PHENET
PHENOTYPING & ENVIROTYPING SOLUTIONS FOR AGROECOLOGY

TOOLS AND METHODS FOR EXTENDED PLANT PHENOTYPING AND ENVIROTYPING SERVICES OF EUROPEAN RESEARCH INFRASTRUCTURES

Deliverable *1.1*

Deliverable *Work plan for the Use Cases*

Due date (as in DoA):	30.06.2023
Actual achievement date:	28.06.2023
Work package:	1
Work package leader:	Roland Pieruschka, Michel Boer
Deliverable leader:	Roland Pieruschka
Version:	V1

Dissemination Level	
PU Public	*PU*
CI Classified, as referred to Commission Decision 2001/844/E	
CO Confidential, only members of the consortium (including the Commission Services)	

Research and Innovation action: GA no. 101094587

Start of the project: 1 January 2023

TABLE OF CONTENT

1 SUMMARY

1.1 OBJECTIVES

The deliverable addresses the coordination activities of Use Cases (UCs) within PHENET with the goal to align the activities between the UCs and Work Packages (WPs), utilize the existing synergies and transform the results obtained within the joint work of UCs and WPs into services that can be implemented in Research Infrastructures (RIs). The deliverable specifically addresses the initial phase of the implementation of the use cases from initial planning where WPs and UCs align their activities in order to have all the required technology and methods in place to deliver the awaited output.

1.2 RATIONALE

The key goal of the deliverable is to summarize the initial steps of the activities within the UCs and align these activities to effectively use the support from the WP 2-5, representing the support for technical implementation of different steps (sensors, data, remote sensing, modelling) as well as align the synergistic activities between different UCs.

1.3 TEAMS INVOLVED

The deliverable is based on the initial workplans that were provided by all UCs for the kick off meeting (February 2023) as a basis to discuss and align the activities of each UC with the WPs. Following the kick-off meeting, very concrete discussions were initiated particularly between the UCs and the WPs with the goal to outline the concrete steps to initiate and perform the proposed work in each UCs. Thus, the deliverable is based on a direct interaction with all the UCs and includes the work plans as well as the first tasks that were finalized and upcoming activities. The focus of the activities spans in most cases the years 2023-2024 as the most important phase to initiate the UC work, analyse it and optimize the activities to maximize the output and impact in the final stage of the project.

2 INTRODUCTION

PHENET addresses a number of grand challenges which are related to advancement towards sustainable agricultural and natural ecosystems by integrating the expertise of Research Infrastructures (RIs) that focus on plant and crop phenotyping (EMPHASIS), ecosystems experimentation (AnaEE), long-term ecosystem observation (eLTER) complemented by data management and bioinformatics (ELIXIR). The general approach of PHENET is to deliver innovative scientific instrumentation, tools and methods within the RIs and use the synergies by linking the co-development and prototyping of new sensors with industry including data analysis (WP2), Earth Observation (EO) services connected to ground based data (WP3), further developing FAIRification of the data generated within the project and beyond (WP4) to enable a link to modelling solutions as digital twins and hybrid AI to transform data produced into usable knowledge and prediction (WP5), complemented training, and interaction with relevant stakeholders (WP6).

In very practical terms, the ambitious goals of PHENET will be addressed in eight dedicated Use Cases (UC) that address scientific challenges associated with the key aspects of sustainable agroecosystems and a transition towards agroecology by utilizing the support from different WPs. The approach will deliver innovative services that will address environmental and societal challenges such as climate change adaptation, mitigation measures, it addresses food security and sustainability, connects different RIs and make an important step to enable the European Plant Science and Ecology communities to have access to tools and methods and translate them into services and maximize their use by the community.

Built around the UCs, the WP1 will coordinate the progress of the work as well as an interaction between the UCs as well as UCs with the WP2-6. This approach will deliver innovative scientific instrumentation, tools and methods relevant for plant phenotyping and envirotyping that will be implemented as novel cross-disciplinary services linking different RIs, for a diverse user community. Specifically, the deliverable provides an update on the initial activities of the UCs, their interaction with the WPs and as such it summarises the approaches for interaction and communication (including WP6) to effectively enable progress of the UCs.

3 RESULTS

The deliverable summarizes the current state of the use cases (UCs) in PHENET including activities that require the support from different work packages (WPs) as well as the interaction between the UCs. One of a general activity is also the definition of the experimental sites, particularly the envirotyping capabilities with the goal to enable interoperability and compatibility of data obtained in different field sites and use cases. In a first step a general description of the sites has been collected, which will be further extended with the description of the environmental monitoring and simulation capabilities on different sites (the current overview of the sites is summarized in Annex 1).

In the following, each UC is described with general objectives and concrete steps that were finalized, are in process or will be addressed specifically within the years 2023 and 2024. Additionally, a short description of the expected results and potential services that may emerge from the UCs are described, which will be extended and elaborated during the progress of the UC work.

3.1 UC1 PLANT HEALTH: VALIDATED SENSORS AND METHODOLOGY APPLICABLE FOR BIOTIC STRESSES IN WHEAT.

Partners: AGROSCOPE, CRA-W (Lead), GEVES

Objective

The objective of this UC plant health is to validate sensors and methodology dedicated to assess biotic stresses in wheat. UC1 will build on extended experience acquired in INVITE project in Fusarium head blight - FHB (Fusarium sp.) and will deliver approaches for the quantification of wheat FHB with the potential to be transferred to various cereals for other ear diseases (e.g. re-emerging diseases in relation to the decreasing of pesticides application) or for other leaf diseases (e.g viruses). It will create the connection between platforms and models for real time prediction of disease appearance for instance in precision agriculture.

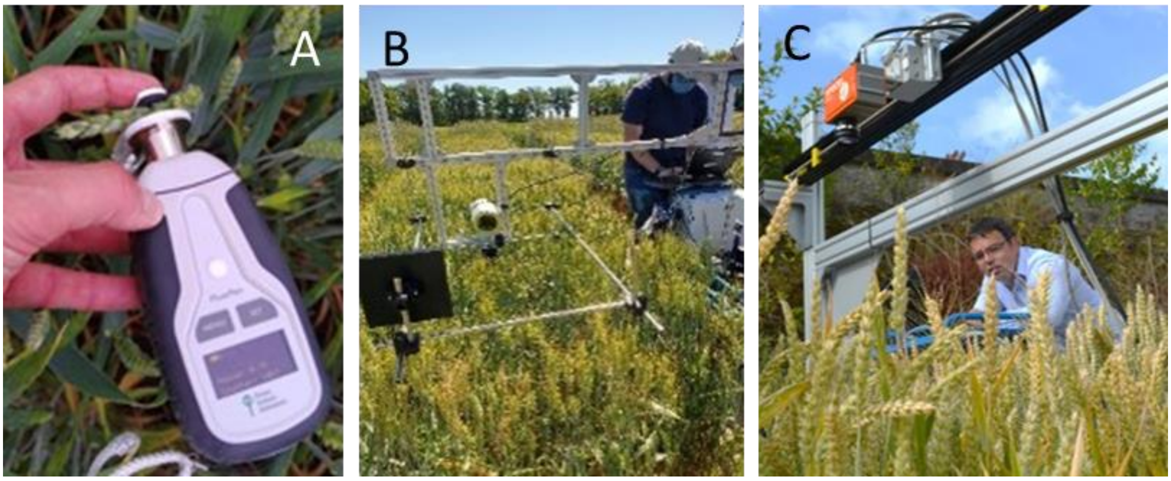

Figure 3.1.1 *Methods used in this UC to assess plant health status. A: Handheld fluorometer; B Hyperspectral NIR imaging*

Work plan

- The UC will use existing trials, mainly on winter wheat and barley, sown in autumn 2022. Those trials were selected in the experimental sites of each partner based on the targeted disease. FHB disease on spikes will be assessed on 3 sites (Belgium, France, Switzerland) using handheld device, PSI FluorPen 110 (Agroscope) (Fig 3.1.1 A), a VIS-NIR multispectral imaging system, Silios CMS4 (Geves), a NIR linescan hyperspectral imaging system, Specim FX17 (CRA-W) (Fig 3.1.1 C) and a NIR snapshot hyperspectral imaging system, Hinalea (CRA-W) (Fig 3.1.1 B). The last one is a new non-invasive sensor technology allowing the wavelength selection according to the targeted disease. RGB images will be acquired on all the sites using Literal (old release) Phenoman (Geves, Agroscope) or smartphone (CRA-W). Schedule: 01/2023 – 09/2023 Link to WP2.

