possibility is to focus on intervals of values like in traditional subgroup discovery, however it would also be interesting to consider second order features such as slope or frequency.

Research units: LACODAM, INRIA

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Main scientific field: Life and environmental sciences

Internship - 2018

Advanced modelling of the effect of drinking on the rumen temperature for milk cows

Abstract: In the context of Livestock Precision Farming, individual profiles of rumen temperature are now available. For instance, the NewMedria's thermobolus sensors provide rumen temperature each 5 minutes. This monitoring allows early detection of health problem (Timsit et al. 2011) or imminent calving. Nevertheless, the rumen temperature evolution is a complex process depending on numerous parameters. The temperature may undergo sharp variations during drinking phases, because of ingested water decreasing the rumen temperature (Bewley et al. 2008).
The aim of the internship is a better understanding of the relation between rumen temperature and drinkings. The interest of this exploratory analysis is to assess to what extent the temperature variations can be used to predict the ingested water amount (that could constitute a proxy for intake) and so to detect individual digestive specificities.
Approach: Rumen temperature time courses will be considered in relation with drinking time and volume that can vary every day. Several parameters are relevant (drinking time, water temperature, individual, meal digestion) and must be included in a chain of models. These models, either static or dynamic, will be adapted from literature:

- Model of rumen temperature drop following drinking sequences, based on the mixture equation for 2 fluids with different temperatures (rumen internal fluid and fluid ingested during drinking). This model will also consider the fraction of drunken water bypassing the rumen to go directly into the digestive tract.

- Dynamic model of the subsequent rumen temperature increase, whose parameters depend on multiple factors.

- Model of the rumen volume and of the bypass fraction that could depend on cow and on its age.

- Model of the ingested volume taking into account external losses during drinking.

The model parameters will be estimated to account for individual effects, age factors and measure uncertainties. Nonlinear mixed effects models will be explored. These methods will highlight and validate the effects mentioned above, and allow quantifying their individual variability.

Available data: Data are already available for 3 experiments where drinking and food sequences are precisely known in terms of times and amounts, as well as rumen temperature time courses and environmental conditions. In each experiment, a sample of 4 to 8 cows is available. Each experiment is conducted over 1 to 3 months involving different animals. Another dataset with a new experimental protocol, including more animals (60-70 cows) during at least 3 months, will be available at the beginning of the internship.

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Main scientific field: Life and environmental sciences

Internship - 2018

Data analysis of real-time body temperature measurements in pig: data mining approach to predict animal responses to heat stress

Abstract: Affordable measurement of core body temperature in a continuous, real-time fashion is now possible in livestock. Body temperature is a key physiological parameter that provides important insights into the study of thermoregulation, physiology and behaviour or responses to environmental change Up to now, the reference method for monitoring internal temperature was based on punctual rectal temperature measurements by using a medical thermometer. This method requires the immobilization of the animal with possible bias in the body temperature determination due to the animal stress. We recently validated in pig a new system for a continuous monitoring of internal temperature based on the use of telemetry pills. This system is composed of an implantable pill that wirelessly and continuously transmits BT to a dedicated recorder. Our works showed that changes in internal body temperature in pigs can be explained by factors related to livestock conditions (especially climatic conditions) and / or by factors related to the animal (level of physical activity, feeding behavior, growth potential, etc.). This continuous monitoring of internal temperature associated with an ad-hoc mathematical analysis could be an interesting source of information in the future to assist the farmer in managing his herd. The objectives of this studentship are 1/ to initially identify different profiles of nycthemeral body temperature variation, 2/ to investigate the association between profiles of temperature changes and heat tolerance and 3/ to improve prediction of heat tolerance from body temperature profiles previously measured in thermoneutral conditions. To carry out this work, the student will have an access to a database with individual data of body temperature (1 measurement/min) obtained on a total of 60 animals submitted to experimental thermal challenges during the growing-finishing period.

Research units: PEGASE, INRA

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Main scientific field: Technology and Sciences

Internship - 2018

Discrimination of tropical tree plantations

Abstract: The management, operation and analysis of large datasets produces new values in a growing number of fields (financial, commercial, scientific, etc.) leading to major transformations in the practices concerned. Agronomy, by means of increasingly reliable observation devices (sensors, imaging) is also changing in this direction.

This course aims at the extraction of new forms of knowledge concerning cows in buildings, thanks to the data of geo-localization that are recorded daily and at high frequency (1.6 Hz). In order to detect changes in the state (disease, heat, etc.) of bovines, we propose to work on two interdisciplinary approaches, using mathematical modeling, inferential statistics and computing. The first outcome of the work on stochastic modeling carried out within MISTEA proposes to model the different possible states by a centered individual model [1,2] focused on the detection.

The second one relies on the matrix profile [3] and allows to identify repetitions of patterns between time series or within a series. Faced with mass data problems (160 dairy cows x 144,000 positions (x, y) x 180 days), these two complementary approaches both require data distribution methods and parallelization of algorithms and models. The objective of the course is to adapt these two approaches to cow data in order to anticipate signs of interest on the condition of bovine animals. Finally, in a more exploratory part of this work, it will be necessary to envisage the possibilities of combining the two approaches. A first track would be to study how. On the basis of the information provided by the modeling, we can target and improve the data analytics (matrix profile) approach.

Research units: MISTEA, INRA

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Main scientific field: Life and environmental sciences

Internship - 2024

Grouping together during hot weather? A study of the collective behaviour of aggregation in sheep.

Abstract: In grazing livestock farming systems, sheep express a unique collective behaviour of aggregation linked with environmental heat. During the expression of this behaviour, which can last several hours in the event of prolonged heat, individuals no longer ingest. The collective dynamics associated with the expression of this behaviour, their links with environmental temperature and the individual or collective fitness associated with the expression of this behaviour are poorly determined.

However, this behaviour well known by shepherds can be a hindrance to the herd's performance and as well as an issue for the management of animal welfare. The global evolution of climate and the multiplication of heat waves in the Mediterranean area accentuate the need to study this behaviour in order to understand it and propose ways of managing the grazing environment.

During this project, using digital tools, we will focus on the characterisation of (i) the collective dynamics of grouping (using embedded radio transmitters and ultra wideband sensors) and (ii) the environmental conditions within these animal groups (using sensors for temperature and gas content such as CO2 and O2), in relation to the local climatic conditions (temperature, humidity and solar radiation sensors). This monitoring will be carried out in different groups of ewes (5 to 15 individuals) at the Domaine du Merle (Institut Agro Montpellier, Salon-de-Provence). This monitoring will be completed by behavioural and health monitoring of the flock, notably by monitoring the level of oxidative stress with the assay of plasma metabolites.

This project represents a great opportunity to formalise research collaboration between the CRCA and UMR SELMET teams.

Research units: CRCA - Centre de Recherches sur la Cognition Animale, Université Toulouse III - Paul Sabatier École doctorale

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Stake 2 – A better society inclusiveness for ICT-enabled agriculture

Challenge 0: Transversal subjects

Main scientific field: Engineering sciences

Internship – 2025

Spatial transfer of deep learning models for rapeseed crop mapping

Abstract Nowadays, more and more remote sensing data are available, offering the possibility to follow a geographical area over time. The time series thus generated represent an essential source of information to efficiently manage agriculture on a territorial scale.

To this end, remote sensing data is used as input to machine learning (ML) methods to provide updated land cover maps. To do so, ML methods require a large amount of ground-truth data, which poses challenges for their applicability where little or no reference data is available.

Re-using ground-truth data acquired at a particular study site to transfer the learnt model to a different area would avoid (or reduce) new costs and take advantage of previous investments. Unfortunately, directly transferring a model from a geographical zone to another one can be inefficient as the two regions may present different environmental and/or climatic conditions. This results in differences in the distribution of the acquired satellite data.

This internship proposal aims at developing an innovative deep learning/transfer learning method with the aim to transfer a model learnt on a particular area (where ground truth data is available) to a different geographical area where no available ground truth data is accessible.

In the context of this internship we will exploit freely available multi-temporal Sentinel-1 imagery, less sensitive to cloud occlusions due to the intrinsic nature of the SAR signal, with the aim to build a deep learning classification model for the mapping of the rapeseed crop culture. In addition, the designed deep learning method will exploit recent domain adaptation techniques to cope with the transfer task between three different geographical areas, namely: France, USA and Canada. We will evaluate the capability of the underlying deep learning model to be calibrated over one of the three areas and deployed on the remaining ones.

Research units: TETIS, INRAE

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Main scientific field: Human and social sciences

Funded post-doc – 2022-2024

How to adapt "rfid / rfid-sensor" technology through co-creation to better value agriculture in the food chain?

Abstract: Since 2007, IES has been working on RFID technology deployment with Tageos company, working on numerous technological obstacles including the RFID labels production at large volume and low cost. The democratization of this technology seems to be acquired in recent years, in particular with the traceability on supply chains (for example Decathlon). However, many socio-economic sectors, including the agrifood sector, wish to add a sensor functionality to this traceability format. With this in mind, IES and IATE have developed a simple, low-cost “SENSOR- RFID” label to follow food spoilage in a modi.

Research units: IES, MoISA, Université de Montpellier

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Main scientific field: Human and social sciences

Labeled PhD – 2022-2024

Co-producing knowledge, accelerating transitions. Lessons from a research intervention in experimental and participatory research projects

Abstract: At present, little is known about how experimental and participatory research projects deliver on their promise of innovation, as their actual contribution to the intended transformations has so far been little studied. Similarly, there is no widely applicable evaluation scheme to capture essential information about the outcomes of these experimental and participatory projects and to guide the design of transition experiments. Therefore, based on Occitanum's digital innovation ecosystem, this research aims to answer the following research questions: How can experimental and participatory research projects foster innovation in the agro-ecological transition? In order to answer these questions, the research will draw theoretically on actor-network theory (ANT), as this approach enables us to study how networks of human and non-human actors articulate to foster innovation as a process.

Research units: AGIR, INRAE

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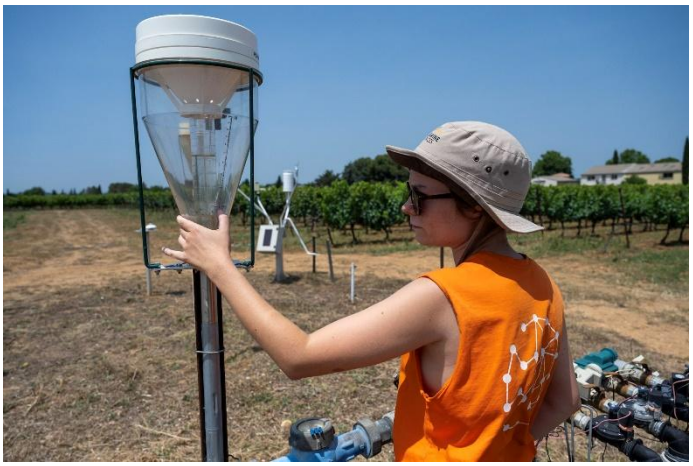

Main scientific field: Human and social sciences

Labeled PhD – 2024-2027

Geopolitics of Digital Platforms in Agriculture:

Present Situation and Future Challenges

Abstract: Digital platforms are transforming agriculture by acting as intermediaries between producers, consumers, and distributors. They optimize information flows, reduce transaction costs, and promote the adoption of technologies such as precision agriculture and artificial intelligence Platforms enhance traceability across value chains, increase system efficiency, and facilitate market access for smallholder farmers. As a result, digital platforms can lower entry barriers and foster equitable participation in agricultural economies. The control of data introduces a geopolitical dimension to this transformation, as platforms disrupt traditional modes of intermediation and redefine power dynamics within agricultural value chains. The monitoring of information, essential for optimizing decisions under crop stress conditions, is crucial for shaping policies due to its impact on global food systems. This thesis integrates platform economics and agricultural economics by studying the role of platforms in restructuring tangible and intangible flows. Platforms shift value toward digital interactions and challenge traditional models by enabling efficient exchanges between stakeholders This shift reflects a historical decoupling of physical and informational assets. The analysis conducted in this thesis will culminate in scenarios for the future of agriculture in the age of digital platforms. It will highlight opportunities for innovation and sustainability while addressing risks, such as data monopolies. Policy recommendations will aim to align platform operations with broader socioeconomic and environmental objectives.

Research units: INRIA

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Main scientific field: Human and social sciences

Cofunded PhD – 2018-2021

Is innovation in smart agriculture responsible?

Abstract: Smart agriculture is likely to contribute to the improvement of sustainability. However its environmental and social impacts are sometimes denounced. In fact, with the appearance of controversial technologies, such as biotechnologies, nanotechnologies, but also ICT in general, the concept of responsible innovation has emerged at the beginning of the 2000's, and since gained attention in the world, especially in developed countries, such as those situated in Europe. Responsible innovation refers to the inclusion of the stakeholders into the innovation process, and to the anticipation of social and environmental effects an innovation may induce. Given this, we may ask our self the following question: Does responsible innovation lead to a better adoption of digital agriculture innovations? To answer to this question, it will be necessary: 1) To clarify concepts and definitions (responsible innovation, digital agriculture). 2) To draw up an inventory of the advantages and negative impacts digital technologies may have, especially in agriculture. 3) To identify relevant case studies, in the field of digital agriculture innovations, to describe innovation processes, and characterize them in terms of responsibility, using qualitative methods. 4) To assess the adequacy between the innovation process and users adoption. 5) Finally, recommendations could be made for improvement of processes, and a method could be proposed. The case studies will be chosen in the field of smartphone apps for agriculture. Some of them will come from southern countries to enrich the analysis.

