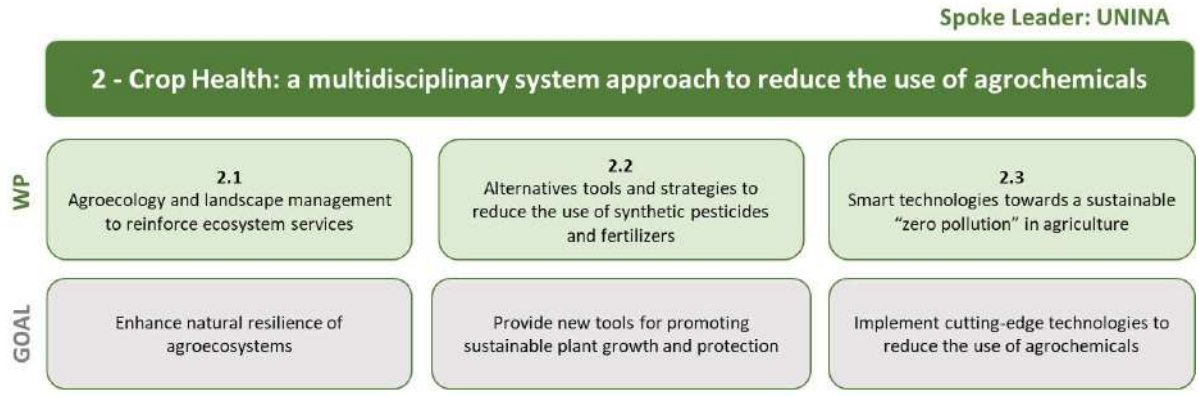
SPOKE 2



Work package number	2.1	**Lead beneficiary**	UNIPD
Work package title	Agroecology and landscape management to reinforce ecosystem services		
Start month	1	**End month**	36

Objectives

- To evaluate the role of different managed and un-managed habitat types in supporting agrobiodiversity and related ecosystem services key to crop production
- To elucidate mechanisms underpinning the relationship between agrobiodiversity and ecosystem services key to crop production
- To develop cost-effective and expeditious (bio)monitoring tools and protocols for indicators of agroecosystem health
- To develop a Decision Support System (DSS) supporting farmers and policy makers in the adoption of management strategies promoting functional biodiversity and ecosystem services

Description of work

Task 2.1.1 *Farm and landscape management strategies promoting functional biodiversity at multiple spatial scales* **(M1-M36; task leader:** UNINA; **partners involved:** UNINA, UNIBO, UNIPD, UNIBAS**)**

European agriculture often adopts a land sharing approach that integrates both biodiversity conservation and food production on the same landscapes. Here, we will apply a multi-habitat sampling approach to evaluate the role of different habitat types (both crop and non-crop) in supporting below- and above-ground biodiversity and related ecosystem services key to crop production. In particular, we will test how different agro-ecological strategies can affect multiple taxa across different trophic levels and how different landscape compositions and configurations can support biodiversity and ecosystem services.

Methods: several regional observational studies across representative landscape gradients will be performed. Farms will be selected along statistically orthogonal gradients in local management (e.g. IPM vs. organic farming), landscape composition (e.g. crop diversity) and landscape configuration (e.g. edge density). In each farm, biodiversity and ecosystems services will be sampled and quantified using traditional and modern techniques (e.g. DNA metabarcoding, soil respiration etc.).

***Initial TRL*:** 2

***Final TRL*:** 4

Task 2.1.2 *Mechanisms underpinning the relationship between biodiversity, above and below-ground services sustaining primary production and crop health* **(M1-M36; task leader:** CREA; **partners involved:** UNINA, UNITO, CREA, UNICT**)**

In the first place, this task will investigate understudied biodiversity-ecosystem service relationships. In particular, soil harbours a substantial fraction of the Earth's biodiversity, whose role in contributing to many crucial ecosystem

functions is largely unknown. Subsequently, we will unravel the potential interactions between below-ground and above-ground ecosystem services (e.g. primary production, biocontrol, pollination). Such context dependency and interactions among services will have important practical implications in defining a virtuous management of multiple services in complex systems, such those represented by the Italian agroecosystems.
Methods: first, the actual biotic drivers of soil ecosystem services (and their interplay) will be investigated at the mesocosm-level by manipulating soil communities and by adopting a multifaceted approach relying on innovative technologies (e.g., genomics and transcriptomics), as well as non-invasive technologies, such as X-ray tomography. Second, semi-field, plot, or mesocosm experiments will be performed by manipulating several below-ground and above-ground ecosystem services. In these experiments, additive, synergistic and antagonist effects of multiple services will be investigated and their contribution to crop yield quantified under realistic field conditions.
***Initial TRL*:** 3
***Final TRL*:** 5