- Wheat bunt disease on spikes will be assessed on one site (Belgium) using a NIR linescan hyperspectral imaging system, Specim FX17 (CRA-W) and a NIR snapshot hyperspectral imaging system, Hinalea (CRA-W). Barley Yellow Dwarf Virus (BYDV) disease on leaves will be assessed on one site (France) using RGB camera on the perch Phenoman-Arvalis (Geves). Schedule: 01/2023 – 07/2023 Link to WP2.
- It is also planned to set up such experimental trials with cereals in autumn 2023 for the next campaign. Schedule: 06/2023 – 03/2024.
  Based on the output of the activities obtained in the first half of the project, further experimental and modelling activities will be planned to complement the data sets Schedule: 08/2024 – 07/2025. Link to WP2

<table>
<tr><th colspan="4">2023</th><th colspan="4">2024</th><th colspan="4">2025</th></tr>
<tr><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td></tr>
<tr><td colspan="3">Experiments in field trials (Belgium, France, Switzerland)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="4">Set up such experimental cereal's trials for the next campaign</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="7">Datasets will be exploited for a global wheat challenge dedicated to stress detection at spike level</td></tr>
</table>

<u>Expected results</u>

- The UC will aim at addressing the spectral, spatial and time resolution needed to identify multiple diseases at different scales through a cereal trials network. Time series of spectral acquisitions and visual observations will be performed at plant and experimental plot level.
- The acquired data will be used for the benchmarking of data standards for stress identification, visual observations, spectral acquisitions required for disease identification (WP4). Some datasets will be exploited for a global wheat challenge dedicated to stress detection at spike level, planned for 2024-2025.
- Several modelling approaches based on multivariate analysis, wavelength selection (spectral disease index) or combination of both previous approaches (WP5).
- Strategies for combining sensors/devices and real-time modelling will be defined in relation to the needed sampling and the disease(s) development cycle (WP2).

<u>The expected services</u>

- This work will be transferred to the breeder's community and to the examination offices.
- Reference data sets that can be used for AI training will be provided to the community as a RI services (by EMPHASIS).
- Data sets will be available for further studies, metanalyses.
- The models will be available to the community after a publication as open source models available on dedicated repositories such as Quantitative Plant (https://www.quantitative-plant.org/)

3.2 UC2 Soil Health and Root Phenotyping: Innovative, automatable soil imaging techniques to determine key belowground parameters in real time at plot to landscape scale.

Partners: BOKU (Lead), UPorto, S4ML

Objective

The UC will deliver an innovative approach for the in situ quantification of soil physico-chemical and root properties, which are often missing in agricultural and ecological applications or surveyed at coarse resolutions. It will utilize portable, high-performance near infrared (NIR) instruments, increasingly established as a rapid and cost-efficient laboratory technique, taking the technique from the laboratory to the field for fast, automatable on-site surveys of key soil parameters such as soil organic carbon (Figure X). Specifically, the UC will:

- Determine dependency of calibrations (on ground truthing data) on soil type, texture, moisture & rooting densities (Figure 3.2.1).
- Develop analysis pipelines and a User Interface for use in RI (Figure 3.2.2).
- Relate surface measured by unmanned aerial vehicles (UAV) and deep soil C pattern for upscaling soluble organic compounds (SOC) at landscape levels and define sampling strategies (probe insertion, and ground truthing) for heterogeneous landscapes.
- Link ex situ soil spectral libraries to in situ spectra.
- Develop ontology, data format, (European) ex situ spectral library.
- Train-the-trainer courses for a wide adoption of the techniques.

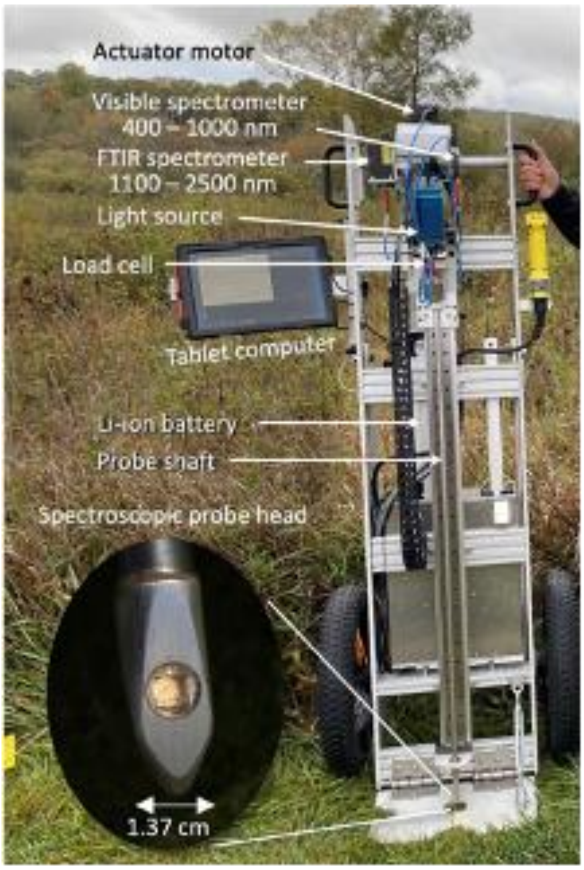

Figure 3.2.1. Subterra Green prototype (TRL 5-6) from S4ML

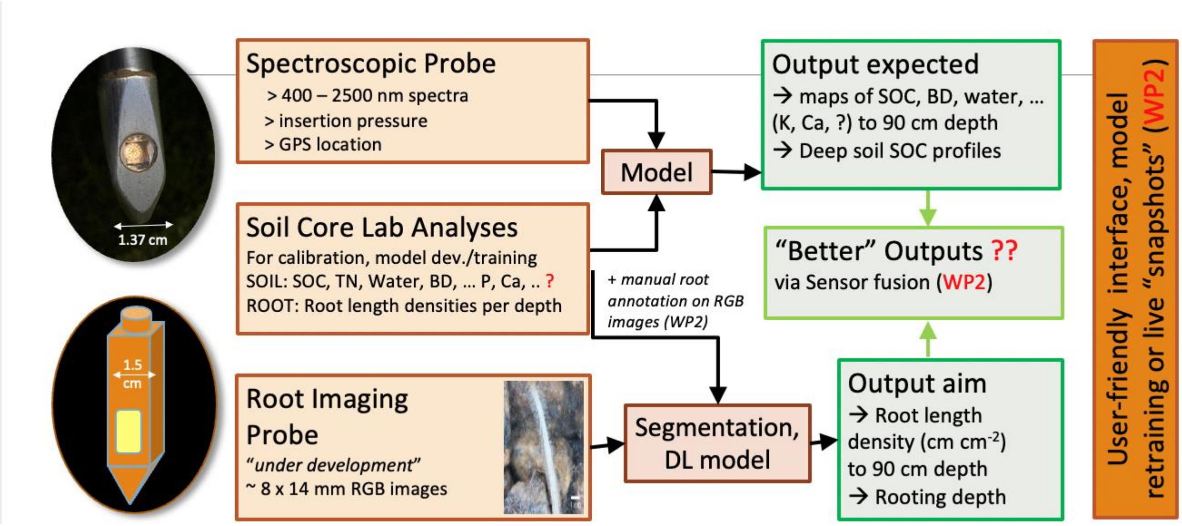

Figure 3.2.2. Work flow for Modelling and integration of hyperspectral and Root detecting RGB probes to a user-friendly interface

<u>Work plan</u>

Activities conducted/planned for 2023 - 2024:

- The start of the UC has been delayed due to the shift of PI at BOKU from Boris Rewald to Hans Sandén. The delivery of the S4 Mobile Laboratories Subterra Green has been delayed and will arrive end of June instead of end of May. This led to that we partly missed the opportunity to use the soil coring of the Barley field, by the EU project Barley MicroBreed, for ground truthing data. Schedule: 05/2023 – 07/2023, finalized. Link to other WPs: None.
- Root probe is under development and testing at Vienna Scientific. Schedule: 01/2023 – 01/2024, Link to other WPs: None.
- Hiring personal:
  - A Post-Doc has been hired to coordinate a campaign that will be started to take probe and soil samples for testing the hyperspectral camera on different soil types to improve the algorithms. Schedule: 07/2023 – 09/2023. Link to WP2.
  - A PhD-student will be hired and work initially at BOKU (2 years) and then at Porto university (1 year). The PhD-student will collect ground truthing data and improving the algorithms for both hyperspectral and root probes.
    - Rework root probe Schedule: 1/2024 – 6/2024 Link to WP 2
    - 3D mapping of the soil carbon on a landscape level
      - Vienna, Schedule: 03/2024 – 12/2024. Link to WP3.
      - Porto, Schedule: 03/2025 – 12/2025. Link to WP3.