Research units: MoISA, MRM, Institut Agro

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Main scientific field: Human and social sciences

Labeled PhD – 2019-2022

Reinforcement learning for developing country agriculture: a virtual personal adviser for risk mitigation and multi-objectives optimization.

Abstract: Reinforcement learning (RL) has shown spectacular progress in recent years, especially when combined with deep learning for game playing with Deepmind's AlphaGo (https://deepmind.com/blog/alphago-zero-learning-scratch/). While applied in marketing or pharmaceutical contexts, agriculture remains a poorly explored ground for RL applications. Agriculture is all about sequential decision making under uncertainty, making RL techniques particularly appropriate. With the emergence of bigger data collection at different scales by technologies such as remote sensing, ground-based sensors and real-time customer feedback with smartphone applications or interactive voice response (IVR) systems, a new frame of active and online learning emerges where RL appears to be increasingly relevant.

Current decision support systems for agriculture use static rules for decision making (if-then-else) employing statistical models complemented with agronomic and farm data, remote sensing, and some finite uses of machine learning outputs. The rules tend to be defined for specific management tasks (e.g. irrigation or fertilization) yet tend to not include the whole sequence of decisions, the profile of the farmer making the decision, optimization for multiple objectives (e.g. economic, environmental, social), or accounting for stochasticity (risk quantification). All of these are important for achieving relevant, secured and personalized agronomic recommendations. Those objectives can be fulfilled thanks to new RL advances.

RL techniques allow to take into account uncertain impact of choices (such as crop management) and stochastic events (such as pests or weather). With model-free methods, problems that are too complex to be explicitly defined (in our case whole-farm planning) can be learned directly by interacting with the environment (i.e. directly by trying an action guessed to be the best in the real world). This is a learning frame of trials and errors: a recommendation is given, then its impact (called the 'reward') is assessed and future recommendations adjusted according to past experiences. These techniques can as well learn from historical data (e.g. soil, crop, climate data), linking them to what is called a 'context', making learning quicker and richer while quantifying uncertainty related to a recommendation.

First, this PhD aims at designing tailored RL algorithms for agriculture with state-of-the-art techniques to give continuously improving advice to farmers, especially in a developing country context with limited data. By leveraging RL expertise from INRIA (SEQUEL Research team) combined with agronomists' knowledge from CIAT, CIRAD and other research-for-agricultural development institutes we aim to build a novel multi-objective (economic, social and environmental) and relevant RL system for personalized and real-time recommendations for agronomic practices with a risk quantification component. This system will be operationalized as a personal virtual adviser queryable via IVR systems or other smartphone applications. This virtual assistant self-learns from earlier experiences (past recommendations followed by feedback

from farmers) while relying as well on existing knowledge (historical data). Recommendations are provided according to space, time and individual farmer's context. For instance, a recommendation would be of the

"The choice expected to maximize your objectives is planting maize variety x the third yth week of august with a density of z plants per hectares".

Second, once the algorithms are tested in silico and ready for use, use cases will be conducted with smallholder farmers in Malawi. Available datasets consist of multi-dimensional data integrating location, normalized difference vegetation index, precipitation, temperature, soils, land use, and historical crop productivity, as well, Digital Globe archives of sub-meter resolution satellite images, to delineate favorable areas and key limiting factors for maize production for the whole national territory of Malawi. Testing will be conducted through AirTel/Viamo M'Chikumbe interactive voice response-based advisory service which already has 726,000 registered farmers in Malawi. It offers a powerful way to interact directly with individual farmers via their mobile phones and provide tailored guidance across the entire country. If experiments are successful, it is expected that the methods and techniques developed in this PhD could be extended to other project sites in e.g. Colombia, Nigeria, Mexico, and India, that is to say to millions of smallholder farmers.

Research units: Aïda, CIRAD

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Main scientific field: Human and social sciences

Internship - 2018

Description of the institutional context of the sectoral innovation system of digital agriculture

Abstract: Today, digital technologies are emerging as a means of improving agriculture in terms of productivity, environmental protection, working conditions of farmers and traceability of food to the consumer. As such, they are one of the priority objectives for innovation in French and European agricultural policies. Thus, digital agriculture is a strategic issue for France as described in the report Agriculture innovation 2025 (Bournigal, Houllier, Lecouvey, Pringuet, 2015) as well as in numerous reports published by European bodies (European Parliament, 2016, for example).
The objective of this work is to provide an overview of the institutional environment of digital agriculture at the national and European levels, based mainly on neo-institutional theories. The aim is to highlight:
- The institutional environment of digital agriculture;
- The institutional framework of digital agriculture;
-The process of institutionalizing digital technology in agriculture.
In order to understand the various institutional pressures, isomorphisms (normative, coercive or mimetic) at work (DiMaggio and Powell, 1983), several questions can be asked:
- Which institutions are involved (Friedberg, 1998)?
- Which policies, packages and measures are aimed at promoting the development of digital innovations in agriculture?
- Who are the stakeholders involved, from producers of technologies, research-related, to farmers and other users in food systems, including prescribers, and also agricultural advisors?
The theoretical framework may be based on the notion of "sectoral innovation system" defined by Malerba (2002) as " a set of products and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products ». This framework should make it possible to identify categories of tools, according to their characteristics, their specific uses.

From a methodological point of view, the work will be carried out essentially by means of a bibliographic study but also by telephone or face-to-face interviews with local actors (including members of the Agrotic chair) which will complement and precise Information previously collected.

This step consisting in identifying the institutional context of digital agriculture is an important prerequisite for further work to better understand the uses of digital technologies in agriculture and their impacts on farms. In particular, it is necessary to identify the digital tools adopted and their mode of dissemination, by considering the preliminary steps to use, which led to the adoption of these tools.

Research units: MoISA, Institut Agro

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Main scientific field: Technology and Sciences

Internship - 2022

Exploring the diffusion and adoption of innovations in agriculture: an application to communicating water meters

Abstract: Recently, digital technologies applied to agriculture have developed strongly, considerably modifying farmers' practices and crop management methods. Moreover, these farming habits are currently strongly conditioned by the concern to respect the environment. Therefore, even if such digital technologies offer a solution to farmers, they raise many questions about the negative effects they could cause (inequalities between farmers, industrialisation of agriculture, ownership and leakage of data, etc.). Studying the dynamics of adoption and dissemination of these tools is a key step in setting up public policies to promote a virtuous impact of these technologies. Nevertheless, conducting this type of study requires taking into account the different actors in the system in their diversity, but also in their interactions. Indeed, the processes of diffusion of innovation are guided by interpersonal interactions between individuals. Moreover, the perception of digital technologies and their use are very heterogeneous among farmers and it is therefore important to take this heterogeneity into account in the model.

Research units: MIAT, IATE, INRAE

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Main scientific field: Life and environmental sciences

Funded post-doc – 2024 - 2026

Development of a machine learning framework for the prediction of food security indicators at country scale from heterogeneous data

Abstract: Food Security (FS) is a central problem in many areas of the world, as also testified by its presence as one of the 17 Sustainable Development Goals (SDG 2 - Zero Hunger). To monitor food insecurity situations, several early warning systems are active today, such as GIEWS (Global Information and Early Warning System, FAO), and FEWSNET (Famine Early Warning Systems Network, USAID). These systems use a limited set of data types, i.e., agroclimatic data from satellite images and indicators extracted from household surveys about nutritional, economical and production-related factors. Also, human intervention is often needed to combine and summarize all the sources of information. Our hypothesis is that heterogeneous open data, related at different levels with food security, can be used to provide a machine learning based framework able to automatically produce FS indicators able to take into account the multiple and interrelated reasons behind this phenomenon. Some examples may be raster data containing spatial information, volunteered geographical information, meteorological data, quantitative economic indicators, and textual data from local news media. The aim of this Post-Doc is to consolidate and extend the recent works on this topic resulting from a collaboration by UMR TETIS and UMR MoISA, mainly thanks to a PhD Thesis co-financed by #DigitAg. More specifically, we want to develop a suite of user friendly data science methods (e.g., a Python library) able to retrieve and exploit heterogeneous data to effectively produce food security indicators at national scale. Besides data processing in itself, the need to collect, integrate and assess the quality of such heterogeneous multi-source data introduces several additional challenges in this context. The use of rich ground truth data provided by CGIAR (e.g., RHoMIS - Rural Household Multi-Indicator Survey) will allow to test the proposed methodologies on different countries in Africa and South-Eastern Asia.

Research units: TETIS, CIRAD / MoISA, INRAE

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Main scientific field: Technology and Sciences

Funded post-doc – 2024 - 2026

Construction and Impacts of interdisciplinarity in the Digital Agriculture Convergence Lab

Abstract: #Digitag is a Convergences Institute (CI) dedicated to digital agriculture that was created at the end of 2016 in Montpellier, with branches in Toulouse and Rennes. Its aim is to build the scientific foundations for developing responsible digital agriculture. To achieve this, its research involves understanding the impacts of digital technology on agriculture and building the technological building blocks and organizational, economic and social models enabling the development of responsible digital farming. In 2022, after 5 years of existence, #DigitAg benefits from more than 700 people who claim to be members of the IC, based on 29 research units and around 20 associate researchers. The research conducted at #DigitAg mobilizes three "scientific domains": engineering sciences, life sciences and human and social sciences. #DigitAg funds theses and post-docs under cotutelle agreements, implementing different levels of interdisciplinarity: association of disciplines from the same "scientific field" (simple interdisciplinarity), association of disciplines from different fields (extended interdisciplinarity), with some projects mobilizing disciplines from all three fields. The construction of this interdisciplinarity is an integral part of the Convergences Institute, as it corresponds to the demand of "Convergences". It has extended beyond theses and post-docs, to include the scientific leadership of #DigitAg (#DigitAgora, seminars, website, etc.) and its governance bodies. However, this interdisciplinarity has been organized in a pragmatic way, without any particular theoretical framework, giving priority to exchanges between researchers or students from different disciplines, and seeking to integrate knowledge to answer the questions posed, including by socio-economic partners. Today, #DigitAg wishes to take a reflective look at the construction of this interdisciplinarity and offer an enlightened reading of it, based on a scientific approach, that can be shared beyond the CI on both its advantages and its limitations. Through the experience of #DigitAg, the aim is also to analyze the conditions for the development of an interdisciplinarity that would be, in part, specific to research on digital agriculture, and, in part, positioned with regard to current issues of research responsibility that are leading to an evolution towards more participative and transformative modes of research. An interdisciplinary working group will be set up around the post-doc, for regular exchanges, with members of the Convergences #DigitAg Institute management (K. Gauche, deputy director, V. Bellon-Maurel, director, J.M. Touzard, axis leader), Julien Mary (scientific referent, MSHSud), C Lannoux (in charge of interdisciplinarity, INRAE) and P.B. Joly (ASIRPA method specialist, INRAE).

Research units: MoISA, INRAE/ITAP

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Stake 2 – A better society inclusiveness for ICT-enabled agriculture

Challenge 5: ICT and new farm advisory services

Main scientific field: Life and environmental sciences

Co-funded PhD – 2021-2024

Model inversion from crowdsourced agricultural data: application to the estimation of crop and soil parameters in viticulture

Abstract: This PhD topic is positioned in the continuation of the research work carried out within the framework of the ApeX-Vigne project. A previous PhD allowed the initiation of a crowdsourcing project in agriculture and more specifically in Viticulture. This project is based on the use of a free and open source mobile application allowing professionals of the wine industry to collect standardised, timed and geo-referenced observations of the vine water status at the plot level. Since 2018, Apex-Vigne provided each year a large database (approx. 7000 measurements/year) at a regional scale. The aim of the PhD thesis is to take advantage of the massive nature of the data collected in order to estimate cultivation parameters that are difficult to measure (soil water holding capacity) but essential for the implementation and calibration of decision support models based on the water balance for irrigation management. The PhD thesis will consider several scales of application: plot, domain, region. The originality of the proposed approach is to integrate crowdsourced observations in a water balance model inversion approach. The scientific novelty of the approach comes from the type of data considered: imprecise, asynchronous, heterotopic, massive. Our approach thus makes the hypothesis that the imperfection of crowdsourced data will be largely counter balanced by the volume of data available. The considered approach is based on 3 steps of which each one is original: i) the development of a transfer function allowing to relate crowdsourced observations to a classical output variable (OV) of a water balance model like the predawn water potential, ii) the spatial consolidation of the OV, this step makes the hypothesis that the OV is spatially auto-correlated, it is at this level that the imperfection of the data will be taken into account by geostatistical approaches, iii) the model inversion itself, based on OV estimates and climate data of the vintage, the thesis will aim at inverting a water balance model in order to produce estimates on crop parameters (It will focus as a first step on the estimation of a parameter that is difficult to access: the soil water holding capacity.

Research units: ITAP, LEPSE, Institut Agro

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Main scientific field: Human and social sciences

Co-funded PhD – 2019-2022

Digitalisation and transformation of agricullltural R&D. New service models for new agricultural models?