Task 2.1.3 *Technologies of environmental monitoring and biomonitoring to assess the impact of agroecological strategies* **(M1-M36; task leader:** UNIBO; **partners involved**: UNINA, UNIBO, UNITO, e-GEOS, ENG)
Innovative strategies for the (bio)monitoring of agricultural areas are fundamental for a better understanding of the individual and cumulative effect of different farmland management systems on the environment. Such strategies can guarantee benefits to food, health, water and climate, all aspects which are deeply interconnected with biodiversity. While previous monitoring efforts have mostly focused either on habitat type and above-ground biodiversity, there is now the need to have a holistic understanding and to capture the complexity of biodiversity responses to land-use intensification. Within this framework, T2.1.3 aims to develop and validate cost-effective and expeditious tools and protocols for monitoring key farmland-associated species, from both above-ground and soil communities, and soil functionality, which can be used as indicators of agroecosystem health.
Methods: the new generation of biodiversity assessment tools (e.g., eDNA metabarcoding, DNA microarray-based technologies, acoustic stations, proximal sensing such as time-lapse cameras and remote sensing) have been proposed as reliable methods for measuring and tracking changes in biodiversity. In this task, the accuracy of such types of approaches in detecting the selected bioindicators, targeting both aspects of farmland biodiversity (taxa diversity and functionality), will be validated in selected case-study areas representative of the Italian agroecosystems. These technologies can be used for a non-destructive and non-invasive monitoring of a variety of species and the associated ecosystem services (such as for pollinators and parasitoids).
***Initial TRL*:** 4
***Final TRL*:** 6

T2.1.4 *Modelling the impact of agroecological strategies on functional biodiversity and on ecosystem services* **(M6-M36; task leader:** Engineering; **partners involved**: UNINA, UNIBO, UNIPD, UNIBAS, UNITO, CREA, UNICT, e-GEOS, ENG**)**
Developing spatially-explicit models for assessing the impact of agroecological strategies on ecosystem services and implementing the achieved information into an integrated Decision Support System, will guide farmers and policy makers in the adoption of management strategies promoting functional biodiversity and ecosystem services at multiple spatial scales. This will allow us to shape resilient agroecosystems and preserve the current natural capital. The DSS will give the possibility of forecasting different scenarios resulting from the individual farmer choices across real landscapes and from different policy contexts (e.g. CAP). The empirical data from the previous three tasks will be used as inputs for the DSS .
Methods: starting from the data collected in the previous tasks, spatially-explicit predictive models will be estimated and implemented into a GIS environment (QGIS). These statistical models will be regionally validated and will feed data into a decision support system (DSS) that will help coordinate private and public interventions across heterogenous landscapes. To guide policy and stakeholder decision-making, land-use scenario analyses will also be performed.
***Initial TRL*:** 4
***Final TRL*:** 6

Deliverables
D2.1.1 Report on the effect of farm and landscape agroecological strategies on multiple taxa and associated ecosystem services (M36)

D2.1.2a Report on key biodiversity-ecosystem functioning relationships supporting crop production and health (M36)
D2.1.2b Report on the interactions between ecosystem services supporting crop production and health (M36)
D2.1.3 Protocols, advanced methods and new bioindicators for evaluating the impact of agroecological strategies on farmland functional biodiversity (M36)
D2.1.4 Development of a preliminary DSS tool supporting farmers and policy makers (M36)

Milestones
M2.1.1 Definition of study case areas (2 to 3) and establishment of sampling protocols (M6)
M2.1.2 Establishment of mesocosms (15 to 25 for each tested condition) in walk-in climatic chambers, and setup of semi-field experiments in experimental farms (2 to 4 within each study case area) in which biodiversity and ecosystem services will be manipulated (M8)
M2.1.3 Establishment in two to five experimental farms of (bio)monitoring devices targeting different components of above and below ground biodiversity (M18)
M2.1.4 Establishment of spatially-explicit models for assessing the impact of agroecological strategies on ecosystem services within the study case areas (M24)

Interactions with other Spokes
The experimental approach developed will be used to analyze data generated by observations carried out by Spoke 3 (*WP3.2 - Innovative strategies to protect natural resources and reduce agriculture environmental impact*), Spoke 4 (*WP4.2 - Smart climate agriculture and forestry: from sustainable products to the bioeconomy*), Spoke 6 (*WP6.1 - Farm management models to enhance sustainability and resilience in different agricultural scenarios*) and Spoke 7 (*WP7.1 - Integrated models to develop marginal areas*) in relevant environments, characterized by different management strategies and landscape composition.

Work package number	2.2	**Lead beneficiary**	UNITO
Work package title	Alternatives tools and strategies to reduce the use of synthetic pesticides and fertilizers		
Start month	1	**End month**	36

Objectives
- To provide alternative tools for plant protection and nutrition/growth promotion that can replace the use of synthetic agrochemicals.
- To enhance plant defense and nutrition/growth through genetic improvement, the use of microorganisms and plant signaling molecules.
- To use biocontrol agents both as organisms and as source of biopesticides and biostimulants, which will be also obtained from different biomasses.
- To develop formulation nanotechnologies that will allow safe and efficient delivery of biopesticides and biostimulants.
- To develop non-chemical pest control strategies.