Joint activities of the UC2 team:

- Identify field sites for landscape scale mapping (Austria , Portugal) and develop efficient spatial sampling scheme guidelines (probing and calibration). Schedule: 1/2024 – 6/2024. Link to WP3.
- Approaches for enhanced up-scaling of (deep) soil C stocks from field to landscape level. Schedule: 9/2024 – 3/2025. Link to WP3.
- Develop root length estimation pipeline, online, allow for potential retraining of ML models with limited user input. Schedule: 01/2024 – 12/2025. Link to WP2.
- Integration of the hyperspectral and root probe data and building in situ database. Schedule: 10/2025 – 7/2026. Link to WP2.
- Define the data output format, online databases for ex situ spectral, RGB data. Prepare in situ spectra from selected BOKU samples, compare to ex-situ spectra (BOKU or U Porto facilitate to find partner. Schedule: 1/2025 – 3/2026. Link to other WP4.

- Development of in situ soil spectral libraries as proxies for lab-derived soil health indicators. Schedule: 3/2025 –9/2026 Link to WP4.
- Training for use of the sensor within Research Infrastructures. Schedule: 10/2025 and 6/2026. Link to WP6.

2023				2024				2025				2026			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	PI change														
Root probe development and testing															
		Hiring perdonal: PhD sudent, Postdoc													
				Identify field sites / develop sampling											
						Upscaling from field to landscape									
				Develop a root length estimation pipeline											
										Integration of the hyperspectral and root probe data					
								Define the data output format							
									Soil spectral libraries						
											Training for use of the sensor				

Expected results and services

- Spectral probe application in European agroecosystems.
- Application of new root probe for breeding climate-smart crops.
- Landscape-scale, deep soil C mapping.
- Method publication on relation between in situ / ex situ soil spectra.
- Method and data publication on new ex situ soil spectral library.
- Co-creation of ready-to-use soil spectroscopy and root imaging module, ready for robotic automation.
- New, FAIR ex-situ soil spectral library to be used by multiple stakeholders.
- User interface for RI + stakeholders to operate, re-train (models of) the soil and root probe device; RIs include new services in their catalogue.
- User interface and model to select effective sampling designs for landscape wide C mapping.
- S4ML leverages on the project to develop, provide new services to customers.

3.3 UC3 GxE cereals: Model-assisted wheat phenotyping to predict genotype performance and adaptation to future environmental conditions.

Partners: INRAE (France) – UMR LEPSE, UMR EMMAH, UE DiaScope, UE Pheno3C, UE AgroPhen, UE La Motte, UMR MISTEA (through WP4), URGI (through WP4): Agriscope (Switzerland); ETH Zurich (Switzerland) – Dep. Of Environmental Systems Science; Universidade NOVA de Lisboa (Portugal) - Plant Ecophysiology and Metabolism lab; INIAV (Portugal) –Polo de Elvas; Université Catholique de Louvain (Belgium) – Earth and Life Institute (through WP 3); Wageningen University and Research (Netherlands) - Laboratory for Geo-information Science and Remote Sensing (through WP 5); Biometris (through WP5).

Objective

The main goal of UC3 is **developing a new model-assisted phenotyping strategy to improve the knowledge on genotype-by-environment (GxE) interactions** of winter wheat genotypes. In model-assisted phenotyping, crop-process based models are used to identify functional traits of wheat genotypes through the assimilation of repeated multi-sensor and multi-scale observations of structural and morphological traits over a large environmental condition (Figure 3.3.1). The UC3 will implement such strategy in a panel of 30 wheat genotypes monitored in France, Switzerland and Portugal. The UC will cover the following specific objectives:

- Constructing a multi-scale phenotyping data acquisition framework on research infrastructure (RI) and farmer fields (on-farm-experiments, OFE) by combining high-throughput phenotyping platforms, IoT and very high-resolution satellite platforms.
- Estimating functional traits and understanding GxE interactions from the assimilation of multi-experiment and multi-environment phenotyping and envirotyping observations into a process-based crop model.
- Evaluating the contribution of cost-efficient satellite+IoT phenotyping over fields distributed in different agro-climatic conditions in the estimation of functional traits.
- Defining an 'optimal' experimental design based on multi-environment and multi-scale observation networks to describe GxE in wheat.

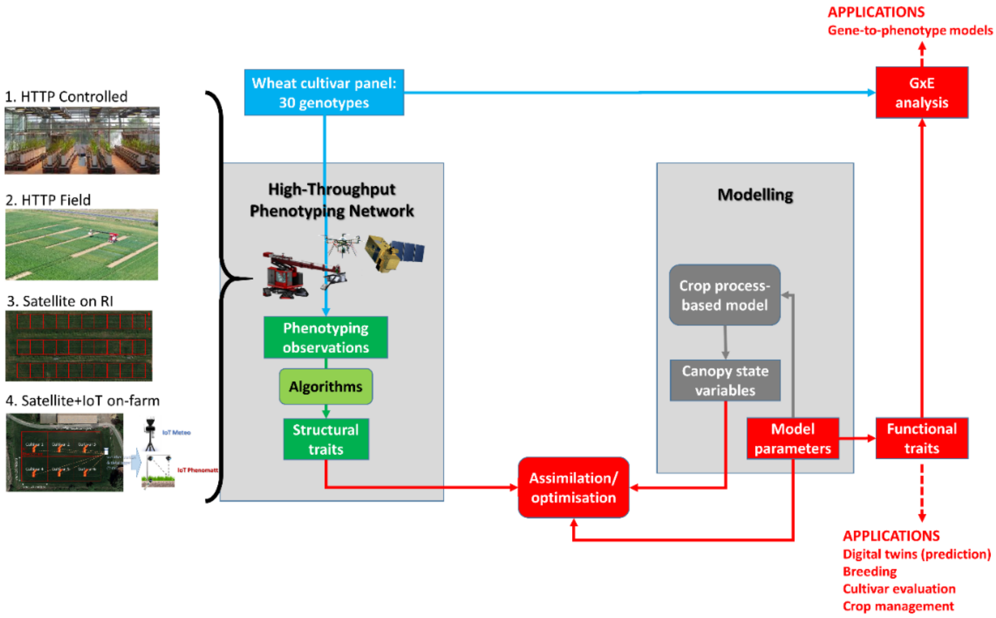

Figure 3.3.1 Schematic description of the approach in UC3: model assisted phenotyping utilizing the assimilation of repeated multi-sensor and multi-scale observations of structural and morphological traits of wheat.