Abstract: The aim of the PhD is to analyse the effects of the digitalisation of agriculture on the functioning of agricultural R&D. There is a need to better understand how digitalisation transforms the collective organisations that farmers have set to produce knowledge on the technologies they use. Digitalisation of agriculture comes with the emergence of a market for Decision Support Tools, with alliances and competition between actors to create value and knowledge with and for the farmers. New actors are active in this market: start-ups, multinational firms… These actors can potentially impact the economic models of services delivered to farmers (advisory services, knowledge brokering, experimental platforms…). They can also contribute to changes in the networks, rules and institutions of agricultural R&D. These trends also question the nature and content of agronomic knowledge on which farmers' Decision Support Tools are built. What are the sources for this knowledge? Who invest in the validation of the relevance and robustness of this knowledge? Is this knowledge compatible with the development of agro-ecological conceptions of agriculture? The PhD thesis will benefit from the research project H2020 AgriLink, coordinated by Pierre Labarthe. This will allow the PhD candidate to implement a comparison between three countries: France, the Netherlands and United Kingdom. The methodology will be based on qualitative field work, with interviews of public and private actors of agricultural R&D and of the supply of services for farmers. An in-depth analysis will be implemented on the development of a given technology in the three countries. The technology is to be identified by the PhD candidate. This PhD will reinforce the relations between the laboratories AGIR and Innovations for the analysis of digitalisation of agriculture in a pluridisciplinary perspective, building on economics and management sciences.

Research units: AGIR, INNOVATION, INRAE

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Main scientific field: Life and environmental sciences

Co-funded PhD – 2024-2027

Identifying unexpected observations in territorial crowdsourcing projects for agriculture: the case of vine water status monitoring at regional scale

Abstract: In the context of climate change, monitoring vine water status at the regional scale is of paramount importance for short- and long-term decisions. One of the promising approaches for this monitoring is the collaborative collection of observations by stakeholders of the wine industry, known as crowdsourcing. Crowdsourcing has already demonstrated its ability to collect a large amount of observations, particularly with the ApeX-Vigne application initiated by the project team. For the democratization of this approach, the missing link is the development of methods for analyzing the collected data. The identification of unexpected observations is a particularly important challenge, as these may be either aberrant observations that need to be eliminated to improve the overall quality of the dataset or, on the contrary, interesting observations that may reflect an original growing system or atypical soil and climate conditions.

The phenomena under study are seasonal and generally follow a known and expected temporal dynamic. They also often depend on the environment (soil, climate, etc.), as for drought, and are therefore also spatially structured. The approaches that will be explored in this thesis will seek to use this knowledge about the phenomena under study to define expected behavior and identify observations deviating from it. The formalization of this knowledge may be based on historical data (e.g. historical time series of vine water status monitoring on reference plots) or auxiliary data (e.g. time series of remote sensing images). Spatio-temporal statistical methods will be used, and a Bayesian framework will be favored. Other approaches, such as the use of conformal prediction, may also be tested.

Research units: ITAP, MISTEA, Institut Agro

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Main scientific field: Maths and its applications

Internship - 2024

Algorithm for management zones generation driven by the performance of crop management operations

Abstract: Zoning problems (dividing a plot into management zones) are at the heart of digital agriculture, as they enable the implementation of spatially differentiated Crop Management Operations (CMO). However, zoning algorithms are generally not directly determined by the impact of these spatialized CMO. However, this information becomes accessible through the predictions of crop models or the use of adapted data. The aim of this internship is to develop a new algorithm for generating optimized delineation of crop management zones based on the performance of CMO. The algorithm will output a zoning associated with a CMO recommendation per zone (irrigation level for example). The optimal recommendation will be based on a variable spatially observed on the agricultural plot. The proposed zonings will respect spatial constraints that will be managed using a method already developed at UMR MISTEA [Loisel et al. 2019].

The first case study is that of a crop irrigated using various possible irrigation modalities and under a global quota constraint. The agronomic variable on which the zoning will be based will be the water reserve in the soil, mapped on a plot.

The master student will be hosted by INRAE Montpellier's UMR MISTEA and co-supervised by researchers and associate professors from UMR MISTEA (P.Loisel and S.Roux) and ITAP (H.Jones).

Research units: MISTEA, INRAE

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Main scientific field: Technology and Sciences

Funded post-doc – 2022-2023

Added value of farmers' weather IoT stations and ensemble weather forecasts to provide local advice on water management integrating uncertainty

Abstract: Agriculture is one of the activities most impacted by weather hazards, modulating in particular the crop cycle, irrigation management, crop protection, etc. This sector has a strong demand for decision support tools (DST) aimed at adjusting crop operations according to weather constraints. In recent years, weather forecasts have evolved, now offering information on uncertainty. These probabilistic forecasts, also known as ensemble forecasts, make it possible to propose realistic scenarios to represent the uncertainties of forecasts up to 15 days. In addition, farmers are equipping themselves with connected stations to provide weather observation to the DST. Nevertheless, the deployment of these new low-cost stations raises the question of their quality and therefore of the associated uncertainties as well. At the same time, all these elements contribute to the construction of precision agriculture.

The objective of this post-doc is to evaluate the impact of the uncertainties of weather forecasts on water balance forecasts and, ultimately, on the recommendations made by the DST for irrigation management. For this purpose, the overall forecasts will be used. In addition, the sensitivity of these DST to the three main categories of uncertainty sources will be jointly evaluated: the overall forecasts, the meteorological observations from connected stations and the agronomic parameters or input variables. We will consider 2 decision support tools for irrigation management in vineyards and maize. It will show the interest of ensemble forecasting approaches compared to classical forecasts or frequency approaches.

Research units: Acta, Mistea, ACTA

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Main scientific field: Technology and Sciences

Co-funded PhD – 2020-2023

Use of agent-based simulation and argumentation framework to better understand the diffusion and appropriation of communicating water meter technology in agriculture

Abstract: These last years have seen a strong development of digital technologies in agriculture, which have already largely begun to impact farmers' practices. While these technologies offer a unique opportunity to contribute to the emergence of a more environmentally friendly agriculture, they also raise many questions about the negative effects they could be causing (inequalities between farmers, industrialization of agriculture, data ownership and leakage, etc.). This thesis project aims to study different levers that could allow the appropriation and virtuous diffusion of digital tools in agriculture. To do this, it proposes to build a simulation model to evaluate different policies (training of farmers, communication around digital tools, etc.) at the scale of a territory. The model will be based on the coupling between agent-based modeling and argumentation theory. The objective is to start from the field using methods from experimental economics and surveys, and to analyze the arguments used by the various actors on the use of these tools to propose a rich and realistic modeling of the phenomena of appropriation and diffusion of innovations. This modeling approach will be applied to study the case of communicating water meters (similar to Linky for electricity meters) among farmers in Occitanie. These tools, which could lead to better management of water resources, are now a source of tension for many farmers. The application challenge is to better understand these tensions and evaluate strategies to overcome them.

Research units: MIAT, IATE, INRAE

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Main scientific field: Human and social sciences

Co-funded PhD – 2019-2022

Digital agriculture: the question of labor in agricultural holdings. Territorial trajectories and coexistence

Abstract: Digital agriculture (DA), including information and communication technologies (ICT) and automated agricultural machinery, is the subject of many hopes to transform agricultural models. Some even talk of a revolution and consider it as a source of innovation sometimes for a more sustainable agriculture sometimes for more competitive farms. The scientific literature focuses on the operation of these digital tools and their economic impacts. A broad field of research seeks to understand the contribution of this DA to the transformations of agriculture. Agricultural holding is a relevant entry to understand both the consequences of the DA on the ongoing changes in labor in agriculture but also to identify changes in the management strategies. Mobilizing analytical frameworks of economic and social geography, this thesis project explores the changes induced by the DA in the socio-economic and territorial logics of farms. These results will allow us, in a second time, to study how the DA changes the modes of coexistence of agricultural holdings and agricultural models in the territories studied.

Research units: INNOVATION, AGIR, INRAE

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Interactive exact optimisation for numerical services to agriculture

Abstract: The trend towards a precise, numerical, and data intensive agriculture brings forward the need to integrate in a unique decision support methodology optimization techniques that are efficient, interactive, robust and adaptable. We propose to develop a decision calculus strategy for the management of agricultural activity that combines the efficiency and precision of optimisation methods based on linear integer programming and heuristics, and the flexibility and modularity of constraint programming methods. With the perspective that custom decision support services should be offered to farmers, we make the hypothesis that historics of data, as well as daily updates of informations such as meteorology, crop evolutions and traceability informations should be available. This hypothesis allows for studying strategies that combine off-line (back office) approaches for searching best production processes that meet farmer criteria, and on-line (front office) approaches to contextualize and adapt solutions. We also make the hypothesis that distributed computing platforms could collaborate on calculus and numerical studies will be conducted on this topic, using available data and web services.

In fine, the methodology should integrate stochastic features because of the uncertainties of agricultural production. A first characterization and evaluation of solutions for the current decision period can be based on models built from data historics. In a second step, it is planned to make use of probability estimators linked to meteorological forecast to offer robustness oriented interactivity to the user of decision support tool and decision maker.

Research units: LIRMM, ITAP, Université de Montpellier

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Main scientific field: Human and social sciences

Co-Funded PhD – 2017-2020

Legal study of digital platforms in the area of Digital Agriculture

Abstract: This phd study is dealing with the legal and ethical analysis of digital platforms in the area of Digital Agriculture. It is proposed to think in a efficient way how french and european law can lead agricultural and farming activities in the specific digital context of the Internet of Things (IoT). Through connected objects (embedded sensors in agricultural equipment), farmers are producing lots of data, e.g. about ground or water state, etc. Data are collected through sensors by companies who offer then to farmers a range of services of data handling. These different services are used by farmers — who are standing in the middle of the information system — through digital platforms. The question that come up is to know how platform activities are regulated, especially when platforms are resulting from a private, private/public initiative. The question has to be answered in accordance with different types of legal rules of several disciplins or legal subjects (private/public Law, and through private Law: IP/IT Law, contract Law, criminal Law). A lot of matters or questions are actually concerned, and specificly: dissemination of data related to agricultural technical and economical activities (open data/privacy/trade secrets) ; terms and conditions (licences) of the use of data by farmers or by others persons (researchers, citizens) ; security of data storage and dissemination. Besides the research will consist to answer theses questions precisely and clearly, through different ways (methods) of regulation (contracts, best practices, legal propositions), which can insure a well balance between opposite interests and make farmers free of their economical and technological choices. This study will be based on a state of art, considering that less scientific litterature (in legal discipline) is concerning the question in its entirety. This fact contributes to indicate its innovative dimension.

Research units: LiCem, ACTA, Université de Montpellier

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Main scientific field: Technology and Sciences

Internship - 2021

DeepBeesAlert: towards a system of sustainable management and protection of pollination resources

Abstract: The honey bee, Apis mellifera, an essential link in biodiversity and the main pollinator of many food crops in Europe, is experiencing an unprecedented decline. Pesticides, parasites and climate change are contributing to this decline, as is the Asian Hornet, whose main prey is the honey bee. Accidentally introduced in France in 2004, this hornet is gradually invading Europe, ultimately threatening agriculture and our food security. While the research undertaken to control this predator is multiple and not very ecological, the hornet's behavior in front of hives has never been studied in detail and its impact on bee populations has never been precisely quantified. However, only the automatic processing of behavioral data acquired en masse on a national scale will allow us to evaluate the economic cost of this predator, to know the types of apiaries that are most impacted and to warn about the moments or conditions favourable for intervention or trapping.

This project aims to develop a reliable and automatable methodology for counting predation events at the entrance of hives in order to quantify the hornet's impact on apiaries and analyze its evolution over time and the factors likely to influence it. This will involve studying the behavior of hornets and counting from video surveillance data on the hives the catch/attack ratio of the bees over time in order to highlight possible correlations between the predation rate and the seasons, the hours of the day and the weather conditions. From 2016 to 2020, hives coupled with weather stations were equipped with cameras of different resolutions filming continuously one day per week between July and November (about 450 hours of acquisition).

The internship consists in setting up and validating automatic processing solutions coupling Deep Neuron Networks to detect and track objects in videos with variable acquisition frequency (from 25 to 240 fps) on fast moving and erratic data.

The student will have to carry out bibliographical research integrating recent significant advances in video processing (road traffic, bird flight, etc.), deploy and evaluate a convolutional neural network adapted to the specific detection of hornets and captures; object "tracking" scripts will complete the solution to correctly count the objects of interest in each video; finally, an analysis of the tracking trajectories of each object will be undertaken to address the behavioral study (visits, attacks and captures) of hornets. The student will have to evaluate the results produced by the selected solution and analyze the counting errors measured to improve the proposed system and thus enable to initiate large-scale statistical studies aimed at establishing correlations between predation rates and environmental factors.

Research units: AMAP, CIRAD

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Main scientific field: Human and social sciences

Internship - 2020

Digital companies: for which farmers and which agricultures? The case of the dairy cattle sector

Abstract: Digital farming (DF), including information and communication technologies (ICT), agricultural robot and big data leads to many hopes for transforming agricultural models. Some speak of revolution and see it as a source of innovation sometimes for a more sustainable agriculture sometimes for more competitive farms. The scientific literature is mainly focused on the technical aspects of these digital tools and their economic impacts. A wide field of research has presented itself to understand the contribution of this DF to the socio-economic transformations of farms. It is against this background that a PhD work (#DigitAg) is being taken since early September 2019 at UMR Innovation. This study aims to understand the change of farmers' work in farms adopting digital technologies. As digital concerns society at large, beyond the farm's level, we consider the agricultural innovation in a sociotechnical context. This study is also interested in an innovation system dedicated to the digitization of agriculture (training courses, exhibitions, research units, agricultural councils, experimental farms, etc.) and in markets. Understanding this context involves studying the strategies of the institutions with which the farmer interacts (professional organizations, actors of agricultural council, suppliers of inputs and machines, state services, etc.). This internship will aim specially to characterize the representation of agricultural modela and farm systems held by digital companies. A focus will be made on strategies of conceptions and marketing that they implement. We formulate two hypotheses:

• DF companies have representations on current farms' models and model to promote from their point of view. They design their products and services and target farms from this representations of the companies' representations of current farms diversity and farms to encourage come out the products and services design and the selection of targets farms.