Description of work

Task 2.2.1: Improved genetic materials to reduce the use of agrochemicals (M1-M24; task leader: UNICT; **partners involved**: UNINA, UNIPD, UNITO, CREA, UNICT, CAI)
Protocols for assessing the level of resistance/tolerance and nutrition/growth performance of plant genetic materials made available by Spoke 1 will be developed. This will be done at laboratory, semi-field, and field level. Moreover, to assess the risk associated with the use of new genetic material, protocols for measuring the impact on non-target organisms (selected representatives of different ecological functions and trophic guilds) will be also developed.
Methods: bioassays will be developed to assess the nutrition/growth performance of plant genetic materials and their impact on fitness of pests and pathogens, focusing also on the underlying mechanisms of action. The effects on non-target organisms, such as biocontrol agents, pollinators and beneficial microorganisms will be also assessed

with both *in vitro* and *in vivo* protocols, at individual and population level, integrating biological, behavioural and *omic* data.
***Initial TRL*:** 3
***Final TRL*:** 5

Task 2.2.2: Plant multitrophic interactions underlying agroecosystem stability and resilience (M1-M24; task leader: UNINA; **partners involved**: UNINA, UNIBO, UNIPD, CREA**)**
Several fungal and bacterial strains that occur naturally as part of the root microbiota have a nutrition/growth promoting effect, or are used for biocontrol but have also an indirect effect against pests via the plant, by activating defense response pathways. We will study the impact of beneficial microorganisms inhabiting rhizosphere soil and/or associated with plants on plant nutrition/growth and on pest/pathogen control; we will elucidate the molecular mechanisms underlying these interactions. In addition, the effect of the use of beneficial microorganisms will be evaluated along the trophic chain. These studies will provide the background knowledge for a targeted manipulation of these multitrophic interactions, using selected microorganisms and/or natural molecules modulating these interactions, to enhance the plant nutrition/growth and defense barriers while reducing the risk to which non-target species can be exposed.
Methods: the induction of plant growth and defense responses by microorganisms and their metabolites, as well as by plant signalling molecules will be characterized at functional and molecular level, using both *in vitro* and *in vivo* bioassays, complemented by multiple *omic* analyses and functional studies aiming at defining targeted application strategies.
***Initial TRL*:** 3
***Final TRL*:** 5

Task 2.2.3: Biological control (M1-M36; task leader: CREA; **partners involved**: UNINA, UNIBO, UNIPD, UNITO, CREA, UNICT, CAI**)**
The diffusion of biocontrol agents largely relies on the availability of high-quality products and of adequate technologies for their use, aiming to reduce the production cost and to enhance their efficacy. This can be achieved by implementing cutting edge technologies for their selection, production, quality control, storage, and distribution in the field. Moreover, to facilitate the authorization for importing biocontrol agents from foreign countries for classical biological control, it will be crucial to define new risk assessment schemes that can provide a holistic evaluation of the impact that these organisms can have on non-target species.
Methods: protocols for scaling-up the production and storage of beneficial organisms and microorganisms will be developed and quality control methodologies, based on genetic analysis and targeted bioassays, will be established. The impact of biocontrol agents on non-target species will assessed also with the use of landscape specific modelling approaches.
***Initial TRL*:** 4
***Final TRL*:** 6

Task 2.2.4: Biopesticides and biostimulants (M6-M36; task leader: UNIBAS; **partners involved**: UNINA, UNIBO, UNIPD, UNITO, CREA, UNIBAS, UNICT, CAI, ENI**)**
Biopesticides and biostimulants will be identified by functional studies of multitrophic interactions in T2.2.2 and by screening for biological activity of the natural compounds obtained from biomass processing in Spoke 8. Specific bioassays will be developed to assess their efficacy and ecological sustainability. For the selected bioactive compounds/strains formulation strategies will be developed, aiming to increase their shelf-life, resistance to environmental degradation and to facilitate, when appropriate, the uptake by plant tissues or target organisms. Novel tools for risk assessment will be developed for this category of "low risk agrochemicals".
Methods: molecules of different origin will be tested to assess their impact on nutrition/growth and against selected pests and pathogens, as well as on non-targets, using both *in vitro* and *in vivo* experimental approaches, complemented by *omic* analyses to identify functional biomarkers. For the most promising candidates, tailored formulation strategies will be developed, to promote efficacy and sustainability. Among others, biocompatible humo-pectic hydrogels for soil delivery will be considered, while microparticles (MPs), nanoparticles (NPs) and carbon quantum dots (CQDs) will be considered for products to be sprayed on plants. Semi-field and field trials will be designed for selected formulations of effective molecules.
***Initial TRL*:** 4
***Final TRL*:** 6