<u>Work plan</u>

Experimental trials in PHENET UC 3:

Site	Conditions	Harvest years	Institute	RI	OFE	Country	GxMxR	Phenotyping method	Contact
M3P	Controlled	2025, 2026	INRAE - UMRX LEPSE			France	30x3x3	PhenoArch platform	pierre.martre@inrae.fr
Maugio	Field	2025, 2026	INRAE - UEX DiaScope			France	30x3x3	Phenomobile HTTP	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Toulouse	Field	2025, 2026	INRAE - UEX APC			France	30x3x3	Phenomobile HTTP	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Clermont-Ferrand	Field	2025, 2026	INRAE - UEX PHACC (Pheno3C)			France	30x3x3	Phenomobile HTTP	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Eschikon	Field	2025, 2026	ETH - Zurich	X		Switzerland	30x3x3	Spidercam HTTP	andreas.hund@usys.ethz.ch
Elvas	Field	2025, 2026	INIAV - Elvas	X		Portugal	30x3x3	Camera-based HTTP	ruben.vicente@itqb.unl.pt; rita.costa@iniav.pt
Le Rheu	Field	2025, 2026	INRAE - UE LaX Motte			France	30x1x1	Satellite	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr

Maugio-Sat	Field	2025, 2026	INRAE - DiaScope	UEX	France	30x1x1	Satellite	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Toulouse-Sat	Field	2025, 2026	INRAE - APC	UEX	France	30x1x1	Satellite	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Clermont-Ferrand-Sat	Field	2025, 2026	INRAE - Pheno3C	UEX	France	30x1x1	Satellite	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Changins	Field	2025, 2026	Agriscope	X	Switzerland	30x1x1	Satellite	juan.herrera@agroscope.ch; didier.pellet@agroscope.ch
Zurich	Field	2025, 2026	ETH - Zurich	X	Switzerland	30x1x1	Satellite	andreas.hund@usys.ethz.ch
Lisboa	Field	2025, 2026	INIAV - Elvas	X	Portugal	30x1x1	Satellite	ruben.vicente@itqb.unl.pt; rita.costa@iniav.pt
Chartres	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Orleans	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Fourques	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Castelnaudary	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Gannat	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Francueil	Field	2025, 2026	Farmer field	X	France	6x1x1	Satellite+IoT	pierre.martre@inrae.fr; raul-lopez-lozano@inrae.fr
Changins-Farm	Field	2025, 2026	Farmer field	X	Switzerland	6x1x1	Satellite+IoT	juan.herrera@agroscope.ch; didier.pellet@agroscope.ch
Portugal-Farm-1	Field	2025, 2026	Farmer field	X	Portugal	6x1x1	Satellite+IoT	ruben.vicente@itqb.unl.pt; rita.costa@iniav.pt
Portugal-Farm-2	Field	2025, 2026	Farmer field	X	Portugal	6x1x1	Satellite+IoT	ruben.vicente@itqb.unl.pt; rita.costa@iniav.pt

Additionally, we are in contact with partners in Germany and Croatia, outside the PHENET consortium, who are interested in conducted field experiments with the PHENET bread wheat, both on RI and OFE. This would further strengthen the data that the UC will obtain and experimental data from previous projects are expected to be included in the PHENET UC3, and to contribute to WP5, but we have not established the list of trials yet (to be done during 2023).

Activities conducted/planned for 2023 - 2024:

- Definition of the wheat genotype panel. Description: Identification of a common group of 30 winter wheat cultivars with a priori different characteristics on what concerns architecture, cold requirements, precocity and tolerance to diseases. The panel of 30 genotypes will be grown in France, Portugal and Switzerland. Status: Completed. The panel of 30 cultivars have been defined. Breeders have been contacted to get samples for seed replication. Schedule: 01/2023 – 03/2023. Link to other WPs: None.

- Preparation of a common database of traits observed of the panel from previous and existing experiments. Description: Collecting phenotyping and envirotyping observations of the PHENET wheat panel from previous and ongoing projects that could be used for GxE analysis. Status: on going. Destructive/manual data collected in existing projects in the PHENET panel (BreedWHeat, ANR FFAST, H2020 INVITE) have been collected and are currently being formatted in the ICASA v2 format. Work has also been initiated with WP4 (INRAE UMR-MISTEA) to develop a seamless workflow of data from acquisition to modeling based on ICASA and AgMIP data standards and tools and using the information system for phenotyping PHIS.

Schedule: 03/23-12/23. Link to other WPs: WP4 for the data model and semantic link to ICASA v2.

- Preparation of the connected sensors (pheno & envirotyping) to install in on-farm experiments. Description: Defining and acquiring the IoT (Internet of Things) devices that will be installed in the on-farm experiments to collect phenotyping (wheat traits from RGB images) and envirotyping data (weather, soil moisture). These observations will complement satellite monitoring in on-farm experiments. Status: on going. The requirements for the IoT system have been defined. A prototype of IoT system for testing would be ready for autumn 2023. The operational deployment of IoT in on-farm experiments is expected for Autumn 2024. Schedule: 06/23 - 09/24. Link to other WPs: WP2.

- Definition of Plant phenotyping methods, algorithms and traits to estimate from field platforms. Description: Analysis of the algorithms currently used to estimate wheat traits (e.g. plant/green area index, heads density, canopy height) from HTTP by the different RI. Definition of a common set of algorithms to be used by all RI. Status: Not yet started. Schedule: 07/23-08/24. Link to other WPs: None.

- Seed increase of the PHENET bread wheat panel. Description: Seed increase of the 30 wheat genotypes for the 2 years of experiments in RI. Status: We are looking for a subcontractor to carry out the seed increase. Schedule: 09/23-07/24. Link to other WPs: None.

- Definition of the on-farm experiment network. Description: Identifying the farmers that will take part in the network of on-farm experiments. Status: On-going. Alerady 8 farmers have been identified that are willing to collaborate to the project. Schedule: 03/23-12/23. Link to other WPs: Interactions with the UC F2P.

- Experiments on RI – year 1. Description: First year of experiments in controlled conditions and field RI platforms (France, Switzerland, Portugal) over the PHENET panel (30 varieties). Status: Not yet started. Schedule: 09/24-07/25. Link to other WPs: WP4 for experimental design and statistically analysis of the results, WP 3 for the estimation of wheat traits from satellite on RI.

- On-farm experiments – year 1. Description: First year of on-farm experiments for wheat phenotyping by satellite and IoT for a reduced number of genotypes from the PHENET panel. Status: Not yet started. Schedule: 09/24-07/25. Link to other WPs: WP 3 for the estimation of wheat traits from satellite on RI.

2023				2024				2025			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Definition of the panel											
	Preparation of a common database of traits										
		Preparation of the connected sensors									
			Definition of Plant phenotyping methods, algorithms and traits								
			Seed increase of the PHENET bread wheat panel								
	Definition of the on-farm experiment network										
							Experiments on RI – year 1				
							On-farm experiments – year 1				

<u>Expected results and services</u>

- Advanced methods to analyze and predict G x E (x M) interactions.

- Improved genotype-to-phenotype process-based models.
- Database to support and benchmark for future HTPP and model development.
- New traits for the breeding of climate resilient genotypes.
- Multi-scale HTPP for research and innovation.
- Innovative methods and tools for breeding and variety evaluation.
- Cost effective methods for post-registration variety evaluation and crop management (smart agriculture).

3.4 UC4 GxE orchard: apple tree development, fruit and health status in contrasted environments.

Partners: CSL (Lead), WBF, INRAE, IRTA, B3F

Objective

The use case dealing with the interaction between apple genetics and environment (UC4 GxE orchard) will aim at assessing the apple tree physiological and health status in contrasting environments with abiotic and biotic stress for an optimum management of fruit quality in these conditions. For this purpose, we will use a dedicated set of sensors that will be adapted to quantitatively monitor apple tree, fruit quality, growth and health status. The use case will use a multi-site experimental design called «the apple REFPOP» planted in 2016 following the same experimental design on five locations representing various biogeographical regions in Europe, including 534 genotypes. First attempts to phenotype this collection started already in the European project INVITE and will be intensified within PHENET. At the end of the project, we will have developed, validated and applied high throughput new generation monitoring devices linked to artificial intelligence and machine learning. They will be able to phenotype the apple tree status in contrasted environments and under water or pathogen stress and detect symptoms of disease and pest for an optimum management of fruit quality in these constrained conditions.

Figure 3.4.1 Orchard and an example of hand hold measurement of a surface temperature.

Work plan

All experimental sites are divided into two parts: the first part is to be managed with the common agricultural practice of the country, the second is to receive alternative management conditions (low pesticide or water input). The first part consists of two randomized complete blocks, totaling together 1068 trees, each block containing one replicate per genotype. The second part also consisted of two randomized complete blocks, each containing one representative of approx. one-third of the genotypes (on average 184 genotypes).