• digital companies contribute to the differentiation of farm path. The internship will focus on dairy cattle farming systems, as this sector has been using digital technologies for a relatively long time. The study will concern about twenty companies selected according to qualitative sampling (size, years of existence, type of products and services such as robots for milking, the cowshed cleaning or feed supply and/or connected devices). Semi-structured interviews will be conducted to gather a free speech while addressing specific topics and previously formulated questions. These themes will be structured along three main lines:

• Company history and strategy (objectives, design and commercial strategies)

• Customer features and customer relationships (diversity and farmers targeting, selection criteria, contract modalities, etc.)

• Vision of agriculture: investigate the representations and values carried forward by companies about agriculture and farmers (identified issues and supported agricultural models).

Research units: INNOVATION, INRA

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Stake 2 – A better society inclusiveness for ICT-enabled agriculture

Challenge 6: ICT and agricultural territory management

Main scientific field: Life and environmental sciences

Funded post-doc – 2024-2025

Development of a machine learning framework for the prediction of food security indicators at country scale from heterogeneous data

Abstract: Food Security (FS) is a central problem in many areas of the world, as also testified by its presence as one of the 17 Sustainable Development Goals (SDG 2 - Zero Hunger).

To monitor food insecurity situations, several early warning systems are active today, such as GIEWS (Global Information and Early Warning System, FAO), and FEWSNET (Famine Early Warning Systems Network, USAID).These systems use a limited set of data types, i.e., agroclimatic data from satellite images and indicators extracted from household surveys about nutritional, economical and production-related factors. Also, human intervention is often needed to combine and summarize all the sources of information.

Our hypothesis is that heterogeneous open data, related at different levels with food security, can be used to provide a machine learning based framework able to automatically produce FS indicators able to take into account the multiple and interrelated reasons behind this phenomenon. Some examples may be raster data containing spatial information, volunteered geographical information, meteorological data, quantitative economic indicators, and textual data from local news media.

The aim of this Post-Doc is to consolidate and extend the recent works on this topic resulting from a collaboration by UMR TETIS and UMR MoISA, mainly thanks to a PhD Thesis co-financed by #DigitAg. More specifically, we want to develop a suite of user friendly data science methods (e.g., a Python library) able to retrieve and exploit heterogeneous data to effectively produce food security indicators at national scale.

Besides data processing in itself, the need to collect, integrate and assess the quality of such heterogeneous multi-source data introduces several additional challenges in this context. The use of rich ground truth data provided by CGIAR (e.g., RHoMIS - Rural Household Multi-Indicator Survey) will allow to test the proposed methodologies on different countries in Africa and South-Eastern Asia.

Research units: TETIS, MoISA, CIRAD

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Main scientific field: Human and social sciences

Co-funded PhD – 2021-2024

Supporting the transformation of an agro-ecosystem for a sustainable management of the commons. The case of the relationships between water management, sanitary risks and quinoa production practices on the Bolivian Altiplano

Abstract: This thesis is part of the Wasaca project (Wastewater irrigation: a sustainable agriculture adaptation to climate changes over the Bolivian Altiplano?) funded by Agropolis Fundation. In the framework of WP3 ("Engaging stakeholders in the adoption of sustainable agricultural practices"), the topic aims to set up a participatory modeling approach called "ComMod" around the availability of water resources, linked to environmental and health issues, to collectively consider sustainable trajectories for 2050 and 2100.

ComMod favors role-playing games, which limits the temporal exploration of simulations. However, the technical originality of this thesis is based on the use of hybrid simulations by allowing participants to interact with a digital simulator and to project themselves over the long term. Its objective is to determine what are the necessary conditions for the participatory modeling approach to allow a sustainable transformation of the management of commons, here applied to a specialized socio-agroecosystem for the production of quinoa. A critical posture is proposed to respond to the issues of social equity and to take into account power asymmetries. In terms of the stakes involved in the science-society dialogue, the approach will facilitate interactions between scientists and local actors, who can share their knowledge, jointly build scenarios and collectively consider solutions or new forms of organization to strengthen the management of commons. Innovative tools will be mobilized and developed to help the collective management of this territory by promoting the transparency of the approach and the information produced. The societal purpose is sought through the appropriation of the approach and tools by the actors, which will guarantee the continuity of the project. The design and implementation of computer tools will go hand in hand with work in the social sciences, which requires a strong involvement in the field and with farmers' organizations, as well as the participation of the actors and other researchers of the project. This places the PhD student, de facto, in a voluntarily interdisciplinary approach.

Research units: Sens, G-eau, CIRAD

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Main scientific field: Engineering sciences

Labeled PhD – 2023-2026

Multi-source satellite image segmentation for the extraction of landscape elements applied to agricultural parcels delineation

Abstract: This thesis aims to tackle the problem of automatic extraction of agricultural plots on a territory from remote sensing data at high and very high spatial resolution, as well as its characterization in terms of land use and land cover. Indeed, such information is now of fundamental importance at several scales, from crop monitoring to territorial planning and agricultural statistics, and the richness of the satellite remote sensing offer suggests the possibility of significantly reducing the costs for its acquisition as well as its regular update. Some research work mobilizing methods from artificial intelligence for the automatic extraction of agricultural plots from satellite imagery has recently been proposed, but this is mainly work that directly deploys techniques from the state of art in computer vision in this field of application, without specific adaptation to the satellite remote sensing domain. This particularly concerns taking into account the multi-source, multi-temporal and multi-scale information which arises from the variety of data currently available. To this end, the thesis project plans to mobilize deep learning techniques such as semantic segmentation, instance segmentation, panoptic segmentation and active contours to propose new specialized approaches in the analysis of satellite data for the boundary extraction task applied to the delineation of agricultural plots, as well as for the characterization of the corresponding land use in terms of cropping practice. The approaches developed as part of this thesis for the characterization and extraction of agricultural plots will be tested and evaluated over study areas in France (Pays de la Loire, Gard) as well as territories of the Global South (Benin)

Research units: TETIS, INRAE

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Main scientific field: Maths and its applications

Labeled PhD – 2022-2025

Optimal control of irrigation: a dual modeling approach combining a mathematical and a simulation model; Application to Optirrig

Abstract: This project concerns irrigation decision support tools based on the optimization of numerical models developed at INRAE within the AQUA department (Optirrig model) in a context of climate change and preservation of water resources. The motivation is to provide a decision i) in real time, based on the information provided by the sensors (in particular humidity) as feedback controls, ii) integrating seasonal management constraints such as quotas, iii) integrating meteorological information not precisely known in the medium and long term (“adaptative” control laws). The targeted approach is a "double modeling" approach that relies on developing a mathematical model that is a companion to the numerical model to be optimized, as well as on developing mathematical optimization methods on the companion model. These targeted methods are related to the optimal control theory for which promising first results have been obtained in previous works. The Phd advisors are research scientists in applied mathematics and the research scientist responsible for the development and operational uses of the numerical model Optirrig.

A final goal of the project could be to test in real conditions the irrigation strategies developed in the thesis, via the installation of Optirrig on a Raspberry-Pi processor usabale to collect observation data of the water status of the soil and allowing a closed-loop control of irrigation.

Research units: MISTEA, INRAE

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Main scientific field: Technology and Sciences

Labeled PhD – 2021-2024

Development of a digital tool for evaluating soil quality in a participatory manner

Main scientific field: Technology and Sciences

Abstract: In addition to their agronomic and production functions, agricultural soils produce multiple ecosystem services. Mapping indicators of these multiple potentialities is required to support planning decisions, particularly to control the artificialization of soils generated by urban growth.

However, the soil quality indicator maps produced still have a number of operational limitations:

- Soil classification is carried out by a small panel of experts without local users having 1) been identified and 2) participated in the design and representation of these classifications. This can hinder the acceptability of these classifications and their use in land use or occupation decisions;

- The cartographic form of the output is also defined without consultation, particularly on the way in which cartographic uncertainty is communicated, which can lead to misinterpretation and biased decisions;

- Users cannot introduce local knowledge to correct the regional estimates of soil properties on which the soil indicator maps are based.

In order to overcome these limitations, we propose to develop a participatory approach to soil quality zoning based on the replacement of conventional maps by interactive visualisation tools allowing future local users to be involved in the soil quality assessment mapping process.

Research units: LISAH, TETIS, INRAE

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Main scientific field: Life and environmental sciences

Labeled PhD – 2020-2023

From satellite images to land use systems: detection and characterization of large-scale land acquisitions from Earth Observation data

Abstract: Large scale land acquisitions (LSLAs), often referred as “land grabbing”, refers to the control of large pieces of land by individuals, states or companies for agricultural purposes, logging, tourism, conservation, mining, urban expansion or large infrastructural works. This study deals with agricultural LSLAs, the most common type of LSLAs. Given the availability of favourable biophysical resources and the lack of strong land tenure regulations, those investments are mostly prevalent in developed countries (75% in Africa). Because information of those acquisitions is scarce and dicult to obtain, systems allowing LSLAs detection, characterization and monitoring in space and time are needed. With the increasing availability of global satellite data products, technological development in cloud computing, image and data mining analysis, remote sensing (RS) has appeared to be an interesting tool. Their repetitive coverage at short intervals and consistent image quality, combined with the free-of-cost availability of dense temporal series of satellite images, have explained their wide use in land use and land cover change detection studies. However, because LSLAs are the manifestation of complex human-environment dynamics in a given place, they are not directly observable from RS images. While their detection is often impossible based on land cover observations only, these land use systems may be inferred from observable activities, structural elements in the landscape or spatiotemporal characteristics at dierent scales. This research aims to explore the potential of RS data to detect and characterize agricultural LSLAs at dierent scales. The challenge here is to relate the radiometric signal, which is sensitive to the biophysical properties of the surface, to the land use system in place. In this research, RS indicators and methods will be reviewed and a conceptual approach will be proposed and tested on a set of study cases in Senegal.

Research units: TETIS, CIRAD

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Main scientific field: Engineering sciences

Internship - 2024

Spatial transfer of deep learning models for rapeseed crop mapping

Abstract: Nowadays, more and more remote sensing data are available, offering the possibility to follow a geographical area over time. The time series thus generated represent an essential source of information to efficiently manage agriculture on a territorial scale.

To this end, remote sensing data is used as input to machine learning (ML) methods to provide updated land cover maps. To do so, ML methods require a large amount of ground-truth data, which poses challenges for their applicability where little or no reference data is available.

Re-using ground-truth data acquired at a particular study site to transfer the learnt model to a different area would avoid (or reduce) new costs and take advantage of previous investments. Unfortunately, directly transferring a model from a geographical zone to another one can be inefficient as the two regions may present different environmental and/or climatic conditions. This results in differences in the distribution of the acquired satellite data. This internship proposal aims at developing an innovative deep learning/transfer learning method with the aim to transfer a model learnt on a particular area (where ground truth data is available) to a different geographical area where no available ground truth data is accessible.

In the context of this internship we will exploit freely available multi-temporal Sentinel-1 imagery, less sensitive to cloud occlusions due to the intrinsic nature of the SAR signal, with the aim to build a deep learning classification model for the mapping of the rapeseed crop culture. In addition, the designed deep learning method will exploit recent domain adaptation techniques to cope with the transfer task between three different geographical areas, namely: France, USA and Canada. We will evaluate the capability of the underlying deep learning model to be calibrated over one of the three areas and deployed on the remaining ones.

Research units: TETIS, INRAE

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Main scientific field: Engineering sciences

Co-funded - 2024

Identifying unexpected observations in territorial crowdsourcing projects for agriculture: the case of vine water status monitoring at regional scale

Abstract: In the context of climate change, monitoring vine water status at the regional scale is of paramount importance for short- and long-term decisions. One of the promising approaches for this monitoring is the collaborative collection of observations by stakeholders of the wine industry, known as crowdsourcing. Crowdsourcing has already demonstrated its ability to collect a large amount of observations, particularly with the ApeX-Vigne application initiated by the project team. For the democratization of this approach, the missing link is the development of methods for analyzing the collected data. The identification of unexpected observations is a particularly important challenge, as these may be either aberrant observations that need to be eliminated to improve the overall quality of the dataset or, on the contrary, interesting observations that may reflect an original growing system or atypical soil and climate conditions.

The phenomena under study are seasonal and generally follow a known and expected temporal dynamic. They also often depend on the environment (soil, climate, etc.), as for drought, and are therefore also spatially structured. The approaches that will be explored in this thesis will seek to use this knowledge about the phenomena under study to define expected behavior and identify observations deviating from it. The formalization of this knowledge may be based on historical data (e.g. historical time series of vine water status monitoring on reference plots) or auxiliary data (e.g. time series of remote sensing images). Spatio-temporal statistical methods will be used, and a Bayesian framework will be favored. Other approaches, such as the use of conformal prediction, may also be tested.

