M2 – Estimation des paramètres variétaux de variétés commerciales de blé à partir de l'assimilation des données satellitaires à haute résolution spatiale dans le modèle de culture SiriusQuality

Contract: Internship
Duration: 6 months
Beginning: 01.03.2025
Remuneration: ~ 650€/month (4.35€/h)
Deadline: 15.01.2025

INRAE presentation

The French National Research Institute for Agriculture, Food, and Environment (INRAE) is a major player in research and innovation. It is a community of 12,000 people with 272 research, experimental research, and support units located in 18 regional centres throughout France. Internationally, INRAE is among the top research organisations in the agricultural and food sciences, plant and animal sciences, as well as in ecology and environmental science. It is the world's leading research organisation specialising in agriculture, food and the environment. INRAE's goal is to be a key player in the transitions necessary to address major global challenges. Faced with a growing world population, climate change, resource scarcity, and declining biodiversity, the Institute has a major role to play in building solutions and supporting the necessary acceleration of agricultural, food and environmental transitions.

Work environment, missions and activities

Context:

Varietal improvement offers opportunities to increase the genetic variability of plants, representing significant potential for enhancing cultivated species in the context of growing global food demand and the need for sustainable agriculture. However, the real contribution of these advancements to crop productivity depends on identifying the links between plant genetic characteristics (genotype) and the biological processes that result in differential plant responses to environmental conditions (phenotype) (Tardieu et al., 2017). Observing phenotypic characteristics of plants is a first step toward establishing these genotype-phenotype connections. In recent years, field phenotyping platforms have become operational (Araus & Cairns, 2014), enabling the automatic and high-throughput acquisition of multiple traits of cultivated plants (e.g., leaf area, height, spike density) across trials involving diverse species and varieties in different environments, using various types of sensors (Rebetzke et al., 2019). Moreover, thanks to new constellations of high spatial resolution satellites (≤10 m), such as Sentinel-2 or PlanetScope, remote sensing can provide global observations of key traits like the green leaf area index (GAI) or the fraction of intercepted radiation (fIPAR) at a significantly lower cost compared to field phenotyping platforms. This satellite-based approach represents an innovative method in phenomics, breeding and varietal evaluation, as well as precision agriculture. All these traits are the result of interactions between genotype and environment (GxE), serving as indicators of plant behavior in a given environment (soil, climate, agronomic practices). However, these traits alone do not allow for the prediction of species or varietal performance (biomass, yield, carbon and nitrogen balance) under different environments (Araus et al., 2022; Cabrera-Bosquet et al., 2012; Cobb et al., 2013). In summary, a strong link between genotype and phenotype remains to be established (Fiorani & Schurr, 2013). This is the primary goal of the FFAST research project (2022-2026), funded by the French National Research Agency (ANR).

Internship objectives:

The internship, funded by the Institut de Convergence #DigitAg, is part of the ANR FFAST project, coordinated by the CAPTE team. This project aims to develop a new model-assisted high-throughput phenotyping method. High-throughput observations of wheat structure acquired via phenotyping platforms for various varieties, along with high-resolution spatial and temporal satellite data, will be integrated into the SiriusQuality (SQ) wheat crop functioning model. This integration will estimate model parameter values characterizing each variety. **The objective of this internship is to evaluate the usefulness of assimilating these satellite data into the SQ model, in addition to high-throughput phenotyping observations, to characterize the behavior of soft wheat varieties across different environments.**

The internship work will involve the following tasks:

- Building an assimilation dataset using time series of GAI and fIPAR observations obtained via remote sensing, as well as weather, soil, technical itinerary, and phenology data (field observations) collected during the two studied cropping years.
- Proposing an error model within the Bayesian system DREAM(zs) (Laloy & Vrugt, 2012; Vrugt, 2016), adapted to account for observations from multiple measurement instruments (high-throughput phenotyping and remote sensing) and diverse informational contexts for the model input data (experimental platforms and farmer fields).
- Identifying and estimating varietal parameters of the SiriusQuality (SQ) model that describe the behavior of the studied wheat varieties in relation to the environment, and characterizing the contribution of satellite data to their estimation.

The parameter estimation system for SQ is already implemented and relies on the CroptimizR R package, developed at UMR EMMAH. It has been tested with destructive and high-throughput phenotyping data from experimental platforms. Estimations will be conducted using the computational cluster meso@LR. The student will join the #DigitAg community, which provides numerous opportunities for professional networking.

This internship is co-supervised by two INRAE units: EMMAH (AgroParc Campus, Domaine St Paul, Avignon) and LEPSE (La Gaillarde Campus, Montpellier), with visits to LEPSE planned.

References:

Araus, J. L., Buchaillot, M. L., & Kefauver, S. C. (2022). High Throughput Field Phenotyping. In M. P. Reynolds & H.-J. Braun (Éds.), Wheat Improvement (p. 495-512). Springer International Publishing. https://doi.org/10.1007/978-3-030-90673-3_27

Araus, J. L., & Cairns, J. E. (2014). Field high-throughput phenotyping : The new crop breeding frontier. Trends in Plant Science, 19(1), 52-61. https://doi.org/10.1016/j.tplants.2013.09.008

Cabrera-Bosquet, L., Crossa, J., Von Zitzewitz, J., Serret, M. D., & Luis Araus, J. (2012). High-throughput Phenotyping and Genomic Selection : The Frontiers of Crop Breeding Converge. Journal of Integrative Plant Biology, 54(5), 312-320. https://doi.org/10.1111/j.1744-7909.2012.01116.x

Cobb, J. N., DeClerck, G., Greenberg, A., Clark, R., & McCouch, S. (2013). Next-generation phenotyping : Requirements and strategies for enhancing our understanding of genotype–phenotype relationships and its relevance to crop improvement. Theoretical and Applied Genetics, 126(4), 867-887. https://doi.org/10.1007/s00122-013-2066-0

Fiorani, F., & Schurr, U. (2013). Future Scenarios for Plant Phenotyping. Annual Review of Plant Biology, 64(1), 267-291. https://doi.org/10.1146/annurev-arplant-050312-120137

Laloy, E., & Vrugt, J. A. (2012). High-dimensional posterior exploration of hydrologic models using multiple-try DREAM (ZS) and high-performance computing. Water Resources Research, 48(1), 2011WR010608. https://doi.org/10.1029/2011WR010608

Rebetzke, G. J., Jimenez-Berni, J., Fischer, R. A., Deery, D. M., & Smith, D. J. (2019). Review : High-throughput phenotyping to enhance the use of crop genetic resources. Plant Sci., 282, 40-48. https://doi.org/10.1016/j.plantsci.2018.06.017

Tardieu, F., Cabrera-Bosquet, L., Pridmore, T., & Bennett, M. (2017). Plant Phenomics, From Sensors to Knowledge. Current Biology, 27(15), R770-R783. https://doi.org/10.1016/j.cub.2017.05.055

Vrugt, J. A. (2016). Markov chain Monte Carlo simulation using the DREAM software package : Theory, concepts, and MATLAB implementation. Environmental Modelling & Software, 75, 273-316. https://doi.org/10.1016/j.envsoft.2015.08.013

Training and skills

Profile: Master's degree/Engineering degree – training in agronomy or applied statistics/mathematics.

Knowledge required/Appreciated experience: Knowledge of the R language, organization, teamwork, having experience with remote sensing data would be a plus

Languages: French, English

INRAE's life quality

- 2.5 days of leave per month accrued ;
- Access to sports and cultural activities ;
  Access to collective catering.

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