The main activity in UC4 for the running year 2023 is the definition and the acquisition of the dedicated set of sensors to be used. The phenotyping device to be acquired should allow the acquisition of information in order to measure the following parameters with the specified accuracy:

Parameter	**Expected accuracy/classes**
Flowering intensity	Class 1 to 9
Tree architecture	maximum height, maximum width, tree volume, total length of branches, total length of trunk (during winter time), if possible tree architecture reconstruction
Number of fruits	maximum acceptable error 10% accuracy on absolute number
Fruit size	5 mm diameter classes at harvest
Fruit size (dynamics)	track 5 single fruits per individual starting from 35 mm size
Color	maximum acceptable error 10% accuracy on percentage of red overcolour
Health status of the trees (general index)	3 classes based on the detection of the sensitivity / resistance of trees to pests on leaves
Health status of fruits (general index)	3 classes based on the damage on fruits caused by the main pests and pathogens

Due to administrative and regulatory issues which still have to be finally solved under the supervision of the PHENET project coordinator, this part is delayed but hopefully fulfilled by the end of the year. This would allow the partners to start in 2024 with the implementation of the acquired instruments in the phenotyping of the apple refpop on the five sites which differ significantly in terms of their pedoclimatic conditions. WP2 will support the UC4 testing sites with expertise on sensors and their implication in the practical outdoor assessments following the work plan below.

<table>
<tr><th colspan="4">2023</th><th colspan="4">2024</th><th colspan="4">2025</th><th colspan="4">2026</th><th colspan="4">2027</th></tr>
<tr><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td><td>Q1</td><td>Q2</td><td>Q3</td><td>Q4</td></tr>
<tr><td colspan="4">Aquisition and implementation of the high throughput phenotyping</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="4">High throughput phenotyping of required traits</td><td colspan="4">Second round of high throughput phenotyping of required traits</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">First round of trait measurements including validation of subsamples</td><td colspan="4">Second round of trait measurements including validation</td></tr>
</table>

WP4 will support the creation of a workflow to transfer the WP2 sensors data to the UC databases. WP5 will support the UC with the modelling of the acquired phenotyping data in order to create provisional models and decision support systems.

<u>Expected results and services</u>

- Further phenotyping of the refpop with innovative high throughput tools
- Substitute a significant number of manual phenotyping evaluations in the orchard with new hight hroughput methods and tools in order to accelerate the development of smart breeding and crop modelling
- Get more powerful and deep information on the kinetics of physiological parameters and diseases including (internal) quality assessment of the refpop with the support of IT and IoT engineers and biostatisticians of PHENET
- Better exploiting G x E X M interaction on apple, creating provisional models and decision support systems
- Deploying digital twins services for orchard systems in support to improved GxE analysis
- As a « side effect » the tools might be implemented in smart farming concepts.

3.5 UC5 Farms 2 Platforms (F2P): phenotyping capabilities of RI to support innovation towards the agroecological transition at the farm level

Partners: UCL (LEAD), SC

Objective

The lack of interactions between farmers and the scientific community is one of the factors that hinders the agroecological transition. While innovation is largely in the hands of farmers, the main agricultural research capacity is located in research centres and industry which foster on mainstream avenues.

Small private actors have established farmers networks and typically document the evolution and diversity of management practices in farmers' fields to provide locally relevant advice.

The objective of the Farms2Platforms use case is to demonstrate (i) that small private actors can also leverage on RI capacities to draw scientifically valid conclusions on farmers innovations and (ii) that the field deployment of IoT and the coverage of EO products are key to the success of this partnership.

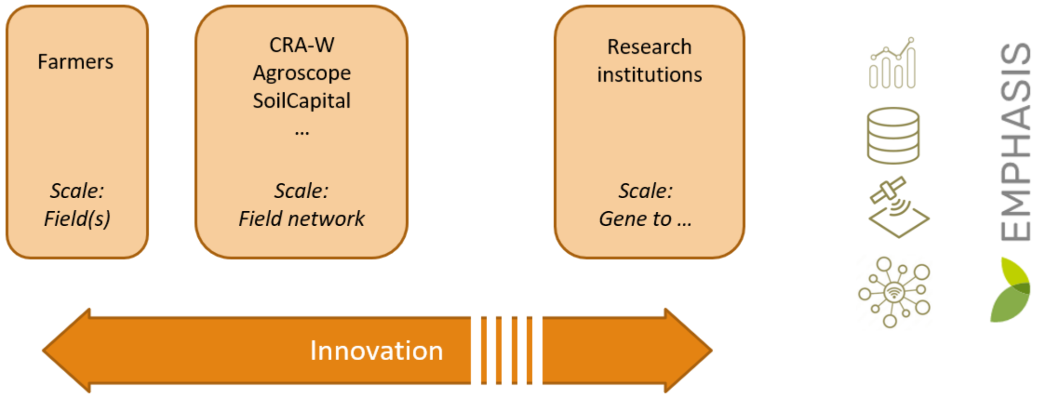

Figure 3.5.1 Schematic representation of the interaction between farmers and research infrastructures in this UC.

Soil Capital (including partners entities such as CultivAe) will play the role of the small private actor. It has a network of 600+ farmers with an interest in management practices that increase soil carbon. A core activity of SoilCapital, not directly related to PHENET activities, is the estimation of soil carbon evolution in farmers fields. A key information for this estimation is the type and date of soil preparation practices. UCLouvain will play the role of the RI, with its experimental farm, phenotyping instrumentation, data storage facility and modelling capacity (Figure 3.5.1).

Work plan

The work plan is to contact two iterations of an interaction loop where an innovation question from the farm context will be sketched, translated in a RI context (scientific question), tested in RI and in farmers' fields thanks to the deployment of IoT (WP2) and the recourse to EO data (WP3). The analysis of the results will be carried out and disseminated by the small private actor (as user of the RI services).

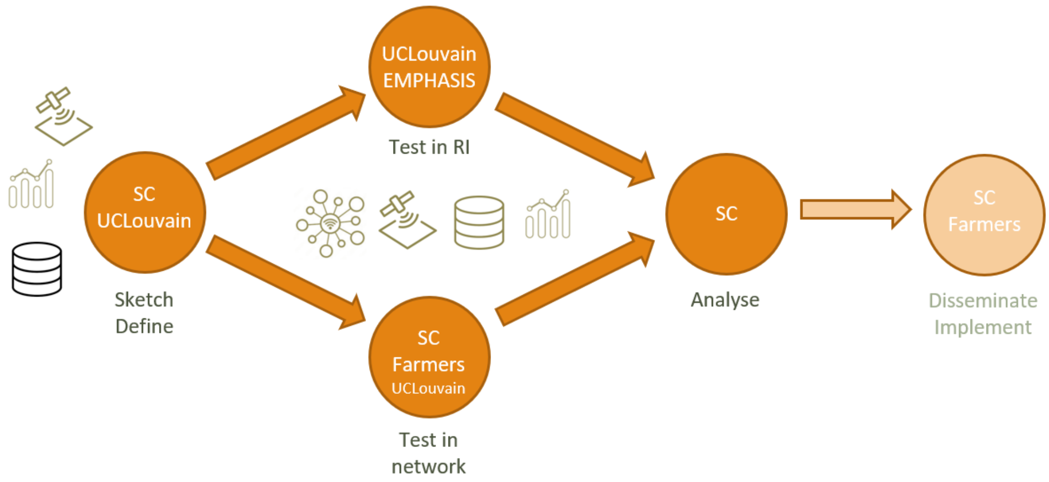

Figure 3.5.2 Schematic representation of two iterations of an interaction loop

In May-June 2023, UC Louvain has conducted a field survey in Walloon Brabant (Belgium) to identify a set of fields with diverse soil management practices. This set will serve to evaluate the feasibility to detect specific soil management practices using EO data, in anticipation of the first iteration in 2023-24. Schedule: 01/23-06/23. Link to other WPs: none.

Two seasons of trials will be conducted (a priori 2023-24 and 2024-25) which include instrumented sites in the UC Louvain farm and a number of farmer fields (to be identified by Soil Capital) equipped with IoT and monitored throughout the season. Through these iterations, Soil Capital will gain new expertise in the exploitation of IoT and EO, using tools supported and maintained by EMPHASIS. Schedule: 08/23-08/25. Link to other WPs: WP 2 and 3.