Research units: ITAP, INRAE

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Main scientific field: Engineering sciences

Co-funded Post-doc – 2024-2026

Determinants, modalities and value of data sharing by farmers and SMEs in blockchains for transparent and sustainable food supply chains

Abstract: Consumers' mistrust of complex food systems increases with the number of food scandals and sanitary crises. To address this, producers and retailers are experimenting with blockchain, "a digital, decentralised and distributed ledger in which transactions are recorded and added in chronological order with the goal of creating permanent and tamperproof records" (Treiblmaier, 2018, p. 547). It offers a novel way to trake and trace products along food supply chains (FSCs), thank's to the members' contribution and joint construction of immutable information that can be visible to all and communicated to consumers. It has the potential to improve the functioning, digitisation, automation and sustainability of FSCs. While blockchain allows for the design of new collective and participative modes of organisation, it is also a monitoring system whose transparency is co-constructed through the sharing of sensitive data previously kept private. The conditions to enable these potentials and minimise the risks of this technology are therefore unknown.

The post-doctorate is part of an ANR JCJC project proposal that assesses the potential of blockchain to make FSCs more participative, transparent and efficient, to contribute to the transition towards sustainable food systems. Focusing on farmers and SMEs, the post-doctorate aims to better understand the conditions, modalities, risks, reluctances, and individual and collective costs and benefits of data sharing in FSCs for traceability, transparency and valorisation of practices. The determinants and valorisation of data sharing are examined in the context of power dynamics within FSCs. Mobilising management, economic, environmental and data sciences in a participatory approach with farmers and SMEs, the project aims to develop a grid structuring the co-construction of information for sustainable, transparent and efficient FSCs, and to identify the data necessary for its construction, while helping to prepare these producers for the challenges of the spread of such systems of FSCs' transparency.

Research units: MoISA, TETIS, INRAE

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Main scientific field: Engineering sciences

Funded Post-doc – 2024-2025

A hybrid approach to combining biophysical modeling and remote-sensing derivatives model 3D canopy architecture in vineyards for differential management.

Abstract: Measuring the size, shape and density of vineyard canopies is not easy. The canopy will continually evolve over the season and the 3D characteristics of the canopy will strongly influence the need for and the efficacy of crop protection actions during the season. Proximal sensors can provide high-resolution information on the 3D canopy structure, but are limited in the spatial and temporal resolution of deployment. Satellite imagery provides high-resolution spatio-temporal information on vineyard vigour, but the image information is only partly influenced by canopy shape. Therefore, neither sensing system, in its native form, is capable of providing relevant vineyard information to support in-season, differential crop protection strategies. This project will use derivatives from remotely sensed imagery, obtained via time-series analysis of vegetation indices and from inverse radiative transfer models, to generate models that can predict the 3D characteristics of vineyards over a large area. The calibration and validation data for these models will be derived from high-resolution LiDAR data at selected points. The processing of these LiDAR data will be based on new algortihms that provide 3D information on the vineyard canopies. The modelling of the 3D canopy characteristics with the remote-sensing derivatives will be performed using a mixture of linear and non-linear machine-learning methods. Once a stable model has been found, the predicted, large-scale 3D canopy information will be substituted into exisiting spray deposition models to evaluate if the 3D canopy predictions are of sufficient quality to be used for management.

The project will be built of existing data sets (Sentinel 2 imagery and LiDAR campaigns by UMR ITAP) and existing programmed algorithms for data processing (time-series, LiDAR and radiative transfer models from both UMR ITAP and TETIS). It seeks to connect several previous #DigitAG projects to generate useful, operational vineyard information.

Research units: ITAP, TETIS, INRAE

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Main scientific field: Life and environmental sciences

Labeled PhD – 2020-2023

Territorial evaluation of the role of crop-livestock integration in carbon sequestration by cultivated soils in West Africa

Abstract: Carbon sequestration in cultivated soils is a major issue for climate change mitigation and preserving or even increasing their fertility. In the African Sahel region, regular inputs of organic matter is necessary for the preservation of their carbon stocks. Livestock raising is responsible for part of the GHG emissions of the agroecosystems, yet contributes thus to their sequestration potential, notably through manuring. It is the main driving force of organic matter transfers in the agrarian systems and integration of livestock and crop farming might constitute central characteristics in the identification of levers for carbon sequestration. The object of this PhD is to describe how crop-livestock integration affects cultivated soils carbon sequestration in Sahel agrosylvopastoral systems using spatialised stock-flow agent-based simulation models. Animal mobility being an essential aspect of the role of livestock farming on organic matter fluxes in the agroecosystems, we aim at its characterisation, in order to determine how it influences carbon fluxes. Through transhumance and the dependency to several inputs, the impact of livestock farming in these systems on the environment is partially transferred to other pastoral and agropastoral areas. Including these transfers into flux models should enhance the precision of the carbon balance computed at the scale of the simulated territories. Lastly, the simulation of agrarian systems archetypical of the evolutions of livestock management practices in the region and diverse with regards to their integration level is envisioned to characterise the effect of their progressive intensification on soil carbon sequestration and to produce indicators of these systems efficiency in terms of carbon balance.

Research units: SELMET, SENS, CIRAD

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Main scientific field: Technology and Sciences

Labeled PhD – 2017-2020

Methods for assessing quality of data coming from high spatial and temporal resolution observations: the case of decision making in viticulture

Abstract: Development of new technologies (UAV, Sentinel satellite, smartphones, etc.) has fostered the rise of new sources of information in agriculture. These technologies were mostly designed for other business sectors but still represent potential opportunities for being a support to expertise and decision making in agriculture. However, the data coming from these new sources of information have varied characteristics in nature, quality, and spatial, temporal or spectral resolution and extent. These data characteristics are not necessarily suited to the use as a support for expertise and decision-making. In that respect, evaluating the interest of a new source of observation considering its specific characteristics is a strong operational issue raising methodological scientific questions. This issue should be reinforced in the coming years with the emergence of new technologies with their own characteristics (hyperspectral imagery, nano-satellites, Terahertz, etc.).

In precision agriculture, many papers study the characteristics of measurement systems and optimal acquisition conditions for a dedicated and specific application (characterization of the variability of yield, vigor, water state, etc.). However, to our knowledge, there is no existing method to evaluate the interest of a new source of observation with given characteristics. The thesis will answer this challenge by proposing methods allowing i) to define the interest and the optimal mode of representation of a new source of spatial observation, ii) to evaluate the quality of a spatial data used as a decision support (iii) to improve the quality of spatial data in the particular case of a new source of observations: crowdsourcing.

Research units: ITAP, Institut Agro

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Main scientific field: Technology and Sciences

Internship - 2023

Multi-Modal Temporal Domain Adaptation for Land-Cover Prediction

Abstract: Nowadays, more and more remote sensing data are available, offering the possibility to follow a geographical area over time. The time series thus generated represent an essential source of information to efficiently manage our agriculture on a territorial scale.

To this end, remote sensing data is used as input to machine learning (ML) methods to provide updated land cover maps (LCM). To do this, ML methods require a large amount of ground truth, which poses challenges for their use where little or no reference data is available. For example, when a LCM needs to be updated from year to year.

Re-using ground truth data acquired in the past to transfer a model to a successive period will avoid new costs and take advantage of previous investments. Unfortunately, directly transferring a model from one year to the successive one can be inefficient as the two periods are affected by different environmental and/or climatic conditions. This results in differences in the distribution of the acquired satellite data.

This internship proposal aims at developing an innovative deep learning/transfer learning method to produce a LCM for a year T using remote sensing data on year T as well as previous ground truth data (i.e. year T-1). We will tackle a multi-source framework where the input will be multi-temporal Sentinel-2 imagery and SPOT6/7 imagery with the question of how to fuse these heterogeneous data (in spatial resolution and spectral content). The satellite images will be obtained through the THEIA and PEPS platforms and the Equipex GEOSUD (DINAMIS). The method developed will be evaluated on a study site in West Africa, Burkina Faso, featured by contrasted agricultural landscape.

Research units: TETIS, INRAE

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Main scientific field: Life and environmental sciences

Internship - 2023

Modelling collective strategies of crop-livestock cooperations in landscapes with mobile ovine herds

Abstract: Within the Sagiterres research project, innovative agroecological models have been identified in the Minervois area. They integrate agriculture and livestock in organic field crops, wine and livestock farming systems.

Livestock plays a central role (maintenance of space, supply of organic matter, etc.). However, maintaining livestock raises questions about access to fodder and grazing resources, and about animal movements in the landscape.

The hypothesis made is that the landscape has resources that could be opened up to herds and that it is possible to better coordinate the shepherds with various stakeholders in the landscape (wine growers, cereal growers, municipalities, forest managers, etc.) to adjust the level of stocking density with the available food resources.

A spatialized multi-agent model is being developed specifically within the research project to represent the landscape in its current functioning. It integrates involved stakeholders' logic, potential resources (plant cover, vineyard inter-rows, wasteland, etc.), herds' feeding needs and logistical elements related to space management.

The intern will explore the model and use it to simulate scenarios that will allow the identified initiatives in the landscape to be strengthened, perpetuated and even multiplied. The scenarios could be based on participative workshops conducted during the use of the serious game Dynamix.

Using the main results of the simulations, the intern will be able to evaluate scenarios of the initiatives' functioning and access to resources in terms of services provided in the landscape. The results will serve as a support for discussions on perspectives of a real deployment of such initiatives on the landscape and as a basis to involve territorial actors and public services.

Research units: AGIR, INRAE

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Main scientific field: Maths and its applications

Internship - 2022

A study of explainable machine learning model for land 1 cover mapping from remote sensing data

Abstract: In the continuity of the work carried out within the UMR TETIS on the analysis of satellite imagery for land use and yield estimation (in particular within the framework of the thesis of Yawogan Jean Eudes Gbodjo), we propose an internship of master of the duration of 5 months on aspects in connection with the "explainable machine learning". The objectives of this internship are to better understand if and how the techniques available today in literature and the associated concepts can be leveraged in the framework of satellite data analysis. To do so, the student will first make a bibliographical study of the techniques already proposed to "explain"/"interpret" deep learning models for imagery analysis. Then, experiments will be conducted on reference image datasets to allow the student to appropriate technical and methodological aspects. This task will consist in retrieving approaches already available in open-source (or in the implementation of some unavailable approaches) and in their validation on imaging datasets. Finally, one or more techniques chosen in the previous steps will be analyzed in the context of satellite imagery for a land cover task by leveraging on the data and knowledge acquired in the framework of Yawogan Jean Eudes Gbodjo's thesis.

Research units: TETIS, INRAE

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Main scientific field: Technology and Sciences

Internship - 2020

Multi-temporal and multi-scale satellite data fusion through deep learning methods for land cover mapping

Abstract: Nowadays, more and more data from satellite missions like the European Sentinel program are produced and made available, offering the possibility to monitor the same geographical area continuously over time thanks to high revisit period. Indeed, the Sentinel-1 (A / B) and Sentinel-2 (A / B) satellites acquire respectively radar and optical images of the Earth with a time frequency of about 5 days over the same geographical area and a spatial resolution up to 10 meters. The time series of satellite images thus generated represent a non-negligible source of information for efficiently managing our agriculture and adapting our farming practices to the major challenge of already noticeable changes in the climate. However, the need to put in place methods to efficiently and robustly manage and analyze this large and heterogeneous amount of data is still relevant. It is with this in mind that this internship proposal is included. In the continuity of the past work of Ms. Paola Benedetti (DigitAg master's internship in 2018) and current work of Mr. Jean Eudes Gbodjo (DigitAg thesis), we want to evaluate innovative methods based on deep learning and especially neural networks to map land cover as a fundamental input to crop monitoring systems, by coupling radar (Sentinel-1) and optical (Sentinel-2) time series to 10 meters of spatial resolution with SPOT 6/7 satellite images very high spatial resolution (THRS - 1.5 meters) whose annual acquisition repeatability is more modest. The SENTINEL satellite images will be made available through the THEIA and PEPS distribution platforms while the SPOT6/7 images will be obtained via the GEOSUD Equipex.

The methods developed will be evaluated on two study sites: a first site located in metropolitan France in the Gard department and characterized by a conventional agriculture and a second site (Koumbia) located in West Africa in the Burkina Faso country and characterized by familiar agriculture. In addition, the developed framework may be reused to other study sites such as Reunion Island. The reference data for the Gard site will be built through the Graphical Terrain Register (RPG) and IGN BD TOPO while for the sites of Koumbia and Reunion Island, the UMR TETIS already has the ground truth data acquired via previous field campaigns.

Research units: TETIS, IRSTEA

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Main scientific field: Life and environmental sciences

Internship - 2019

Do farmers' representations of cultivated plants influence the way in which digital technologies are adopted and used in the farm: the case of sound diffusion systems in viticulture and market gardening

Abstract: The use of digital technologies is growing on farms to help farmers better monitor and control their production systems. These technologies make it possible both to acquire numerous and accurate information on the state of animals or cultivated plants, and to act effectively on their direct environment to control their growth and development. The use of digital technologies is growing on farms to help farmers better monitor and control their production systems. These technologies make it possible both to acquire numerous and accurate information on the state of animals or cultivated plants, and to act effectively on their direct environment to control their growth and development. The question of farmers' adoption of such innovative digital applications is generally addressed in terms of attraction or aversion to new technologies and the organizational transformations they imply for the production system. However, considering recent social science works on the human-non-human relationship, it is also useful to question the links between representations that farmers have of animals and plants that participate in their production system, and adoption and use of digital technologies that impact the development and behavior of these living beings.