2023				2024				2025			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Field survey											
		Trials sites in the UCLouvain and farmer fields									
						Trials sites in the UCLouvain and farmer fields					

Expected results

- Proof of concept that plant phenotyping RI can operate with farmers, that is, well beyond the close perimeter of scientific institutions and industry.
- Proof of concept of hybrid experiments combining RI sites and farmer fields and leveraging on IoT deployment and EO data.
- Proof of concept that small private actors can gain expertise and improve their business capacity by using technological solutions developed in/with RI.

Expected services

- The Farms2Platform use case ambition is to demonstrate that research infrastructures can provide services to a new target public, beyond scientists and industries, to support agricultural transition in farmers' fields.
- The service here would be to provide recommendations / specifications / methods / training to non-scientific actors for (i) the extraction of EO data, (ii) the deployment of IoT at farmer sites (iii) the management of own data and (iv) the mobilisation of RI sites to increase the experimental and analytical capacity of private actors close to farmer innovation and field reality.

3.6 UC6 Soil phenology: Climate change as driver of soil phenology

Partners: UHASSELT (Lead), AMU/CNRS

Objective

The key objectives of the UC is to assess temporal dynamics of soil biota and biochemical cycles (fluxes of carbon, nutrients, water), and impacts of climate change on soil processes by utilizing a network of experimental ecosystems allowing climate simulation.

Figure 3.6.1. Ecotones of the Hasselt University

Work plan

The Ecotron experiments were started with the goal to examine the impacts of climate change on heathland and on pear orchards and collects data about (1) carbon, nitrogen, phosphorus and micronutrient cycles (1 min to every 3 weeks sampling events; in both experiments); (2) microbial community dynamics in heathlands (2 sampling events in 2023, and two sampling events in 2024). Data of microbial community dynamics in heathland (i.e. soil microbial community change compared to the baseline of experiment start in 2020 will be analyzed in winter 2023-2024 via metabarcoding. Data on microbial dynamics in pear orchard will be started being collected in autumn 2023. Three sampling events are planned in 2023-2024. Specifically:

- PhD student has been hired and will start her PhD project. The PhD project constitutes a core of the use case. 2023-2024: the PhD student will: (i) prepare a plan of her PhD work, (ii) learn statistical methods necessary to run the project, (iii) run a first PhD sub-project aimed to examine impacts of climate change on activity of ericoid mycorrhizal fungi. Schedule: 06/23-06/26. Link to other WPs: WP2, WP4, WP5.
- AnaEE facilities will be consulted about selecting a rhizosphere camera, and learn the methods to operate it. The camera will be purchased and installed in the Ecotron of Hasselt university. Schedule: 09/23-06/24. Link to other WPs: WP2.
- Joint study in the Mycortron experiment. The study is intended to assess if and how soil microbial community composition is could be detected through multispectral imaging technique. Schedule: 01.2024 – 12.2024. Link to other WPs: WP2.

2023				2024				2025			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		PhD project starts									
			Ecotron experiment								
				Mycotron experiment							

Expected results

- The UC will aim at addressing the connections between microbial community dynamics and biogeochemical cycles. Time series of soil biogeochemical measurements and community dynamics will be performed at experimental plot level.
- The acquired data will be used for analysis of relationships between soil community dynamics and carbon and nutrient cycles.
- Modelling approaches based on multivariate analysis (WP2,5).

The expected services

- Reference data sets that can be used for AI training will be provided to the community as a RI services (by AnaEE).
- Data sets will be available for further studies, metanalyses etc through the services provided by AnaEE.
- The models will be available to the community as open source models available on github.

3.7 UC7 Intercropping: Diversification in Arable Systems

Partners: UBO (Lead), WU

Objective

Adoption rates of intercropping for arable crops remain seemingly low in Europe despite established multiple benefits in comparison to sole cropping, e.g. higher land use efficiency, higher yield stability, higher resource use efficiency, improved soil quality, and reduced need for plant protection inputs. This suggests to strategically move intercropping research to a next level by:

- Making intercropping research more connected and systematic across multiple environments to identify research gaps to more strategically invest research efforts. The focus will be on arable grain crops for food and feed in intercropping.
- Systematically mapping the state of intercropping research for arable intercropping to identify knowledge needs including intercropping management and design on the farm level as well as value chain aspects.
- Providing meta-data and primary data on intercropping research for the science community and general public.
- Harnessing digital technologies such as remote sensing data and machine learning for intercropping research.
- Drawing on datasets of multiple experiments to derive more general conclusions relevant for farming practice and understanding fundamental mechanisms in intercropping.

Figure 3.7.1: Maize and soybean strip intercropping

Work plan

Three main lines of work were developed and the time schedules are given in **Erreur ! Source du renvoi introuvable.**:

- **Quantitative analysis of multiple available experiments at Bonn University**: Data are available on broad range of aspects on morphology, physiology and agronomy to build statistical or machine learning based models to predict intercrop performance. This work will need extensive coordination with all involved researchers at Bonn university and the partner Wageningen University.
- **Systematic mapping of intercropping:** A concept for a systematic mapping for arable intercropping was developed to lay the ground for a stronger systematic research strategy for intercropping in

Europe. Systematic mappings allow to identify knowledge gaps in empirical research and knowledge clusters for secondary research. The systematic map will follow the methods described by James et al. (2016). A protocol for this study will be developed – guided by the standards of the Collaboration for Environmental Evidence - to ensure high methodological rigor and comprehensiveness. Tools like EviAtlas[1] will possibly be used to provide the metadata from the systematic mapping to the community.

- **Remote sensing intercrops:** In a meeting with WP3 we explored the possibility to identify intercropping fields via remote sensing data. Faba bean – oat mixtures at the research stations of Bonn University (Campus Wiesengut and Campus Klein-Altendorf) and will provide a starting point for analysis. WP3 will provide the remote sensing expertise for this study.

Further ideas to be explored are:

- Specific research gaps in intercropping are currently being discussed and identified. One outcome is that so far there seems to be an emphasis on community yield stability in intercropping (Raseduzzaman and Jensen, 2017). However, issues with partial yield stability in intercropping (i.e. stability of individual mixture components) have been reported by farmers and are challenging in farming practice and intercropping adoption (Timaeus et al., 2022). In addition, ecological modeling and experiments from grassland sciences indicate that, indeed, community yield is stabilized compared to pure stands while partial yields show increased variability (Tilman, 1996; Lehman et al., 2000; Louarn et al., 2020). So far there seems to be no quantitative investigation on partial yield variability for arable intercrops, a gap that could be addressed by meta-analytical approaches. This would help to identify drivers of variability, so that barriers to adoption may be removed.
- The spatio-temporal design of intercropping can cross practically relevant farming issues with fundamental agroecological questions that so far seem underexplored in Europe but have been researched more intensively in China (Raza et al., 2020) and might inspire competitive European agriculture. For example, fully mixed intercropping systems cause costly separation procedures to obtain food grade grain quality (Timaeus et al., 2022). This could be avoided if in relay strip intercropping systems. A challenge is then to maintain intercropping advantages related to resource foraging (water, nutrients, light) while other effects might still occur across larger scales (habitats for insects, crop disease suppression).
- Methodological issues for intercropping were discussed in several internal meetings. In the future it might be interesting to improve intercropping experimentation in terms of practical relevance and methodological rigor. To improve intercropping performance and practicability to foster adoption in farming practice experimental researchers might move from comparing mixtures to monocultures in experiments to only compare alternative mixture managements and designs. This could save experimental resources while avoiding to repeat already known results (LER > 1 etc.). Complementary to this, to better understand fundamental eco-physiological processes in intercropping, more rigorous experimental designs might be needed that separate density from diversity effects. So far, many agronomic experiments apply additive mixtures that do not allow to disentangle both factors (in contrast to ecologically focused experiments that implement substitutive designs). Intercropping experiments might also profit from new technologies such as solar-induced fluorescence detection to study plant stress and photosynthesis.

---

[1] https://www.eshackathon.org/software/eviatlas.html

	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Systematic mapping		Development of study protocol (according to Collaboration of Environmental Evidence standards)				Data collection and screening						
								Coding, database building and analysis				
									Developing public meta-database			
Cross experimental analysis				Identification of appropriate experiments	data assimliation		Data preparation and preliminary analysis					
Remote satellite feasibility study			Identification of appropriate experiments and on-farm fields					Feasibility study				

Expected results

- Meta-data base on intercropping to facilitate strategic research
- Improved methodological standards for intercropping experiments
- Cross-experimental analysis: models that are able to estimate intercropping performance and heterogeneity on the basis of species trait combinations, environment and management
- Identify feasibility and highlight key challenges for models to identify intercropping from satellite data

Expected services

- Analytical methods to investigate diversified cropping systems
- Searchable and extendable meta-data base for intercropping
- Providing the basis to develop models to detect intercropping at landscape scale (if feasible)

References

James, K. L., Randall, N. P., and Haddaway, N. R. (2016). A methodology for systematic mapping in environmental sciences. *Environ. Evid.* 5, 7. doi: 10.1186/s13750-016-0059-6.

Lehman, C. L., Tilman, D., and Gaines, A. E. S. D. (2000). Biodiversity, Stability, and Productivity in Competitive Communities. *Am. Nat.* 156, 534–552. doi: 10.1086/303402.

Louarn, G., Barillot, R., Combes, D., and Escobar-Gutiérrez, A. (2020). Towards intercrop ideotypes: non-random trait assembly can promote overyielding and stability of species proportion in simulated legume-based mixtures. *Ann. Bot.* 126, 671–685. doi: 10.1093/aob/mcaa014.

Raseduzzaman, M., and Jensen, E. S. (2017). Does intercropping enhance yield stability in arable crop production? A meta-analysis. *Eur. J. Agron.* 91, 25–33.

Raza, M. A., Cui, L., Qin, R., Yang, F., and Yang, W. (2020). Strip-width determines competitive strengths and grain yields of intercrop species in relay intercropping system. *Sci. Rep.* 10, 21910. doi: 10.1038/s41598-020-78719-y.

Tilman, D. (1996). Biodiversity: Population Versus Ecosystem Stability. *Ecology* 77, 350–363. doi: 10.2307/2265614.

Timaeus, J., Ruigrok, T., Siegmeier, T., and Finckh, M. R. (2022). Adoption of Food Species Mixtures from Farmers' Perspectives in Germany: Managing Complexity and Harnessing Advantages. *Agriculture* 12, 697. doi: 10.3390/agriculture12050697.

3.8 UC8 Landscape: IoT & EO services in support to European landscape adaptation to climate change

Partners: UFZ (Lead), INRAE

3.8.1 Bioindicators for value and status of landscapes with regard to pollinators

Develop, test, improve and optimise prototypes of commercially available bumble bee colonies as bioindicators for value and status of landscapes with regard to pollinators. Bumble bee colonies will be equipped with high-end sensors to assess and monitor pollinator activity, performance, and status.

Application of IoT techniques to combine information from different sensors within pollinator colonies and across the agricultural landscape and develop workflows to synthesise real-time information on pollinator status across scales and related to different environmental drivers.

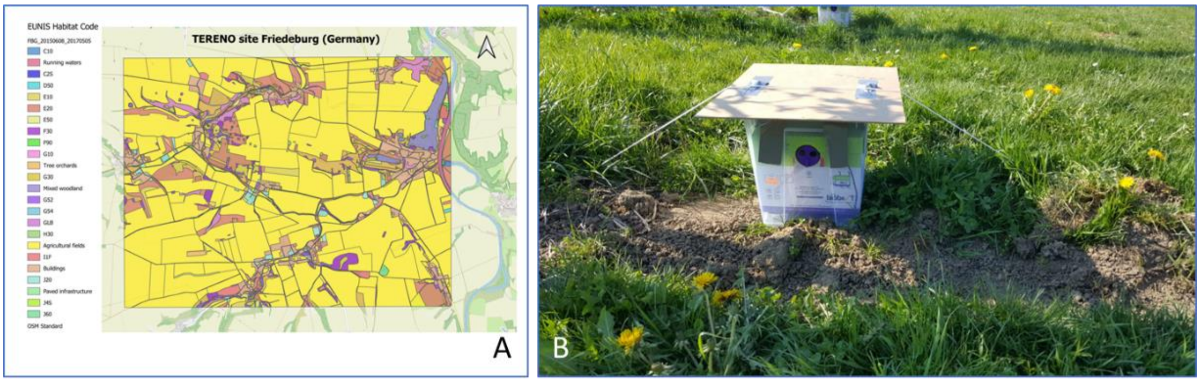

Figure 3.8.1 A Friedeburg (TERENO sites) as a start of the pilot in 2024, B Bumblebee colony

<u>Work plan</u>

Activity for 2023 (and 2024):

- Equipment acquisition:
  - IOT devices => scales, cameras, microphones, temperature logger inside & outside of bee colonies.
    (a) Scales combined with temperature logging inside and outside bumble bee colonies are available at https://www.wolf-waagen.de/?lang=en;
    (b) sound recording (e.g. Audiomoth devices, https://www.openacousticdevices.info/audiomoth);
    (c) camera systems with AI based recognition are available at e.g. https://apic.ai/ (contact request initiated).
- Detailed working plan:
  - Clarification and first tuning about the specific needs (software, visualisation, analysis; remote sensing data) of this UC and the potential contribution of WPs, which will l be an ongoing process with respect to implementation of the UC activities. Schedule: 02/23 - 06/23. Link to WP2, WP3, WP5.
  - Acquisition, testing and validation of IOT devices (scales, cameras, microphones, temperature logger inside & outside of bee colonies) for the upcoming campaigns. Schedule: 10/23 - 04/24. Link to WP2.
  - Start of PhD project (36 months): implementation, performance and analysis of the respective field campaigns. Schedule: 01/24 - 12/26. Link to WP2, WP3, WP5.
  - Field season I (monitoring of 16 bumble bee colonies with IOT devices at the TERENO site Friedeburg [4x4 km]), implementation of data flows. Schedule: 04/24 - 9/24, further repetition will be performed in the following seasons 2025, 2026.

2023				2024				2025			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Clarification about the specific needs											
		Acquisition, testing and validation of IOT devices									
				Start of PhD project: implementation, performance and analysis of the respective field campaigns							
					Field season I				Field season II		

<u>Expected results and services</u>

- Setup of bumble bee colonies as bioindicators for landscape assessment.
- Methods for combination of multiple sensor information.

- Framework for automated pollinator monitoring Expected services.

3.8.2 Assessment and monitoring of landscape dynamics

The Doller valley –France is a community of municipalities stretching from Burnhaupt-le-Bas to the Ballon d'Alsace (total area 100 km2). It has been identified by the Grand-Est region as an experimental area for fir dieback. The UC aims at combining IoT based and light phenotyping tools, up- and -down scaling proxy and remote sensing tools, data assimilation into process-based models, joint use of phenomenological and process-based models into simulation platforms to (i) cope with environmental crisis management, and (ii) feed multi-criteria and multi-risk management decision tools. Specifically, our objectives in PHENET Project are (i) testing, improving and optimising prototypes of sentinel IoTs combined with light phenotyping tools and proxy- and remote-sensing products to assess and monitor forest dynamics and health, (ii) implementing the improved techniques within tree stands and across the forest landscapes, (iii) developing the workflow between them and edge-computing to combine information from different scales (points, transects, surfaces) and real-time information on forest performance with different environmental drivers.