This project aims to address this issue for the original case of sound diffusion systems that are used on farms to protect crops, promote yields, participate in animal welfare. These equipments modify the direct environment of animals and plants, impacting them mechanically or through their senses. Nevertheless, there is no well-established scientific basis for validating the positive effect of such devices, and the use of digital sound diffusion equipments by farmers raises quite naturally the question of the representations that these farmers make of animals and plants present on their farms, and their ability to be positively impacted by sound. The work that we wish to develop along this master thesis focuses on the ethnological analysis of the adoption and use of sound diffusion systems in plant productions. We will target viticulture and market gardening, which are the two largest areas of application of sound devices in agriculture. Conducted on about 20 farms, the student's work will first consist in i) identifying the reasons for the adoption of this equipment and this choice of innovation (sources of information, arguments retained ...); ii) analyzing the use of sound devices and the innovations that this brings to the farm (choice of locations, changes in the use of equipment over time, integration into farm practices, etc.). Referring to social science work that explores the agency of plants, the student will then try to understand the representations that farmers have of cultivated plants, in order to identify a possible correlation between these representations and the kind of adoption and usage of sound diffusion equipments by these farmers.

Research units: MIAT, INRA

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Student's name: Eva SANTOS

Main scientific field: Technology and Sciences

Internship - 2019

DRdN, Raphias and Neurons, a neural network for counting raffia in the wild

Abstract: Palms are one of the most useful plant families, providing many economic, ecological and societal benefits in the tropics[1]. The species of the genus Raphia is the most widely used and important in Africa. However, anthropogenic pressure has negative impacts at the local and regional level on Raphias and no estimates of basic parameters (number of individuals, biomass, etc.) have been undertaken. Under natural conditions, these Raphias gather in swampy forests where the crowns are nested and therefore difficult to count in aerial view. To date, no study has been done on their enumeration despite their societal importance [2]. Recent palm counting studies[3][4] concern only oil palm plantations and use "Deep Learning" approaches[5].

The proposed internship will focus on this "Deep Learning" approach by deploying a neural network specifically trained for the detection and enumeration of Raphias in natural environments on remote sensing images. For this, the trainee will have at his disposal two sets of images: a set of virtual reference images consisting of simulated images from models of Raphias areas modeled using AMAP's Xplo software and a set of real images (UAV images and THRS satellite images) which will serve as validation test. First, the trainee will have to make a state of the art on the "Deep Learning" methods best adapted to the processing of remote sensing images and to our subject of study. Then, it will deploy and configure the selected network and apply it to both data sets. The evaluation of network performance will be conducted by (i) estimating the loss function (overall error), (ii) conventional statistical indicators (measurement) and (iii) geometric indicators (overall Dice index).

The supervision will be carried out by the i2p theme (UMR Amap), the UMR DIADE and by methodological support from UMR TETIS.

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Research units: AMAP, CIRAD

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Stake 2 – A better society inclusiveness for ICT-enabled agriculture

Challenge 7: Integrating agriculture into value chains

Main scientific field: Life and environmental sciences

Co-funded post-doc – 2024-2025

Determinants, modalities and value of data sharing by farmers and SMEs in blockchains for transparent and sustainable food supply chains

Abstract: Consumers' mistrust of complex food systems increases with the number of food scandals and sanitary crises. To address this, producers and retailers are experimenting with blockchain, "a digital, decentralised and distributed ledger in which transactions are recorded and added in chronological order with the goal of creating permanent and tamperproof records" (Treiblmaier, 2018, p. 547). It offers a novel way to trake and trace products along food supply chains (FSCs), thank's to the members' contribution and joint construction of immutable information that can be visible to all and communicated to consumers. It has the potential to improve the functioning, digitisation, automation and sustainability of FSCs. While blockchain allows for the design of new collective and participative modes of organisation, it is also a monitoring system whose transparency is co-constructed through the sharing of sensitive data previously kept private. The conditions to enable these potentials and minimise the risks of this technology are therefore unknown.

The post-doctorate is part of an ANR JCJC project proposal that assesses the potential of blockchain to make FSCs more participative, transparent and efficient, to contribute to the transition towards sustainable food systems. Focusing on farmers and SMEs, the post-doctorate aims to better understand the conditions, modalities, risks, reluctances, and individual and collective costs and benefits of data sharing in FSCs for traceability, transparency and valorisation of practices. The determinants and valorisation of data sharing are examined in the context of power dynamics within FSCs. Mobilising management, economic, environmental and data sciences in a participatory approach with farmers and SMEs, the project aims to develop a grid structuring the co-construction of information for sustainable, transparent and efficient FSCs, and to identify the data necessary for its construction, while helping to prepare these producers for the challenges of the spread of such systems of FSCs' transparency.

Research units: MoISA, TETIS, Institut Agro

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Main scientific field: Human and social sciences

Funded PhD – 2023-2026

Impact of digital use on practices and work in Sahelian pastoral farming

Abstract: The mobility of herders and livestock to cope with environmental conditions and ensure access to livestock markets is at the heart of Sahelian pastoral farming (Cesaro et al., 2010). Access to information on resource status and market opportunities is a major challenge. The improvement of network coverage (Salat et al., 2012), along with the decrease in equipment prices, has facilitated the widespread use of mobile phones by herders in the 2000s. Despite its use still being considered frugal (Ferrari et al., 2023), economic actors and development stakeholders see this tool as an opportunity to increase the productivity of livestock to meet a growing demand for animal products. Development projects for new mobile applications or information systems are underway to provide technical support and facilitate access to markets for these products (Cesaro et Sow, 2021; Cesaro et al., 2021). However, the impact of the use of digital tools on livestock systems is poorly understood, raising questions about the sustainability of these livestock support services. Based on a qualitative study conducted at the scale of livestock farms in Senegal, this thesis will focus on examining how the use of digital technology has contributed to modifying pastoral and agro-pastoral livestock systems, in the practices and ways of working of herders.

Research units: SELMET, Selmet, CIRAD

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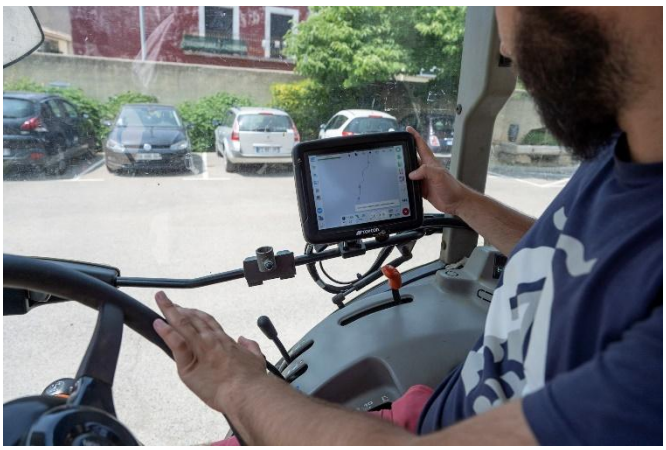

Main scientific field: Human and social sciences

Co-funded PhD – 2021-2024

How digitisation reshuffles the cards between uncertainty and dependencies: A comparative analysis France/Italy of farmers' strategies

Main scientific field: Human and social sciences

Abstract: The project aims to analyze the role of digital tools in strengthening producer-consumer relations and promoting more environmental friendly practices. It is in line with the European "farm to table" strategy of the Green Pact for Europe, which aims to offer healthy consumption to consumers by supporting alternative practices. Digitalization can allow farmers reducing the number of intermediaries, promoting the quality of their products, valuing the specificity of their production and thus obtaining a higher remuneration. However, digitalization does not guarantee the contractual stability of traditional channels. This is why we wonder if digitalization can constitute a way to reduce uncertainty and manage dependency to customers and suppliers. From a theoretical point of view, this doctoral work is based on the theory of dependence on resources (Pfeffer and Salancik, 1978). Our thesis is that digitalization enables the farmer to regain control over the resources that its survival and development require. From an empirical point of view, we mobilize longitudinal exhaustive data from all French and Italian farms (Census of Agriculture and structure survey). We measure the level of digitalisation of producers, the certifications adopted and their marketing methods. In methodological terms, this project is based on simultaneous triple equation models and matching type models. France and Italy are subject to the same requirements in terms of the reduction of phytosanitary products but have different commercial and production strategies. These data will be supplemented by qualitative surveys to appreciate how do farmers estimate their dependence to consumers, distributors, suppliers and complementers and to which extent they consider digitalization as a way to facilitate their access to environment resources.

Research units: MRM, MoISA, Université de Montpellier

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Main scientific field: Human and social sciences

Labeled PhD – 2023-2026

New Business Models for a Co-evolution of Digital, Agroecological and Circular Trajectories

Abstract: The main objective is to analyse how the use of digital technologies transforms existing business models and contributes to the construction of new agroecological and circular business models throughout the agri-food value chain. Digital technologies could be major instruments to support sustainable agricultural development (Lajoie-O'Malley et al. 2020). However, some authors call for a better understanding of the consequences of digitalization (Bronson & Knezevic 2016; Carolan 2017). The co-evolution of digital and agroecological trajectories could present great potential in changing practices and relationships between the actors in the agri-food value chain (Klerkx et al. 2019). Business models related to the circular bioeconomy and agroecology can be considered as innovative management responses to environmental challenges by providing conservation, recycling and reuse of resources using digital tools (Donner et al., 2020).
The envisaged methodology includes: 1) a literature review in order to develop the conceptual framework, 2) a review of existing policies and practices via a document study, and 3) more in-depth qualitative case studies of agricultural and food businesses and value chains. Occitanie is a pioneer in the implementation of regional policies to support the agroecological transition and the circular economy. Thus, the Occitanie region will serve as a main case study to understand the challenges of a co-evolution of digital, agroecological and circular trajectories. However, a comparison with other regions is envisioned. The main expected results of the study include providing an understanding of digital trajectories and their effect on new configurations of the agri-food value chain in order to develop agroecological and circular practices.

Research units: MoISA, INRAE

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Main scientific field: Human and social sciences

Co-funded PhD – 2019-2022

Digital transition in agriculture: description of its deployment and impact on the positioning of farmers in the value chain

Abstract: The project focuses on describing the current state of the digital transition in agriculture and future directions. The objective is to understand and explain the determinants and obstacles to the use and appropriation of digital technology in agriculture, with a perspective that goes beyond the mere diffusion and adoption of innovations. Using concepts from the domains of economics, management and sociology, the selected approach makes it possible to characterize the heterogeneity of behaviors, the implied evolutions for current jobs, and the possibilities of changes in the positioning of farmers in the value chain. From a methodological point of view, the project will develop an analytical framework with a temporal dimension and crossing points between the different stages of the digital transition. The economic impact will be captured through the organizational capabilities approach that allows the identification of practices that generate a competitive advantage and therefore a better positioning in the value chain. Empirically, surveys will be conducted with farmers, agricultural advisers, experimental farms, and digital solution publishers to describe and understand the digital transition in agriculture. Then, interviews will be held to verify the results coming up from surveys and characterize the future directions of this digital transition.

Research units: MRM, MoISA, Université de Montpellier

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Main scientific field: Life and environmental sciences

Labeled PhD – 2020-2023

Spatially explicit modeling and multicriteria evaluation of organic material flows to promote a circular economy at the scale of La Réunion island

Abstract: La Réunion, like many island territories, faces strong challenges of food and energy self-sufficiency, and climate change mitigation. Its volcanic soils and tropical climate are important assets, with high biomass availability, which can supply a circular economy (i.e. in opposition to the linear model "produce, consume, throw away"). There is significant room for improvement in terms of local biomasses recycling with environmental, economic and social benefits for the island. The aim of this thesis is to conduct a multicriteria evaluation of several recycling scenarios aimed at mitigating greenhouse gas (GHG) emissions by valuing local resources versus importing inputs. The conceptual framework of this thesis is industrial ecology. Its scientific originality is built around an integrated analysis of several biomasses recycling scenarios between 4 major sectors of the local economy: agriculture, livestock, agro-industry and urban. The chosen methodology is part of a participatory approach, mobilizing various actors (farmers and their cooperatives, private companies, local authorities, etc.) and a dynamic and spatially explicit simulation tool for a medium-term territorial prospective. This tool will be used to explore, with stakeholders, the dynamics of biomass flows between the 4 sectors mentioned above and GHG emissions. The mobilization of this tool and fine spatial data (such as the geolocation of farms, processing units, relief constraints, roads, etc.) for the management of biomasses at the island scale is new in La Réunion.

Research units: SELMET, CIRAD

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Main scientific field: Human and social sciences

Labeled PhD – 2017-2020

Impact of digital development on farm performance and agglomeration

Abstract: All firm attempt to improve their economic performance, however in our modern-day world, they must be also concerned about their environmental performance. New digital technologies are seen as a new source of performance and innovation gain. In this thesis we will examine whether these technologies can improve the farm's economic and environmental performance. Also, we will investigate how far these technologies influence the agglomeration and the concentration of agricultural activities by releasing the constraints of geographical proximity for the accumulation of knowledge (spillover of knowledge localized) and / or by reducing the congestion factors related in particular to regulations and to the environmental nuisances.