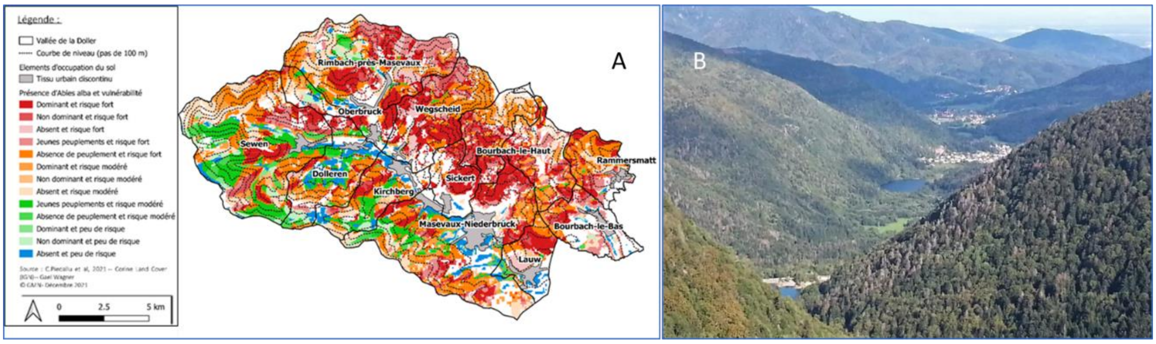

Figure 3.8.2.1 A map of the Dollar valey, B picture of the Dollar valley landscape Copyrights : Christian Piedallu and CCRN 2019 (AgroParisTech)

<u>Work plan</u>

- Stakeholder involvement and information about the Dollar valley and need for the monitoring and assessment of landscape dynamics in times of climate change (series of meetings – every 3 months). The first meeting took place on 17th of May 2023 and the following meeting is scheduled End of August 2023. Schedule: 5/23 - 8/23. Link to WPs: none.
- First installation of prototypes in summer 2023 following a meeting (4th of July) with ALCOM Tech in charge of producing the IoTs. Installation of the devices, first runs of data sets (Autumn 2023), operating system to get the data from the cloud and visualization on a web site (December 2023). This will be complemented by a meeting with WP2 (IPPN Workshop 26-27 June Angers). Schedule: 9/23 - 12/23. Link to WP2 and WP3.
- Communication activities include the participation to Train-the-Trainer course in September 2023. Schedule: 9/23 9. Link to WP6.
- Observation designs across scales (points, transects, surfaces), upscaling the ground-based information, combination with remote sensing information (crops, NDVI, extreme weather events, ...) and downscaling (data assimilation into models). Schedule: 1/24 – 12/24 9. Link to WP3.

2023				2024			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Stakeholder involvement and						
		Istallation of prototypes					
		Communi-cation					
				Observation designs across scales			

<u>Expected results and services</u>

- Forest growth and dieback forecasting.
- Modelling platform to be used by stakeholders (private and public forest managers).

4 CONCLUSIONS

The initial phase of the project was characterized by an intense exchange between particularly the UCs and the WPs to align the activities. All UCs have successfully initiated their activities and have sound work plans for the first two years of the project.

ANNEX

Annex 1: Overview of experimental sites in PHENET

Acronym of trial	Location (city, country)	Season(s)	Crop species	Trial objective	Contact email for trial info	PHENET WP and or UC involved
HTPP on RI	Clermont-Ferrand, France; Mauguio France; Toulouse, France; Zurich, Switzerland; Elvas, Portugal	2024-2025, 2025-2026	Winter wheat (+30 culttivars)	Analyze and model the genetic variability and GxE interactions for structural and functional traits	pierre.martre@inrae.fr; raul.lopez-lozano@inrae.fr	UC3: GxE Cereals
Satellite on RI	Clermont-Ferrand, France; Mauguio France; Toulouse, France; France; Changins, Switzerland; Elvas, Portugal	2024-2025, 2025-2026	Winter wheat (+30 culttivars)	Complete proxi-phenotyping with traits derived from satellite signals	pierre.martre@inrae.fr; raul.lopez-lozano@inrae.fr	UC3: GxE Cereals
On-farm satellite	6 sites in France; 1 site in Switzerland, 2 sites in Portugal	2024-2025, 2025-2026	Winter wheat (+6 culttivars per site, 14 in total))	Combine satelllite and IoT sensors to derive crop model parameters at the genotype level	pierre.martre@inrae.fr; raul.lopez-lozano@inrae.fr	UC3: GxE Cereals
Varietal trial with spikes inoculated with Fusarium Head Blight (FHB)	1 site in Belgium-Gembloux in small plots (10m2), 1 site in France in small lines (1 row spaced by 25 cm), 3 sites in Switzerland in small plots (7m2)	2023-2024	Winter wheat (41 cultivars in Belgium; 50 cultivars in France and 30 genotypes in Switzerland) Durum wheat (10 cultivars in France)	FHB disease on spikes assessment using fluorescence handheld device (Agroscope), VIS-NIR multispectral imaging (Geves) and NIR hyperspectral imaging (CRA-W). RGB images will be acquired on all the sites using Literal (old release) Phenoman and Sony RGB Camera (Geves), using Phenoman (to be discussed with Arvalis) (Agroscope) or smartphone (CRA-W)	p.vermeulen@cra.wallonie.be ; valerie.cadot@geves.fr; juan.herrera@agroscope.admin.ch; andreas.hund@usys.ethz.ch	UC1: Plant Health

Varietal trial with seeds inoculated with wheat bunt	1 site: Belgium-Gembloux in small plots (10m2)	2023-2024	Winter wheat, triticale, spelt, durum wheat (40 cultivars)	Wheat bunt disease on spikes assessment using NIR hyperspectral imaging (CRA-W)	p.vermeulen@cra.wallonie.be	UC1: Plant Health
Trial with natural infection of Barley Yellow Dwarf Virus (BYDV)	1 site: France	2023-2024	Barley	BYDV disease assessment on leaves using the perch Phenoman (Geves)	valerie.cadot@geves.fr	UC1: Plant Health
Fir dieback	More than 100 temporary plots, vosges mountains, france	since 2019	Fir (pure and mixed stands)	Understanding the drivers of fir dieback	laurent.saint-andre@inrae.fr; christian.piedallu@agroparistech.fr	UC8 : Doller Valley
TERENO Insect and bird monitoring	Germany, Saxony-Anhalt; 6 agriculturally dominated landscape test sites of 4x4 km each	since 2009	landscape scale!	investigating the drivers of insect and bird populations	mark.frenzel@ufz.de	UC8 : TERENO sites
	Ecotron Maasmechelen			Enclosed climate change experimental platform system, that entails two experimental ecosystems – European heathland subjected to climate change and pear orchard subjected to climate change	nadia.soudzilovskaia@uhasselt.be	UC6: Soil phenology
	Mycotron			soil biodiversity experiment of Hasselt university (still under discussion but likely will be used)	nadia.soudzilovskaia@uhasselt.be	UC6: Soil phenology
Intercropping	University Bonn		crop rotation	Wiesengut and Campus Klein Altendorf of Bonn University, Germany provide a rich source for the future	tdoering@uni-bonn.de jtimaeus@uni-bonn.de	UC7: Intercropping

Soil Health	BOKU	2023		Agricultural fields at BOKU research station outside Vienna will be used for testing the S4ML Subterra Green and correlate the data with soil samples. Other land uses such as grass land and forest will also be tested	hans.sanden@boku.ac.at	UC2: soil health
Soil Health	BOKU	2024	Barley	A divers landscape in the Vienna area will be sampled to test the hyperspectral camera The Barley field will be used to test the root probe in cooperation with the EU project Barley MicroBreed who look ate root properties and distribution of Barley varaieties.	hans.sanden@boku.ac.at	UC2: soil health
Soil Health	Porto	2025		A divers landscape in the Porto surroundings (Wheatfield from UseCase detail TBC.) will be sampled to test the hyperspectral camera and root camera	hans.sanden@boku.ac.at	UC2: sioil health
Orchard	Rillaar, Belgium		apple	The five locations where the apple refpop. All orchards are divided into two parts: the first part is to be managed with the common agricultural practice of the country, the second is to receive alternative management conditions (e.g., low pesticide or water input).	Walter.Guerra@laimburg.it	UC4: GxE orchard
Orchard	Angers, France		apple		Walter.Guerra@laimburg.it	UC4: GxE orchard
Orchard	Laimburg, Italy		apple		Walter.Guerra@laimburg.it	UC4: GxE orchard
Orchard	Lleida, Spain		apple		Walter.Guerra@laimburg.it	UC4: GxE orchard
Orchard	Wädenswil, Switzerland		apple		Walter.Guerra@laimburg.it	UC4: GxE orchard

F2P	Corroy-le-Grand, Belgium	two seasons starting 2024 or 2025		Small trial with large plots (EO compatible) on innovative management practices (tbd), equiped with IoT and monitored with RI-type phenotyping instrumentation.	xavier.draye@uclouvain.be	UC5: F2P
F2P	Many sites in Belgium/ North of France (to be defined)	two seasons starting 2024 or 2025		Farm network trial with whole fields or large plots (EO compatible) on innovative management practices (tbd), equiped with IoT.	j.vanwesemael@soilcapital.com xavier.draye@uclouvain.be	UC5: F2P