Research units: LARESS (Laboratoire de recherche en science sociale /ESA), ESA

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Main scientific field: Human and social sciences

Internship - 2021

Qualitative interview data from an ecosystem of actors involved in food transparency with blockchain

Abstract: In the framework of research conducted on food transparency using the blockchain and its impacts on agricultural producers, (non-directive and semi-directive) interviews were conducted with various stakeholders. These actors belonging to the agri-food and digital agriculture sector provided a certain amount of qualitative data about the projects they are carrying out in relation to the use of blockchain for food transparency. The intern's mission would be to find a way to analyze this data, to bring a look at the information provided by these actors, to participate in the recruitment of new interviewees, to conduct new interviews, and to participate in research meetings.

Research units: MRM, Université de Montpellier

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Main scientific field: Human and social sciences

Internship - 2020

Productive and commercial strategies: Digital technology for organic certification and short food supply chain sales

Abstract: In a context where the environment is a growing concern, both public and private actors multiply initiatives to guarantee the environmental quality of production sold. As a result, certifications based in particular on the compliance of production with the Maximum Residue Limits and the use of authorized molecules are implemented. Among public, private, national and international certifications that producers must comply with, we focus on the organic certification. In 2018, respectively more than 90% and 75% of consumers reported having already consumed organic certified products or consuming them regularly. In parallel, certified production is developing. Thus, 2 million hectares are organic certified, or 7.5% of the agricultural area. At the same time, and in order to meet consumer expectations of proximity, producers are more likely encline to sell their production through short food supply chain channels (SFSC). By this way, the producer can capture a larger share of the added value, increase his income and thus develop his activity. Today, 1 in 5 producers sells through SFSC, which represents less than 10% of food consumption. On the basis of econometric models based on exhaustive data, our previous work identified brakes and levers – whatever individual, structural, financial and organizational - to SFSC and demonstrated an interdependence between the productive strategy and the commercial one. This interdependence will be reinforced by the framework of the Food and Agriculture Act adopted in 2018, which sets a target of 50% of local or organic or quality products in collective catering by 2022. In order to go further and consider the environment in which producers operate, it is essential to analyse the interaction of digital technology with commercial and productive strategy. In an increasingly interconnected world, we can wonder about the contribution of digital tools on one hand on the strengthening of the producer-consumer link and on the other hand on the enhancement of productive efforts. The objective of the internship is to develop a typology of farms based on the triptych: use of digital technology, marketing methods and production methods.

Different steps will be necessary:

1. Realize a literature review to identify the underlying issues of each item (access to digital, marketing and production methods) and to understand their relationship.

2. Appropriate the data from the Agricultural Census that allow a precise characterization of farms in terms of commercial and productive strategy in relation to their use of digital tools. On the basis of the information available in this Census, farmers using digital tools will be approached through their use of a specialized software for accounting and/or technical management.

3. A statistical and econometric analysis will let appreciate the between: digital access, marketing and production methods.

Research units: MoISA, INRA

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Main scientific field: Human and social sciences

Internship - 2019

Performance and risk in agricultural and agri-food businesses: What can we learn from Business Analytics?

Abstract: French agriculture and agri-business firms have been highly decreasing over the last 20 years (concentration and/or disappearance). From 1988 to 2010, more than a half of farms disappeared and, from 1995 to 2015, the number of agricultural cooperatives fell by 40%. This erosion of this economic network of firms as part of the whole value chain did not necessarily lead to better economic and financial performance, considering that the average added value rate of agri-business firms went down in almost 20 years, from 33% (1997) to 18% (2015). It is so particularly worrying. In this context of repetitive economic and financial crisis, markets high volatility, and the increase of firms' disappearance by closure or liquidation, professionals and public authorities increasingly focused on performance and risks analysis. They show the willingness to prevent firms' difficulties. The aim of this Master internship's proposal is to provide an analysis of the relations between performance and risk in agricultural and agri-food companies in France. To do this, the work will consist of the following steps:

- A review of the literature in Economics and Management to define the notions of risk and performance as well as characterize the causal relationships already identified.

- Identification of the elements of a Business Analytics approach that can be mobilized to investigate and understand the evolution of the risk and performance of agricultural and agri-food businesses.

- A characterization and classification of existing professional and / or public databases, and

- A test of the business analytics approach selected. During this Master internship, the concept of Business Analytics will be considered in these three main dimensions:

- Descriptive: Use of descriptive statistics and data mining to obtain information characterizing the main trends in performance and risk as well as an identification of variables and relationships that may exist, without ex-ante hypotheses, between the concepts of performance and risk in the collected databases.

- Predictive: Suggestion of models based on longitudinal series to forecast potential future evolutions.

- Prescriptive: Based on optimization models, identification of areas where changes can be expected to improve the performance of agricultural and agribusiness enterprises under risk constraints.

During the internship, contacts with both private and public partners in France (APCA, ANIA, Coop de France, Groupama) as well as in the USA (Cornell University and Teradata University Network) are expected. The final objective of the comprehensive project, in which internship topic is considered as a first step, aims to develop a tool as analytical well as consulting services for supporting agricultural and agri-food businesses in preventing of economic and financial risks while maintaining or increasing performance.

Research units: MoISA, INRA

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Main scientific field: Human and social sciences

Internship - 2019

Digital uses in short food supply chains: trends, relational dynamics and prospects for the sustainability of agriculture

Abstract: Short food supply chains are not necessarily new in France but have been renewed since the mad cow crisis and above all their introduction on the political agenda in 2009. Still often associated with activist or protesting forms, they now represent a large diversity of chains, which the use of digital would contribute to develop and to make known, by producers as well as consumers. Players in short food chains, at the same time, are diversifying, with the massive entry of producers from long chains, social entrepreneurs and younger and less-educated consumers: does digital play a role in this direction? Do the equipped chains, mediated by the NICTs, meet the expectations of these new consumers, in terms of information, practicality, guarantees, transparency? If yes, under what conditions? What opportunities and constraints does this generate for producers and entrepreneurs? With which results?

This Master, embedded in participatory and pluridisciplinary research, has two objectives: first, from a first inventory made in 2018 by our team in collaboration with Open Food France, an association specialized in the development of digital projects in short food chains, the objective is to better understand the different uses of digital in short food chains and their roles in the change of scale and in the democratization of these chains, based on framing surveys with experts at the national level (among which experts of the RMT Alimentation locale, co-led by INRA UMR Innovation) and in others countries of Europe (within the focus group on short food supply chains of the European Partnership for Innovation to which INRA takes part). Second, through an analysis of different types of short food chains equipped by NICTs, the objective is to study how NICTs redefine the relations and interactions between producers and consumers and with the team leading the chain, which new resources and constraints (information, information of consumers...) they allow to circulate, and how does this contribute to sustainability, of farms especially.

In collaboration with Open Food France, and by associating inputs from economic and network sociology and management sciences, we will test two hypotheses in particular: relationships only virtual cannot suffice to build confidence in the chain but make evolve face-to-face relations in a positive direction regarding the economic viability of the structures which carry the chain (farms, enterprises); the relations triggered by the use of digital, moreover, favors the evolution of the short food chain towards taking into account new dimensions of sustainability such as the environment, health or ethics.

Research units: INNOVATION, INRA

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Main scientific field: Human and social sciences

Internship - 2018

Identification of the uses of digital, its impacts and consequences in agricultural organizations

Abstract: The use of digital technology on farms is expected to improve simultaneously productivity, traceability, working and living conditions for farmers, and also to reduce negative impacts on the environment. In this perspective, it is necessary to better understand the ways in which these technologies are used and appropriated by farmers, in conjunction with their agricultural advisors, and to measure the impacts and consequences of these technologies in terms of sustainable development. In order to prepare this work, it is necessary to identify the important data to be mobilized by qualifying them and evaluating their links with the uses, the organizational choices and the sustainability of the farms.

The objective of the master's work is to carry out a preliminary study before collecting data on the uses of digital in agriculture, particularly numerical management tools, their impacts on farms, specifically in terms of organizational choices, and their purposes and / or consequences in terms of sustainability. From a theoretical point of view, this work can be based on the concept of management system as defined by de Vaujany (2005). In order not to obscure the interactions between tool (s) and actor (s), it is essential to consider the tool as inserted in a device, an object of analysis particularly interesting for the understanding of the tools of management in situation, to understand their use.

In terms of methodology, the work will be a global reflection based on a documentary and bibliographic study, both theoretically and methodologically (choice of variables to be recorded, modalities of registration, etc.). In addition, a bibliography on the construction of socio-economic observatories can be consulted (see, for example, Chebroux, 2011). Finally, non-directive interviews will allow the student to characterize digital devices, in terms of objects, rules and actors.

A representation of the modalities of use (purposes) attributed to the digital devices will be elaborated. It will allow a first draft of the identification of the potential impacts of the numerical management tools on farms, especially in terms of organizational choices, according to the identified objectives. After describing the potential goals and impacts, a structuring of the latter according to the three pillars of sustainable development will have to be carried out. This work will be based on an analysis of the literature on ICT and sustainable development (see, for example, Faucheux et al., 2010).

The expected deliverable will be the preparation for the implementation of the collection of information to feed a future database, which will complement the data from that of AGROTIC. It will also prepare the collection of data on impacts in terms of organizational choices and the consequences of digital technologies for the sustainable development.

Research units: MoISA, INRA

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Main scientific field: Human and social sciences

Internship - 2018

Universe of opportunities to distribute fresh agricultural and food products with TIC

Abstract: The topic is linked with the PhD topic selected by DigitAg, whose name is " Distributing durably with digital? The case of fresh agricultural and food products ". The objective of the works is to depict the state of art of literature (scientific and grey literature) dealing with present model for the distribution of fresh agricultural and food products, regarding the embedded TIC (nature and articulations of the TIC). This first state of art will highlight the panorama of experiences on the ground (in Southern as well as in Northern countries), and scientific gaps. It will depict also opportunities open by new TIC, and not already implemented through any business model. A particular attention will be paid to relationships between nature of the TIC/usage of TIC/ articulation of TIC within the value network, and features of the distribution systems, in order to draw generalities, as far as possible. As a result, we expect for one scientific publication in the field of Management Sciences. Moreover, the works provided during this Master thesis will be the first step to design the perimeter of the future works carried out in the PhD.

Research units: ITAP, IRSTEA

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Stake 2 – A better society inclusiveness for ICT-enabled agriculture

Challenge 8: ICT and agricultural development in Southern countries (Africa)

Funded post-doc – 2023-2024

Integration of heterogeneous data for simulation of livestock-wildlife contacts

Main scientific field: Life and environmental sciences

Abstract: In a context of human population growth and water scarcity due to climate change in many African regions, a better understanding of how climatic and environmental factors, as well as agricultural and livestock practices, determine the mobility and contacts between livestock and wildlife is a major challenge for identifying management methods that reconcile agricultural development and conservation issues. The aim of this postdoc is to develop innovative methods for integrating heterogeneous data to simulate livestock and wildlife mobility, and potential contacts between them, in the Hwange region of Zimbabwe, and to explore climate change and land-use scenarios defined in consultation with the various stakeholders in the area, in order to test the modeling tool as a decision-making aid for better resource management.

Research units: TETIS, SENS, CIRAD

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Main scientific field: Human and social sciences

Labeled PhD – 2023-2026

Digital platforms and access to agroequipment for Mexican family farmers

Abstract: The doctoral project aims to analyse the drivers for farmers and providers to adopt a digital tool that offers increased access to agricultural equipment. In particular, it will provide a better understanding of how such a digital farm equipment rental platform fits into conventional rural community systems. The lessons from this analysis will provide insights on how, and with what effects, a bundle of socio-technical tools and knowledge products are inserted within the daily life of Mexican family farms, with a particular focus on the co-evolution of access to scale-appropriate agro equipment and farming practices.

Research units: Innovation, CIRAD

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Main scientific field: Technology and Sciences

Co-funded PhD – 2018-2021

Leverage Multi-Source Remote Sensing data via machine learning to improve Crop Monitoring Systems

Abstract: Face to population increasing and the environmental impacts of climate change, ensuring the food security of populations while promoting sustainable agriculture that preserves terrestrial ecosystems and biodiversity (Goals 2 and 15 of the UN Sustainable Development) becomes a major challenge for the future of our society. As satellite missions multiply (eg Sentinel), various sources of information are now available to better characterize agricultural systems and associated practices at the regional, national and global scales. At the same time, the integration of these various sources of data, especially for agronomic issues, remains a real challenge.

The aim of this Ph.D. is to propose new machine learning approaches particularly with deep learning to integrate the multi-source and the multi-temporal information provided by optical and radar time series and very high spatial resolution imagery in order to improve the characterization of cultivated areas and the estimation of agricultural yields from data collected in the field.

The developed approaches will be evaluated with a cross look at contrasting sites in terms of crop systems and / or agricultural practices (France, Senegal).

Research units: TETIS, AIDA, IRSTEA

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Main scientific field: Life and environmental sciences

Labeled PhD – 2016-2019

Spatial estimation of yield for a perennial crop in West Africa: the case of mango case in Senegal

Abstract: In Africa, crop yield estimation is a critical and strategic challenge to face development issues and reduce population vulnerability to global changes. However, tools for harvest estimation are still vague for most of annual crops. In the case of perennial crops (e.g. fruit trees), it exists an important knowledge gap and methods are still missing because of the lowest scientific interest for this kind of crops; although specific questions arise for these crops (e.g. featuring the variability in plant phenology across and between trees, and orchards?). Thus, the aim of this Ph.D. is to develop an operative tool for a multi-scale spatial estimation of mango yield from the tree to the regional scale (the region is the Niayes area in West Senegal, the main horticultural production area of the country). This work will rely on various image analysis methodologies brought together: at regional scale, satellite images will be used to classify mango orchards following a typology of mango-based cropping systems; at orchard and tree scales, yield heterogeneity at the intra and inter orchard levels will be quantified within a monitoring network of 30 orchards representing the cropping system variability of the study area. For this purpose, the number of tree organs (sprouts, inflorescences, green and mature fruits) will be counted by analysis of RGB images at the tree scale, and RGB and multispectral orthomosaics will be acquired by U.A.V. and analysed for agronomic indices at the orchard scale. Agronomic factors of the tree (variety, crown size, height and trunk diameter), agroecological parameters (crop management, cultivated biodiversity, orchards structure) and data describing the environment (landscape structure, climate, pedology) will be taken into account at each scale. In fine, mango production estimated at tree and orchard scales by image analysis will be extrapolated at regional scale by integrating these factors. Finally, this thesis could bring opportunities to develop an innovative tool for multi-scale spatial estimation of mango yields.

Research units: HORTSYS, CIRAD

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Main scientific field: Life and environmental sciences

Labeled PhD – 2016-2019

Modelling green life of banana fruit, impact of spatial variability

Abstract: Decision about harvest time of banana bunches is based on the fruit diameter and fruit age, expressed as a number of degree days. Bunches are harvested as soon as they reach a given target diameter or a scheduled sum of degree days. Empirical limits have been determined by Compagnie Fruitière in order to ensure an optimal Green Life (GL) and to prevent fruit ripening during transportation. Fruit GL designates the period between harvest and banana turning green to yellow. Inappropriate harvest date can lead to the loss of all the shipment. Indeed, bananas produce ethylene during their climacteric period which increases ripening of other bananas. Harvest decision is then an economical and agronomical compromise between yield and safe GL. The method currently used has proven to be robust but may not be optimal. We make the hypothesis that GL could be better estimated by taking into account the production environment, using data from the production information system. The analysis of factors affecting the GL should allow to better asses maturity. The approach chosen is to use spatial information, with different resolutions, and to check the influence of pre-harvest conditions on physiology and maturity evolution after the harvest. The field of study is related with precision agriculture, site-specific farming and information and knowledge management. The main scientific issues are: how to use production data to identify effects on banana GL? (Experimental vs observational studies) How to use spatial information with unsynchronized behavior of individual plants?

Research units: ITAP, IRSTEA

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Main scientific field: Technology and Sciences

Internship - 2021

Design and development of a recommendation Web service of relevant semantic resources in agriculture

Abstract: The master internship is part of the D2KAB project (www.d2kab.org), a research project started in 2019, which aims to help developers and users of agricultural data to transform their data into actionable knowledge. The D2KAB project develops and maintains AgroPortal, a public platform for semantic resources (thesaurus, terminologies, vocabularies, and ontologies), specialized in the agriculture and agronomy domain. AgroPortal is founded and maintained by the LIRMM laboratory in collaboration with the INRAE. It hosts around 126 semantic resources and offers its users a variety of semantic web services (search, annotation, alignment, etc.). Currently, we are implementing a new Web service that makes AgroPortal semantic resources easily interoperable and reusable. More concretely, we adopt open science principle, mainly the FAIR principles (acronym of Findable, Accessible, Interoperable, and Reusable), via the exploitation of automatic techniques. In this context, we are offering an internship that aims to build and implement a recommendation system for semantic resources (described in OWL, OBO, and SKOS) within our platform. We hope that the recommendation system that will be developed by the future intern will support and enhance, on an international scale, AgroPortal's FAIR vision. The main objective of the master internship is to use artificial intelligence techniques for the realization of a recommendation Web service of semantic resources. More precisely, the main missions of the internship concern:

1. The implementation of an identification method for similar semantic resources based on their description (e.g. authors, metrics, etc.) and content (e.g. key concepts, alignments, reused data, etc.).

2. Recommendation of relevant semantic resources using machine-learning techniques aiming to improve the integration and reuse of existing AgroPortal's semantic resources.

3. The development of a human-machine interface for displaying recommendations.

4. The deployment of the recommendation Web service on our portal and testing of the results.

Completing the internship assignments will require motivation to learn semantic Web technologies, a good knowledge of existing artificial intelligence techniques, and technical background of at least one scripting language such as R or Python.

Profile of the desired candidate:

- Computer training, data science or equivalent

- Strong skills in Web development and in C or Java language

- Motivated, autonomous and rigorous

Research units: LIRMM, Université de Montpellier

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Main scientific field: Human and social sciences

Internship - 2024

Evaluation of systemic changes induced by the use of digital technologies on farms: the case study of the SoYield® Decision Support System (DSS) in the Niayes area of Senegal

Abstract: While studies assessing the impact of digital technologies (including Artificial Intelligence) in agriculture are multiplying in Northern and Eastern countries, they remain few and far between in Southern countries, particularly in West Africa. However, one of the conditions for these technologies to truly accelerate structural transformations on farms in these countries is to conduct research into their impact. The aim of this study is to assess the social, economic and technical changes brought about by the adoption of the SoYield® Decision Support System (DSS) by mango producers in the Niayes region of Senegal. Using a qualitative approach, data were collected from a variety of stakeholders involved in the mango sector in the Niayes: small and medium producers, large plantations, banabanas (resellers), trackers, Producers' Organizations (POs) and support services. A thematic analysis was then carried out to process the data. Combining the frameworks of Glover et al. (2019) and Rogers (2003) enabled us to trace the introduction of SoYield® in the Niayes and identify four responses since this introduction: (1) use, (2) non-use, (3) use then abandonment and (4) use and detour. This in itinere impact evaluation showed that DSS induced more changes on the social level (access to new information, time saving, modification of interactions and improved job satisfaction) where changes were less expected than on the economic level (increased bargaining power and income) where changes were more expected. At this stage, the evaluation has not identified any major technical changes. Furthermore, the prospective analysis with actors potentially interested in DSS revealed that Producer Organizations and Support Services are the actors most motivated to use the DSS. What's more, the potential changes identified by all the stakeholders in the value chain point mainly to modifications in the structuring of the value chain and in the bargaining power of producers, thus confirming the changes envisaged in the ex-ante impact path carried out by the DSS designers. However, the stakeholders also identified other potential changes not envisaged in the aforementioned impact path, including the deterioration of the Producer-Banabana relationship and the accession of new members to Producer Organizations. This suggests that the DSS SoYield® impact path needs to be revised with the involvement of stakeholders

Research units: Innovation, Hotsys, Cirad, ITAP, INRAE

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Internship - 2019

The use of smartphones in the Açaí sector in the Brazilian Amazon

Abstract: The use of multifunctional mobile phones (“smartphones”) is spreading among farmers around the world. The different uses that are made of it (access to information on market prices and technical advice, announcement of availability of products, organization for collective deliveries, discussion forum...) have some effects on the agricultural sector. Studies on this subject are still unusual (Baumüller, 2017).

As part of the Açaí'action project (building knowledge and consolidating quality markets for Amazonian socio-biodiversity products), the research training's objective is to collect information on the use of multifunctional mobile phones ("smartphones") by actors in the Açaí sector. The study will focus on producers who harvest açaí in order to measure the impact of these new practices on the prices and the quality. Through smartphone applications (especially WhatsApp), the prices on the places of exchange are instantaneously shared and reach even isolated producers. This news way of communicating and informing is likely to improve the producers’ ability to negotiate, so far very limited and dependent on intermediaries (Pegler, 2011).

The trainee student will have to design a questionnaire, to carry out the survey within two groups of açaí producers (one group using smartphones and one control group), then to analyze the results on the effects of using smartphones on the price and the quality. She or he will have to be fluent in Portuguese.

Field research will be the surroundings of the city of Belém, in Brazil. This city is indeed the main trading center for fruit (90% of national production) and processed products (nearly 50% of national production) (Homma et al., 2006). In Belém, there is a diversity of supply chains: some buyers apply a preferential price to ensure the quality of the fruits and foster the producers (Cialdella et al, 2017).

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Research units: INNOVATION, CIRAD

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Internship - 2018

Application of image analysis for structuring the horticultural sector in Senegal

Abstract: Estimating the spatial and temporal heterogeneity of crop yields is key to address the challenge of development and to reduce the vulnerability of populations. This is all the more true for perennial crops that have received less attention and for which specific question appears (e.g., phenology and characterization of intra- and inter-tree heterogeneity, inter-orchards?). The proposed internship fit into a Ph.D. project that aim to develop objectives and implement tools for multi-scale assessment of mango yield in Senegal by image analysis: at the tree level with photographic images, at the orchard scale with UAV's orthophoto and at the regional scale with satellite images with very high spatial resolution. Finally, the aim of this internship is to quantify and explain the heterogeneities of mango production at different scales with regard to explanatory parameters such as the variety, size and age of the tree, irrigation practices, the type of cultural system, climate etc... The intern will apply ICTs and models developed at the tree and orchard scales to the regional scale involving the actors of the sector (producers, exporters, researchers, technicians...) in the development and use these tools. This internship will permit to address strategic issues for the organization of the mango sector in Senegal: can we quantify the structural heterogeneities of production and estimate the areas cultivated by type of farms and by mango varieties in the study area? In terms of measurement and performance estimation, the trainee will be responsible for establishing the link between the tree and orchard scales with the scale of the area. For this, he will achieve a land use model based on remote sensing procedures (e-cognition) on Pleiades images for estimating and quantifying the mango-tree surfaces in the study area. Then, the intern will carry out spatial analyses (composition and configuration indices) to characterize the orchard surfaces. Finally, the trainee will perform field surveys for identifying the bottlenecks of the uses of these ICT tools (analysis of multi-scale images) for the actors of the mango sector. The results of the internship will be key for the emergence of the mango sector in Senegal as it will help the actors and in particular small producers to grab this ICT innovations in view to better respond to the market's expectations while best answering the issues of food security and loss reduction.

Research units: HortSys, CIRAD

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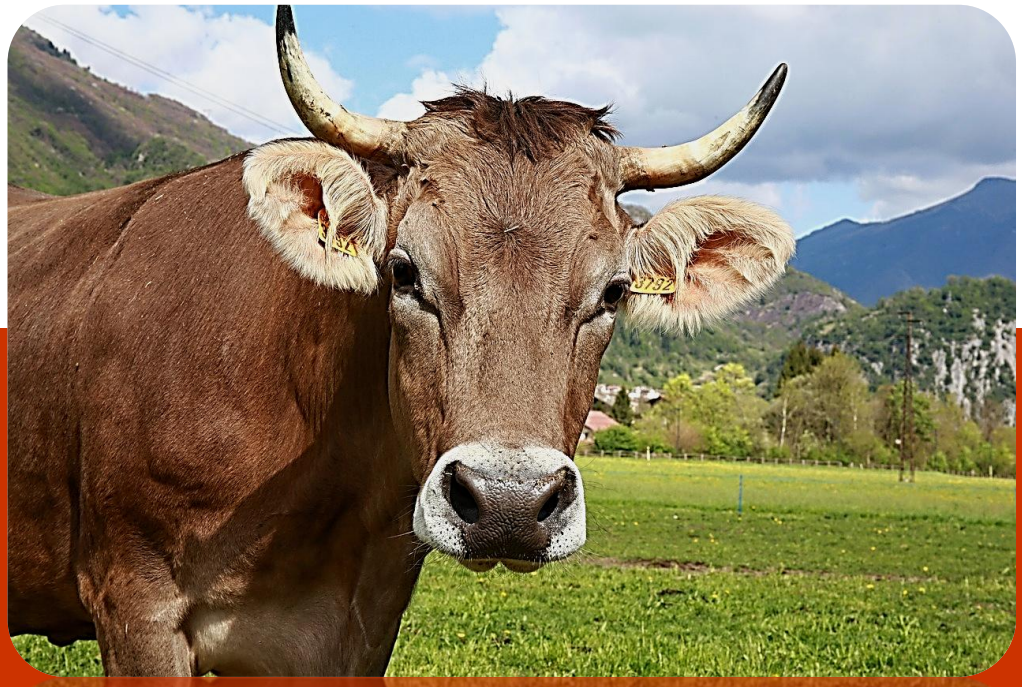

#DigitAg, the Digital Agriculture Convergence Lab is one of the 10 French Convergence Institutes funded under the Investissements d'Avenir program, and the only Convergence Institute dedicated to agriculture.

Created in January 2017, #DigitAg is supported by INRAE and 14 public and private founding members.

#DigitAg relies on strong interdisciplinarity, ranging from agronomic and biological sciences to engineering sciences (computer science, mathematics, electronics) via economic and social sciences (law, sociology, management sciences), with the involvement of 30 research units.

Since 2017, #DigitAg has brought together 1,060 members - including 103 PhD students, 22 post-doctoral fellows, 108 Master trainees, with the aim of fostering the harmonious development of digital agriculture, from data acquisition to use, based on 3 pillars: research, teaching and industrial relations, in France and internationally.

The #DigitAg founder members are: