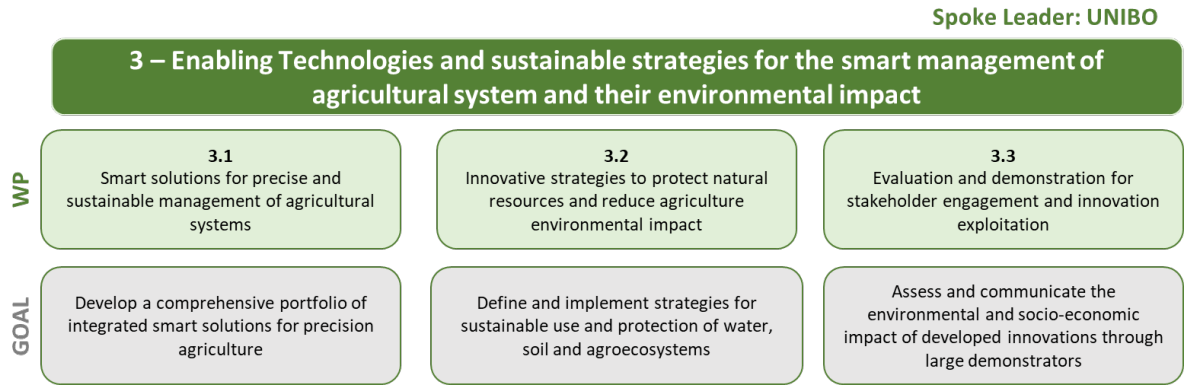
SPOKE 3



Work package number	3.1	**Lead beneficiary**	UNINA
Work package title	Smart solutions for precise and sustainable management of agricultural systems		
Start month	1	**End month**	36

WP Leader: Guido D'Urso [UNINA]

Objectives

- to devise innovative sensor solutions (on-plant, proximal and remote), to generate data flows on critical aspects of crop production
- to apply precision management systems and agroecological services for boosting plant productivity
- to develop and adopt smart tools and vehicles for the automation of precise application of agricultural inputs and the execution of cultural practices by machines and robotic systems
- to provide alternative environmental-friendly solutions for crop management
- to develop innovative robotic systems enabling different levels of automation in crop management
- to develop digital solutions for crop quality assessment
- to develop and implement digital models and integrated AI and Big data platforms tailored for agricultural systems

Description of work

Task 3.1.1 ***Sensor-based, geospatial and digital crop, soil, water, and structures monitoring and modelling*** **(M1- M36) task leader: CNR** [Mirco Boschetti & Piero Toscano]; **partners involved:** UNIBO, UNIBA, UNIMI, UNINA, POLIMI, UNIPG, UNIPR, CNH, IBF, TEL

On-plant, proximal and remote sensors will be developed and tested under selected field conditions, to assess and validate their performance. The sensor-based approach will be integrated and powered by geospatial technologies, geostatistics, geoprocessing and digital models. Image analysis and artificial vision are expected to be widely employed, to provide data on key information elements, such as crop phenology, seed maturity, vegetable growth and fruit size. The work will focus not only on production inputs, such as soil use, water and fertilizer application and monitoring, but also on crop quality and quantity parameters. Models of crop response to management inputs will be developed, to provide real-time management solutions that enable an efficient and optimized input calibration for the construction of a multi-layer "digital twin" of the crop (and related infrastructures such as irrigation systems, structures, and facilities) embedding all the relevant information needed for a optimizing management of various agricultural systems. Energy monitoring and modelling for the design and optimized control of new smart structures and plants and the decarbonization and retrofitting of existing farm facilities will also be applied.

Methods: design, development, integration and testing innovative sensors for monitoring crop, soil, water, structure performances; management modelling, multi-layer virtualization. Lab and field scales implementation and tests.

Research Activity:
CNR: ***Agro-sensing*****.** We intend to: a) implement continuous, in vivo and proximal integrated data acquisition solutions by multi/hyper spectral in situ stations and RGB/multi/hyperspectral imaging systems on autonomous platforms (e.g. UAVs); b) test these systems in simulated and controlled environments and acquire field data from experimental and real farms in synergy with other tasks to exploit also satellite data; c) develop suitable processing solutions (i.e. geoprocessing, machine learning and computer vison) for single sensor and multidimensional data analysis devoted to crop and soil parameters estimation and to the identification of (early) stress situations. This data – information flow will be tested, according to data availability, in the other tasks where modelling solutions for specific crop management will be developed.

UNIBO: ***Proximal and remote sensing crop characteristics and performance*****.** Activities will be focused on applying spectral techniques for proximal and remote sensing in broad field, fruit and vegetable crops. Novel spectral interface technologies (microwave, mm-wave, THz radiation) and advanced machine learning processing will be merged into edge computing devices. Proximal miniaturized soil, trunk, leaf spectra sensors will be deployed for continuous and non-invasive monitoring. In addition, remote multi/hyper-spectral cameras will be used, that can sense over a wide range of wavelengths, providing novel parameters of plant performance. The signal processing techniques will be calibrated to determine crop phenology and growth parameters of different arable crops. Through an extensive data-collection using the on-board sensors of new-generation machines (T3.1.3), the resources employed in agricultural systems will be accurately outlined in real-farming scenarios. In addition, the data will be analysed using geospatial technologies, together with multispectral imagery and vegetation indexes, to study spatial variability and provide inputs for yield monitoring and prediction and will be used for the development of digital twins of smart and sustainable outdoor and indoor production systems (greenhouse and vertical farms). The digital twins will be powered by environmental and energy modeling engines, to allow real time 3D monitoring and simulations of the protected environment. Predictive models will be used to optimize design, control and retrofit of smart and low-carbon greenhouses and vertical farms.

UNIBA: ***Network of IoT sensors for environmental monitoring, water-nutritional status and phytopathogens detection.*** The research activities will be focused on the prototype of an innovative network of IoT sensors with data integration for environmental monitoring, water-nutritional status and phytopathogen detection. The network will be applied close to plants and will include sensors of air temperature and relative humidity; soil moisture, temperature and electrical conductivity; leaf wetness and temperature; solar radiation and PAR for LAI and NDVI evaluation, for the sustainable management of nutritional and water resources. Data measured by the proximal sensors will be related with plant status and macro and micro-nutrient content, evaluated by laboratory and field tests. Hyperspectral radiation sensors for detecting phytopathogens, mainly Xylella in olive grove, will be searched and evaluated to allow early diagnosis of systemic pathogens, especially if characterized by long periods of latency. The data collected by the IoT sensor network will be integrated for monitoring the water-soil-plant system.

UNIMI: ***Sensor based solutions for soil and crop variability detection and input management optimization.*** Geophysical and remote sensing techniques will be used to develop procedures to rapidly investigate horizontal and vertical heterogeneity of soils in at least two agroecosystems (maize and vineyard) and to obtain, through (geo)statistical procedures, maps of homogeneous management zones to be used in PA approaches. In one of the two agroecosystems (maize), an experimental platform composed of plots in which irrigation is applied through different irrigation techniques both pressurized (surface and subsurface drip, sprinkler) and gravity, will be realized. In the plots, through networks of sensors and remote and proximal sensing techniques, variables related to the crop-soil system will be detected and used to guide irrigation management directly and through a Decision Support System (DSS).

UNINA: ***Develop and validate a set of models and algorithms in agriculture and viticulture*****.** The objective of this task is to develop and validate a set of models and algorithms in agriculture and viticulture which use

as inputs a combination of heterogeneous data, such as weather forecasts, satellite observations, imagery acquired through unmanned aerial vehicles (equipped with multispectral sensors) and in-field optical and thermal cameras, and weather station measurements. The models will aim to monitor and predict phenological stages, vegetative growth, and to anomaly detection (biotic and abiotic stresses). A specific activity will be dedicated to the utilization of synthetic aperture radar (SAR) from satellites and drones for detecting soil moisture and canopy growth, with experimental investigation and validation from ground data sets. Intensive field activity will be carried out in commercial vineyards.

POLIMI: Acquisition and analysis of multi and/or hyper-spectral signals and/or images from near- and close-range sensors with artificial intelligence techniques for phenotyping and optimization of agricultural production. Techniques for the acquisition and analysis of signals and/or images will be developed, also based on machine learning and deep learning algorithms optimized for innovative sensors to recognize phenotypic characters and properties of interest in agricultural productions. Techniques that can be applied to proximity signals and/or images captured in the field by means of transportable sensors (i.e., mounted on agricultural machinery or mobile robots) will be considered. The goal is to create, through advanced localization and mapping techniques, very high-resolution reconstructions in which each individual plant is recognized and monitored over time to build a digital twin in the "internet of plants". The results will be validated through data acquisition campaigns in dedicated test fields by comparing the results of the analysis of sensor data with information from the field.

UNIPG: ***Sensor-based monitoring of water and nitrogen status in tomato and olive tree.*** Plant sensors (i.e. RFID sensors of leaf temperature, dendrometers), proximal and remote sensors (i.e. chlorophyll meter, fluorescence-based flavonols meter, thermal imaging systems, multispectral and hyperspectral reflectance sensors) for water and nitrogen status monitoring of processing tomato and olive tree will be tested (and selected) in field experiments with factorial combination of water and N availability. Destructive sampling and sensor-based measurements throughout the crop cycle will be performed to analyze growth, water status and N uptake. Threshold values/indices will be determined for irrigation and fertilization management. Data will be also analyzed by a data-driven approach (see Task 3.1.5).

UNIPR: ***Digital systems for crop monitoring and growth forecasting***. Sensor systems at crop, plot and satellite scales will be developed to allow monitoring of crop growth, their state of health, as well as the microclimate and soil moisture. Acquisition of a novel in-vivo sensor enabling real-time assessment of plant physiology will also be investigated. Trade-offs between specificity and coverage of different sensors together with issues of IoT sensor data acquisition, energy efficiency, data calibration and ground truthing will be addressed. An Unmanned Ground Vehicle (UGV), equipped with Lidar, stereo and multispectral cameras and capable of autonomous navigation and manipulation, will be developed to enable plant/crop phenotyping and health assessment, plant structure monitoring, terrain modeling for water drainage and light exposure prediction, leaf or fruit sample collection.

CNH*: High-fidelity models in several simulation discipline areas to simulate the real machines systems*.
To develop the digital twin platform and its performances, CNH will develop High-fidelity models in several simulation discipline areas to simulate the real machines systems: FEA -, CFD -, NVH -, Vehicle dynamics, System modelling & real-time simulation.
All those models have to be merged and interconnected by the digital twin implementation. Specifically, for the creation of a digital machine, high fidelity models have to be converted into reduced order models i.e., models that are lean and reactive able to well represent the machine in a real-time scenario. The conceived digital twins allow a closed loop remote monitoring of the machines using IoT platforms and the remote interoperability of the physical twin. The Digital twin capabilities begin as a tool of choice in the engineer's toolbox. They can streamline the design process and eliminate many aspects of prototype testing. It helps engineers identify potential manufacturability, quality, and durability issues all before the designs are finalized.
In this environment a wide data collection is needed and essential. To achieve this goal a complete set of tools needs to be used on the vehicles connecting them with a complex infrastructure. Data needs to flow in a consistent way using a capable network. It is mandatory to structure a virtual ambient that will contain the complete set of data and the proper data analytics. At the same time, we need to consider the backward line

of the data that will feed the control of the physical vehicle. The platform shall be able to host remote virtual models running as services in the cloud.

IBF: Analysis of soil variability using remote sensing data. IBF aims to develop rapid tools to map within-field soil variability for annual and tree crops through remotely sensed data. In particular for annual crops the activities will include: a) defining a framework for the creation of a synthetic image of bare soil, using a multi-temporal series of Sentinel2 satellite images; b) semi-automatic identification of the intra-field variability using machine learning techniques. While for tree crops the activity will be same as a) and b) but using as input a single drone image for the study of intra-field variability.

TEL: ***Geo-information services with drones for soil and crop monitoring.*** The research activities will focus on design and demonstration of crop and soil monitoring services using images acquired by drones. Several image acquisitions by drones will be conducted to find out the flight and acquisition parameters (e.g. sensor, height, speed, overlap) that better suit with the crop and soil analysis to be carried out. Once completed the tuning of acquisition parameters, the activity will focus on the development of an end-to-end service that allows the farmers to receive the info-products generated.

***Initial TRL*:** 3
***Final TRL*:** 6

Task 3.1.2 ***Automated, precise, and sustainable plant management systems*** **(M1-M36) task leader:** UNINA [Stefania De Pascale]; **partners involved:** CNR, UNIBA, UNIMI, UNIBO, POLIMI, UNIRC, ISP
The sensors and models developed in Task 3.1.1 will be deployed in test sites on selected key arable and non- arable crops, vegetable crops, fruit and/or winegrapes to validate them, both from the technological and agricultural point of view. Data generated by sensor networks will inform models suggesting appropriate, real-time, crop management strategies. Adoption of management solutions will be assessed *vis-a-vis* crop performance, both in terms of yield, water and fertilizer use efficiency, and in terms of crop/produce/fruit quality. The adoption of different levels of precise mechanization, robotics and automation for optimal plant management will be developed and objectively assessed. An additional effort will be carried out for adapting the identified solutions to the specific agronomic requirements of some crops and farming systems (e.g. conventional, integrated, protected, organic and vertical farming).
Methods: sensor platforms operating in test fields of main agricultural crops. Crop performance assessed via yield, efficiency of use of inputs, quality features. Field-scale implementation and tests.

Research Activity:
UNINA: ***Automated, precise, and sustainable plant management systems*****.** The optimal control of light environment is crucial to enhance the sustainability of protected (e.g. greenhouse) and indoor cultivations (e.g. vertical farm), in terms of both economic performance (increase in yield and product quality) and environmental impact (reduction of resources consumption and emissions). The aims of this task are 1) to characterize the physiological, metabolic and productive response of vegetable, flower and ornamental crops to modulation of light quantity (intensity and duration) and quality (spectral composition) through monochromatic LEDs; 2) to define specific “light recipes” for single crop o group of crops, based on functional changes of light along the phenological phases, able to optimize yield and produce quality in controlled environment; 3) to identify the best lighting system configuration, in terms of distance and position of the light sources with respect to the canopy, to maximize light use efficiency and crop performance; 4) to develop a digital program for light management in controlled environment also to reduce energy consumption.

CNR: ***Intelligent systems for productivity and quality produce in controlled environment.***
Our research activity will explore the potential of AI to control in parallel environmental variables and plant functions affecting the quantity and nutritional value of the produce. The capacity of plants to cope with different environmental biotic and abiotic factors will be tested. We will use species and varieties that have a great potential to contribute to a healthy nutrition, while avoiding problems of food safety.

UNIBA: ***Fluorescence-based biofeedback system to increase the efficiency of use of artificial plant***

radiation. This research will develop a low consumption LED management system, able to vary light intensity according to plant photosynthetic efficiency. A biofeedback system that maintains photosynthetic efficiency at the maximum level will be developed. The efficacy of the system will be assessed by comparing plant production and energy consumption as well as the incidence of the most important plant diseases in this system vs. a traditional one (benchmark). Lettuce (*Lactuca sativa* L.) will be used as a "model crop", grown in a growth chamber equipped with dimmable LED technology and the prototype of an innovative network of IoT sensors, developed within task 3.1.1, will be adapted and used for the evaluation of the lettuce conditions. The outcome will be a biofeedback system based on plant fluorescence composed by a fluorimeter, data logger/controller and LED dimmable fixtures.

UNIMI: ***Flexible platform for high-precision crop-management.*** Selected technologies will be integrated to form a unique, flexible platform enabling to study and validate high-precision approaches at different scales, from single plant to experimental plots, both in open-field and protected arable and vegetable crops relevant to the national scenario. The goals are geared to increase the sustainability of plant management systems, specifically by: i) maximizing the efficiency in use of inputs; ii) increasing yield and quality traits of products; iii) ensuring plant health protection and food safety. The platform will include autonomous vehicles equipped with plant sensors, and actuators for high-precision distribution of water, fertilizers, biostimulants, and protection treatments including novel molecules and microorganisms effective against pathogens. New-generation lighting systems and UV radiation technologies will be integrated in the platform, tailoring the light intensity, the spectral composition, the photoperiod, and possible UV supplementation. High-resolution data on crop response to precision treatments will provide a knowledge base for efficiency indicators and "need-driven" management of the crop.

UNIBO: ***Testing of Task 3.1.1 sensors and models in full field, vertical farming, fruit crops.*** The sensors and the models developed in task 3.1.1. will be tested and validated in the long-term crop rotations trials started in 1966 at Unibo's Experiment Station and still ongoing, which compare cropping sequences under various organic and mineral fertilization, to validate management solutions for specific farming systems and optimize crop yields, water and fertilizer use efficiency, crop quality infield under changing climate scenarios. In addition, the research activities will focus on the application of multi-sensor monitoring to protected and indoor/vertical farming systems where plants are grown under precise cultivation systems powered by LED biostimulation, fine-tuned through 3D light simulation and design. Crops and greenhouse and phytotrons environment will be monitored in real time and data will be processed through advanced analytics to optimize the management of the cultivation environment and LED treatment in terms of yield and active compounds contents, as well as in biological crop protection. Gaining evidence about performance of precise lighting and environmental management will allow the increase of sustainability and competitiveness of the sector. Robot-friendly orchards designs will provide a benchmark for the innovative sensing solutions developed in Task 3.1.1 for scouting traits, and in Task 3.1.3 for performing management operations.

POLIMI: A*utonomous drones for field monitoring.* Fleets of aerial and land autonomous drones are the enabling technologies for field monitoring. Due to the complexity of the agricultural environment, and in particular seasonal and geographical variability (e.g., different soil mechanical/hydraulic properties, high slopes, different crop vegetative stage), it is still hard to guarantee robust and reliable autonomous navigation capabilities. This activity will focus on developing the perception, planning, control and coordination capabilities that support robust and reliable navigation for different soil, crop and environmental conditions. A mechatronic approach will be adopted, exploiting the use of multiphysics simulators. Individual aerial/land platforms and the coordination of a fleet will be considered, also taking into account the issues related to energy management, autonomous battery recharging and the search for a synergy between sensors embarked on aerial drones and on land vehicles.

UNIRC: ***Implementation of precise and sustainable Mediterranean organic crops.*** The research will focus on the development of a DSS able to support timely and effective crop management decisions to obtain high-quality products and a reduction of external inputs. This task will provide innovative agricultural and technological solutions aimed at precise, smart and sustainable plant management systems focused on Mediterranean organic crops (olive and cereal/legumes). Geospatial technologies, geoprocessing and image analysis, considering machine metrics and operating parameters and their transfer through the most

innovative IoT communication paradigms, will be exploited as starting point for the task activity. These technologies will be implemented and tested on the proposed innovative organic crop systems coupled with phenotyping selection, selective site-specific weed management (SSWM), fertilization, and integrated pest management. The tests will include innovative renewable agro-energy systems from integrated sources.

***Initial TRL*:** 3
***Final TRL*:** 6

Task 3.1.3 ***Smart, autonomous, and IoT-based solutions for precise mechanization, irrigation, fertilization*** **(M1- M36); task leader:** CNH [Nicola Raule]; **partners involved:** UNIBO, CNR, UNIBA, UNIMI, UNINA, POLIMI, UNIPR, IRR
Advanced solutions for agricultural systems management will be developed and implemented, allowing precise, low emission, unmanned execution of key cultural practices such as, but not limited to, tillage, seeding, weed management, pesticide, water and fertilizer application, harvesting, pruning and thinning, crop transport and handling. New generation automated and/or autonomous electric machines (e.g., tractors, combine harvesters, etc.) will be developed, tested and validated in real and simulated operating scenarios to assess their safety, efficiency and performance. Innovative robotic systems for smart management of field crops, vegetable/vertical farming, orchards and vineyards, including locomotion systems, cultivation implements, mobile data harvesting systems, will be developed with a special consideration for economic and environmental sustainability. Ground as well as aerial robotic systems will be considered. IoT configurations will be developed, allowing smart operation of vehicles, robots, irrigation/fertigation systems. As integration to smart and IoT-based solutions, agroecological solutions will be developed with the aim to reduce agriculture inputs for more sustainable farming systems.
Methods: implementation of sensors, sensor platforms and models in unmanned, automated configurations, including on board autonomous vehicles and machines; IoT configuration with DSS servers; collection and analysis of machine data (i.e., CANBUS/ISOBUS); integration with agro-ecological services and practices. Prototyping, pilot/field-scale implementation and tests. Fertigation management in greenhouse and indoor/vertical farming systems.

Research Activity:
CNH: ***Autonomous specialty tractor*.** The scope of the activity, articulated on multiple years, is to define the electric and electronic architecture of a future full autonomous tractor including the identification of the functionalities to be automated. The main goal at the beginning is to approach the problem from a pure functional safety viewpoint in order to create a modular architecture that can be easily upgraded to comply with the autonomous task the tractor will have to accomplish in the future. After this initial time consuming but essential phase there will be the implementation of the steps necessary to test the architecture and the control strategy on test rig before the finalization on the real prototype as part of the proof of concept.
***Testing infrastructure for electric architectures*.** Within this task CNH will create a new facility inside the plant located in Modena – San Matteo, with the aim to perform tests and research on hybrid and full electric tractors with different ranges of power. As additional feature it will include an inner Noise and Vibration (NVH) semi-anechoic chamber / quiet room, which will allow a deep analysis on noise-related performances for newly developed architectures (drivelines and /or full vehicles). This will guarantee a unique testing environment to gather acoustic data from the vehicles without any external bias compared to the standard test cells and the field test (background noise, disturbances, no repeatability, ...).
The facility will exploit up to six independent and reconfigurable driving/braking electric motors in order to apply loads on wheel hubs and/or PTOs (Power Take Offs). This capability will cover both driveline-related tests and vehicle-related ones. Motors and cell systems will be equipped with all the mandatory noise insulations to be less impacting as possible on measurement in test room.
This cutting-edge testing facility will allow to test the new under-development electric hybrid architectures (so called “Fulgor” vehicle & Fulgor e-axle) in all possible loading combination between wheels and PTOs, as well as to fine tuning the electrical machine logics by applying and investigating real world profiles. A possible research horizon with this kind of actuation layout will be the measurement of EM emissions of electrical components under loading conditions and in a repeatable environment.
Finally, the new facility will be equipped with all the mandatory tools to perform HV tests: battery emulator, power analyzer, dedicated acquisition systems and a battery storage area or battery shelter. All of the

aforementioned tools are fundamental to provide deep research capabilities on EE systems. Specifically, the battery shelter will guarantee to be compliant also to newest battery architectures.
The cell will include control rooms, a small workshop for tractors set-up and a standard temperature control system (20-43 °C controlled temperature).

UNIBO: ***Automatic monitoring of Ag machinery use to boost efficiency - autonomous rover for orchard cultivation*****.** Large-scale automatic monitoring of the fleet of agricultural machinery in use at the UNIBO farm will be carried out to outline the use of each machine for each field. During the tests, machine operating parameters will be monitored with dedicated instruments. The assessed parameters will be compared with the data of conventional machines to evaluate the added value for farmers in adopting new generation machinery which will be tested in simulated agricultural scenarios.
Within the task and with respect to the new generation of smart vehicles, including fully autonomous tractors and machines, a standardized testing procedure, mainly derived from the already existing ISO standard 18947, will be developed to assess the safety performance of the vehicles, mainly with respect to obstacle detection systems and operational area, with additional measures also for the residual risks that cannot be eliminated. A dedicated track, to simulate different scenarios, and an EMC semi-anechoic chamber, for the electrical equipment and electronic systems mounted on the smart machines, will be created inside the Laboratorio di Meccanica Agraria of the DISTAL, in Cadriano (Bologna), to deep analyze and research the vehicle-environment-human beings' interaction and define equipment and safe use protocols. Once reached the goal, the final step will be to create a site to train students, operators and users to the correct and safe use of the new generation agricultural vehicles. Moreover, advanced solutions for agricultural systems management will be developed and implemented to reduce the pesticides use and encourage the use of sustainable practices. In UNIBO's experimental orchards, innovative methods for orchard floor weed management will be tested. The field trials will consider the efficacy of the alternative methods to control weeds, the effects on tree roots and fruit quality, the impact on soil microorganism and soil fertility and compared with conventional approaches. An autonomous, electric rover capable of management operations will be tested in innovative 2-D orchards. Precise sensor-guided management of fertigation in different hydroponic systems in greenhouse and vertical farming environment will be tested.

CNR: ***Smart solutions for sustainable agriculture.*** The research will test fixed and mobile sensing technologies aimed to data acquisition for automatic, sensor-based management of irrigation and fertilization of agricultural crops, implementing new sensors of crop status - both static and mobile - in open-field and/or protected environments, maximizing the spatial and temporal resolution of the acquired data for better decision support. Descriptive maps thus generated will inform the operational settings to optimize the fertigation strategy. Cultivation techniques based on the described approach will be compared with traditional farming systems. Responses will be evaluated in terms of resource efficiency and effects on production and quality.

UNIBA: ***Autonomous robotic systems for the smart management of Apulian "tendone" vineyards.*** This research will assess an autonomous robotic system for carrying out monitoring activities in "tendone" trained vineyards. An agricultural robot will be designed, assembled and equipped with systems for self-localization and autonomous navigation as well as devices for environment reconstruction and vegetative and fruit parameters detection. The robot will also be fitted with an ad hoc designed and built optical-acoustic sensor able to quantify CO_2 concentration. The possibility to use image analysis to monitor plant diseases will be also explored. Finally, the autonomous robot will be equipped with an *ad hoc* designed and built equipment able to deliver agrochemicals in a targeted manner.

UNIMI: ***Agricultural robot for pesticide and fertiliser distribution at variable rate and site-specific management.*** An agricultural robot will be developed for variable rate, site specific application of pesticides and fertilisers, by applying Machine Learning and Artificial Intelligence techniques. The robot will allow task programming, verification of task execution, and will feature Internet of Things solutions to boost its efficacy and efficiency.

UNINA***: IoT applications, structures and technologies for precise agriculture.*** The focus of this task will be on IoT applications, structures and technologies for precise agriculture. Specifically, the research

activities will involve: 1) the development of collaborative robots for agricultural use in field operations to be mounted on rovers and supported by fleets of drones for preliminary analysis; 2) study of motion planning and control for autonomous robotic systems in precision agriculture technologies; 3) implementing the overall smart and autonomous IoT-based architecture for precise mechanization, irrigation, and fertilization 4) the use of Global Navigation Satellite Systems (GNSSs) and inertial navigation systems (INSs) to provide high accuracy and low cost real-time positioning solutions;, 5) the development and validation of an integrated system of sensors belonging to different families (NDVI, SPAD, MPM-100, etc...) to optimize the management of nitrogen fertilization.

POLIMI: ***Mechatronic smart and autonomous platforms for agriculture*****. T**he aim of the research is to develop a multi-purpose, modular and perfectly integrated platform for crop production in indoor vertical farming. Activities will based both on hardware development such as automatic tools to perform different activities on soil and plants, as well as research to introduce an extensive use of monitoring techniques based on machine learning algorithms. Further, a Smart Precision Irrigation SPI solution will be used to optimize irrigation water and to minimize the use of fertilizer, maximizing agricultural production. The modeling components of the integrated model are already available and their integration will allow advancement in sustainable and resilient design of agricultural practices.

UNIPR: ***Development of an IoT platform and robotic systems for crop management*****.** The objective of UNIPR in this task is two-fold: (i) to develop an IoT platform able to collect, process and communicate data efficiently with the integration of heterogeneous communication systems; (ii) to develop advanced solutions for precision irrigation and fertilization. Solutions to be investigated include variable rate control of hose reels equipped with spray booms or sprinklers and use of the UGV (developed in Task 3.1.1) for field operations such as irrigation monitoring, crop close observation, sample collection. Experimental actuation systems will be implemented and included in the final demonstrator. The research activity will include an initial phase dedicated to the identification of requirements, carried out jointly with other tasks, for the identification of IoT solutions for precision agriculture activities. The following phase will be devoted to the "iterative" development of prototypes at increasing TRL. The final phase will be dedicated to the implementation of a final demonstrator, including all developed technologies, at the campus of the University of Parma.

IRR: Development of irrigation technologies and irrigation management systems for smart irrigation.
The main goals of this research activity will be development of irrigation technologies and irrigation management systems for the application of smart irrigation through DSS and complex networks of Soil-Plant-Atmosphere sensors for adapting crops to climate change, increasing irrigation efficiency, reducing the Water Footprint and energy costs. The technical and hydraulic performance of the prototypes obtained will be compared to the standard one.

Initial TRL**:** 3
Final TRL**:** 6

T 3.1.4 ***Digital solutions for on-farm crop quality assessment*** **(M6-M36); task leader:** POLIMI [Simone Cinquemani]; **partners involved:** UNIBO, CNR, UNIBA, UNIMI, UNIPG, UNIPR, CNH
Crop quality is of paramount importance to ensure economic sustainability for growers and to guarantee product quality. Assessing quality development on field/plant is an integral feature of future production systems, not least to ensure that crop management strategies are tailored towards maximum quality, without sacrificing yields. Proximal and on-board sensing of relevant traits will boost the performance of DSS, that will integrate such aspects on top, and with higher priority, than simply yields. Traits to be monitored could include, but not limited to, dry matter, soluble carbohydrates, mineral elements, macronutrients (e.g., proteins, carbohydrates, lipids), micronutrients and anti-oxidants profile and content, acidity, firmness, colour. Special emphasis will be given to develop static as well as dynamic model-based systems, capturing the evolutionary nature of the crop, having the multilayer data acquired on field or indoor conditions as input and predicting different qualitative and quantitative crop indexes as output.
Methods: integration of non-destructive sensors of crop quality traits on unmanned, autonomous vehicles,

robots; validation of methods based on current state-of-the-art packing house non-destructive techniques. Linear and nonlinear dynamic systems techniques for evolutionary modelling. Prototyping, pilot/field-scale implementation and tests.

Research Activity:
POLIMI: ***Enforcement of decision support strategies for quality assessment based on on-field measurements***. The aim of the research is to develop new interaction paradigms between control systems and automatic sorting machines, climbing on a new frontier of automatic analysis capacity through spectral and hyperspectral detection of qualitative / quantitative parameters and variables of agricultural products supported by deep learning and machine learning paradigms, capable of determining a new level of reference in the agricultural sector.

UNIBO: ***Product quality control in response to management practices.*** Product quality control in response to management practices. The quality of crops (cereals, vegetable, fruit, grapes) will be assessed, in response to precision methods of cultivation involving monitoring of environmental parameters and the control of production factors, such as fertilization, irrigation, crop load, crop protection. UNIBO will design and develop multi-objective path planning techniques for ground and aerial robots employed in smart farms e.g. for fertilization applications or image data collection. The developed techniques will support fleet management and coordination techniques in large-scale farms.
Correlations will be established between management practices and quality traits at harvest, and post-storage, with particular emphasis on storage disorders causing losses of product. Image analysis, spectroscopic analysis and Principal Component Analysis approaches will be employed for detection of quality production and blemishes/defects on products. Guidelines will be developed for field technicians and cold storage managers to help them minimize losses at harvest and the onset of storage disorders.

CNR: ***Digital lean solutions for crop quality assessment.*** The non-destructive and non-invasive monitoring, prediction and characterization of qualitative and morpho-colorimetric traits of berry grapevine (phenolic maturity), olive fruits (acidity), wheat (proteins and moisture), fresh cut packed and unpacked fruit and vegetables (shelf-life, ascorbic acid and polyphenols) will be carried out. Initially, state-of-the-art tools and platforms will be adopted and then coupled with lean and low-cost solutions enabled by the implementation of crop modeling and AI techniques. For all traits, 4 pilots will be set-up to collect data with UAV and/or proximal sensing technologies. For the morpho-colorimetric characterization, RGB and LiDAR sensors will be used, while hyperspectral sensors will characterize quality of olive and wheat. Screen-printing and wireless technologies will ensure the determination of shelf-life and properties of fresh and fresh-cut packed and unpacked products. The acquired data will be exploited for optimizing the available models and for providing machine learning solutions for the automatic recognition and classification of the traits. Analysis and validation of the proposed techniques will be carried out through the comparison with the more traditional approaches.

UNIBA: ***Integrated approaches for the development of a DSS in the evaluation of quality of Mediterranean crops.*** The research activity in this task will focus on i) the development of tools for the early diagnosis of pathogens, and ii) the collection of data on plant pathogen populations and secondary metabolites of the most important Mediterranean plant species, as affected by environmental and agronomic factors (i.e. climate change, soil characteristic and management practices, irrigation, fertilization, etc.) and iii) set-up of a "maturation model" built with near-infrared (NIR) spectroscopy; iv) the development and application of multivariate models based on spectroscopic measurements for the target products quality assessment. The resulting data will be used for the development of appropriate DSS for the management of the target cultures.

UNIMI: ***Non-destructive monitoring of crop performance under drought with and without beneficial endophytic bacteria.*** The research will be focused on crop (e.g. tomato or lettuce) performance under controlled water stress conditions (100 ETE versus 70% ETE) with and without endophytes (sterilised seeds). Experiments will be performed in greenhouses. Endophytes will be applied as seed coating. Water stress will be applied at an early stage of growth and at full plant development. Eco-physiological and growth parameters will be measured during the whole growing cycle. Endophytes will be traced during the

plant development and their mode of action will be explored. Advanced ecophysiological and biomolecular methods will be used to carry out the studies.

UNIPG: ***Digital solutions for on-farm yield and quality assessment in olive oil chain.*** The task will devise digital solutions for on-farm yield and quality assessment in the olive oil chain. An autonomous platform with heterogeneous sensors (i.e. RGB camera and multispectral reflectance sensors) for the estimation of olive yield and plant physiological status will be developed. In addition, NIR technology for non-destructive analysis aimed at determining the quality of olives and defining maturity indices to decide the harvest time will be used. Yield and olive quality (e.g. colour, oil quantity, water and phenolic compounds by lab analyses) will be measured and correlated with sensor-based measurements.

UNIPR: ***Digital solutions to measure the quality of agricultural production in the open field*****.** The research activity will be focused on crops grown in Emilia Romagna. The methodology adopted includes an initial phase aimed at studying and identifying the parameters relating to the quality of agricultural products (e.g., physical parameters -colour, size, damaged fruits-, and chemical and physiological parameters). The second phase will be directly linked to sensors and technologies. In this phase, the best non-destructive technologies will be identified. The last phase will be conducted directly in open-field, and the technologies developed in the previous phase will be validated and implemented. In this sense, the data obtained by the new technologies will be compared with analytical laboratory data. This approach will allow the implementation and optimization of technologies, as well as a development phase based on the iterative implementation of solutions (both sw and hw-sw) with increasing TRL.

CNH: ***Enhancing vehicle sensing capabilities*****.** The scope of the activity is to identify, test and benchmark smart sensors to assess some quality information of the target crops.
In particular, there will be a first phase related to the definition of the target applications where these specific sensors should be tested (e.g. vineyard/orchard plant/fruit quality status). Then, a scouting activity will be performed in order to identify already available smart sensors to accomplish the previously defined tasks.
Sensors will then be installed and integrated with a proper data collection system (DAQ), that will have to be designed and realized based on the specifications of the sensors. It will then be important to define a ground truth, that will be used to objectively compare the sensor output. Data will then be collected in the field (different fields, according to regions, growth stages, environmental conditions, …). Finally, the collected data will be analyzed, and the performance evaluated with respect to the ground truth previously defined.

Initial TRL**:** 3
Final TRL**:** 6

T 3.1.5 ***AI and big-data analytics for the sustainability of production systems*** **(M6-M36); task leader: UNIBO** [Matteo Golfarelli]; **partners involved:** CNR, UNINA, POLIMI, UNICT, UNIPG, UNIPR**.**
This WP will generate a vast amount of data throughout its tasks, enabling the adoption of AI and big-data analytics solutions to improve the efficiency of use of water and fertilizers, as well as labour, machines, and chemicals. Collection, management and exploitation of generated data requires the design and implementation of agri-specific big data hub that integrates and makes information available and that allows the development of analytics (descriptive, predictive, and prescriptive) that will be developed consistently with, and to be functional to, research conducted in all other tasks.
Methods: design and development of Big data and AI platform; implementation and continuous validation of platform. Prototyping, full-scale implementation and tests.

Research Activity:

UNIBO: ***Analytics solutions to manage crops for optimum quality and sustainability.*** Generation and use of real time data of soil water availability in kiwifruit, stone and pome fruit, and grapevine for the determination of the most proper soil water availability for the highest fruit quality of these crops. Establishment of the proper irrigation rate for each phenological phase. Development of operational algorithms and analytics for water management optimization. Determination of kiwifruit genomic response of plants under drought and flood stress to predict kiwifruit vine decline syndrome (KVDS). Development of

operational algorithms for vertical farming systems.

CNR: ***AI and big-data analytics for sustainable production systems*****.** AI and big-data analytics approaches will be applied to the data from T3.1.1 to T3.1.4, with the goal of generating descriptive, predictive and prescriptive maps. Three steps will be considered. First, homogeneous data (e.g., from proximal sensing as well as UAVs and satellites) but at different spatial and temporal scales will be integrated in a single model. Second, data about the same field but from heterogeneous sources will be considered, hence providing models at multiple scales and features. Third, other data not related to the field (e.g., climate disease phenotype) will be used to support predictive and prescriptive models.

UNINA***: Integration of multiple image analysis techniques*****.** The activity deals with the problem of integration of multiple images, remotely sensed in different modality and/or dates, portraying the same scene of interest. This will be achieved by means of AI (specifically, deep learning) techniques. Among the several possible of fusion problems we aim to address one or more of the following ones depending on the monitoring application needs: multi-resolution fusion (e.g., pansharpening); optical-SAR cross-sensor fusion (e.g., reconstruction of missing optical vegetation indexes such as the NDVI); multi-temporal fusion (e.g., for the enhancement of the temporal resolution). The performances of the developed tools will be assessed in terms of both reconstruction quality and impact on related applications (defined by other project partners).

POLIMI: ***Artificial intelligence and multi-modal data analysis for a sustainable development of agricultural production.*** The activity aims to use Artificial Intelligence techniques (Machine Learning and Deep Learning), for the advanced analysis of multi-modal data (i.e., tabular, temporal, spatial, etc.). Supervised and unsupervised learning techniques will be used to correlate and merge the information from data (collected in different ways and with different temporal and spatial scales) in order to provide a descriptive, predictive and prescriptive vision. The results obtained from the developed models will be verified in cross-validation through the standard metrics as regards the descriptive, predictive and prescriptive aspects, comparing them with the physically based models currently used.

UNICT: ***Smart geospatial tools applications in agricultural environments to improve resources use efficiency.*** The main objectives of this task include the description, analysis and predictions of the distribution of biomass resources in the territory, in dependence on relevant variables, by using geospatial predictive models and GIS-based tools. Collection of relevant data for model implementation will be carried out to define a GIS-based and geospatial model at different territorial scales (e.g., provincial, and municipal) and produce related thematic maps, in order to increase knowledge on the relations between potential biomass resources and related variables, and improve resource use efficiency. The case studies will be developed for territorial areas located in Sicily.

UNIPG: ***Data-driven approaches for the analysis of agronomic phenomena and the predictions of quantities of interest.*** Methodologies based on data-driven algorithms will be developed to train models capable of representing the processes considered. Agronomic data will, in particular, be used to train Machine Learning algorithms, exploiting, e.g., regression and classification techniques. Different paradigms will be evaluated, including deep learning methodologies.

UNIPR: ***AI and big-data for the sustainability of agricultural systems*****.** The research activity includes an initial phase of definition of the requirements, carried out in collaboration with the other tasks, for the development of innovative solutions, based on AI and big-data analytics, for the sustainability of production systems. This phase will be followed by an intermediate development phase based on the iterative implementation of solutions (both sw and hw-sw) with increasing TRL. The final phase will consist in setting up a final demonstrator at the University of Parma. This demonstrator, in a controlled environmental scenario, will allow to test and validate the technologies developed during the task in an integrated way with the technologies developed in the other tasks. The validation of the technologies will be carried out on a reference crop, and the plants will be subjected to phenotypic and physiological analyses in order to evaluate their agronomic performance and correlate it with the data obtained with the new technologies.

Initial TRL**:** 3

***Final TRL*:** 6

Deliverables
D3.1.1.1 Mid-term report on monitoring and modelling tools for agricultural systems (M18)
D3.1.1.2 Final report on development, application and field validation of monitoring and modelling project activities (M36)
D3.1.2.1 Sheets on design, schemes, and set-up planning for development of smart cultivation systems (M12)
D3.1.2.2 Final report on testing and field validation of prototypes for smart and sustainable plant management systems (M36**)**
D3.1.3.1 Overall digital and physical architecture platforms plan (M8)
D3.1.3.2 Final report on testing and field validation of solutions for precise input management (M36)
D3.1.4 Report on development and validation of post-harvest digital quality assessment technologies (M30)
D3.1.5.1 Big data and AI platform architecture design and development (M12)
D3.1.5.2 Big data and AI platform implementation and continuous validation (M24)

Milestones
M3.1.1 Experimental design and plans ready (M6)
M3.1.2 All planned and developed solutions/tools/approaches/models implemented at lab/field scale, and ongoing for testing (M18)
M3.1.3 All planned and developed solutions/tools/approaches/models validated or close to validation (M30)

Work package number	3.2	**Lead beneficiary**	UNIMI
Work package title	Innovative strategies to protect natural resources and reduce agriculture environmental impact		
Start month	1	**End month**	36

WP Leader: Arianna Facchi [UNIMI]

Objectives
- to develop best strategies and solutions for the protection of soil and water resources in agricultural systems
- to develop and assess suitable **methods** to optimize, monitor and models soil and water resources at different spatial and temporal scales
- to develop solutions for organic carbon and nutrient/fertilizer management, soil carbon conservation and sequestration and soil fertility
- to develop strategies for the smart and sustainable solutions for use and reuse of water for irrigation
- to enhance the adoption of NBS and ecosystem approaches to face drought, pollution, and loss of soil fertility and biodiversity

Description of work
Task 3.2.1 *Solutions for soil quality assessment and protection* **(M1-M30); task leader:** UNIBA [Francesco Gentile & Roberto Terzano], **partners involved:** UNIBO, CNR, UNINA, UNIPG, UNIRC, IBF, ISP
Soil quality assessment is crucial for food safety and security, and for soil ecological functions. This goal can be achieved through the development of a multifactorial soil quality index able to monitor and evaluate the efficiency and resilience of this natural resource in different agricultural soil management systems. Solutions for the evaluation of soil organic carbon stock and its management will be selected, evaluated and adopted at farm and basin level using physical, chemical, biochemical, and microbiological methods, and modelling. Strategies to protect and prevent soil pollution, loss of soil fertility, and biodiversity will be adopted. Soil quality assessment and protection will be monitored using traditional and smart technologies, modelling and forecasting tools, real- time and sensor-based applications.

Methods: design, development, integration and testing innovative sensors and soil quality indexes, models and forecasting tools, development of soil sustainable management models.

Research Activity:

UNIBA: ***Innovative solutions to assess and protect the quality of vineyard soils.*** The main goal of this research activity is to assess the quality of soils for table grape production by developing specific soil quality indexes (SQI) based on the determination of suitable physical, chemical, biological and phytosanitary parameters and on the assessment of active degradation processes (i.e., soil erosion). Moreover, strategies to restore the soil quality through sustainable agronomic practices will be proposed. To reach this goal the following steps will be followed: i) identification of three vineyards with different degrees of productivity (low, medium, high); ii) establishment of the main physical, chemical, biological and phytosanitary soil parameters that influence the quality of soils for table grape production; iii) determination of the previously mentioned parameters and processes by traditional and innovative methods, including sensors and proximal sensing systems, specifically developed for the purpose; iv) calculation of one or more multifactorial SQI for soil classification; v) propose solutions to restore the soils of poor quality (i.e., with low SQI) by sustainable strategies, such as organic amendment, use of biocontrol agents, bio stimulants, compost, and microbial antagonists.

UNIBO: ***Soil quality and carbon balance evaluation in long-term field experiments.*** Two long-term field experiments belonging to the experimental farm of the UniBo and characterized by different approaches (i.e., different crop rotations and/or different fertilization strategies) will be selected to study the sustainability of agronomic management. Soils will be characterized for the leading chemical and biological properties (i.e., carbon and nitrogen pools, microbial biomass content, enzymatic activities, and nutrients content) from which will be determined a set of simple and complex soil quality indicators. The parameters and the indicators then will be used to determine a multifactorial soil quality index (mSQI) through a statistical process that includes: the selection of the minimum dataset, parameters scoring, and integration of the score into a single value for the type of management. This mSQI will be related to plant performances and microbial community response to the agronomic management, thus to correlate the soil quality to the beneficial effect of agronomic management on plant growth. In the longest experimental field will be possible to apply a mathematical model to evaluate carbon balance dynamics over time.

CNR: ***Set up of biofertilization practices.*** The research will evaluate the effects of plant growth promoting microorganisms on soil health, finalized to the improvement of crop responses. Performances of beneficial bacteria and fungi, in terms of biofilm formation, phosphate solubilization capabilities as well as direct antifungal action and N2-fixation activity will be analyzed *in vitro* through biochemical and gas chromatography characterizations. Single and combined inoculations of the selected strains will then be tested under physiological and abiotic stress conditions by monitoring the effects on plant growth. Spectral analyses will be exploited to correlate soil and plant conditions in order to achieve possible functional-structural plant modeling tools.

UNINA: ***Solutions for assessing soil quality, securing ecosystem services, and protecting horticultural and agroforestry environments under changes.*** Functions and services provisioned by cropped and forested lands help support our society, but they are also vulnerable and should be exploited with great care. Advanced and integrated monitoring techniques and efficient models will be set up to reliably assess the influence exerted by both natural and anthropogenic disturbances (such as variations in climate seasonality, drought, post-fire effects, contamination of shallow groundwater) on the sustainable use of land and water resources in agroforestry as well as in peri-urban environments.
The physicochemical and mineralogical properties of soil will be assessed; moreover, the total and bioavailable/bioaccessible contents of nutrients and contaminants will be measured to appraise soil fertility and identify possible soil contamination. The cultivation techniques and management of green areas will be developed on sustainable/resilient and site-specific models leading to a better use of resources and the enhancement of the soil and biodiversity. A key component of this task is coupling monitoring and modeling to identify dynamic indicators for assessing the vulnerability of selected agroecosystems to adverse conditions.

UNIPG: **Multi-factorial indices for soil quality assessment.** Multifactorial indices of soil quality and functionality will be determined in conventional, low-input and organic cropping systems within Long

Term Experiments. Crop yield, soil organic carbon, soil nutrient availability, soil hydrological, biological, microbiological and genomic characteristics will be measured. Variable interaction and selection will be performed by statistical analysis. Indices validation will be performed at farm level.

UNIRC: ***Solutions for soil quality assessment and protection.*** The activities will aim to: a) Develop methods to value the impact of conventionalized" and "agroecological intensified" organic farming systems on soil biodiversity and ecosystem functions. b) Perform field studies to determine at what extent soil biodiversity and soil ecosystem functioning are vulnerable to external input and management. c) Identify processes that indicate when soil is approaching the limits of their natural functioning or productive capacity. d) Identify key indicators for soil sustainability assessments, that are most suitable to capture the complexity and multifunctionality of sustainable farming systems and that are best suited to serve as a basis to develop guidelines and scientific evidence-based policy making. e) Develop multifactorial soil quality indices able to monitor and evaluate the efficiency and resilience of soil resources in different agricultural soil management systems.

IBF: Soil quality estimation through remote sensing. IBF aims to develop rapid tools to map topsoil organic carbon. In particular, will develop a semi-automatic estimation workflow for topsoil organic carbon using multisource remote sensing data. The workflow will be able to generate several predictive remote sensing data related to soil organic carbon variability. Finally, using a series of statistical tests, the best set of covariates and the best machine-learning algorithm will be identified for organic carbon mapping.

***Initial TRL*:** 3
***Final TRL*:** 6

Task 3.2.2 *Sustainable strategies and practices for soil fertility management* **(M1-M36) task leader:** UNIBO [Moreno Toselli], **partners involved:** UNIRC, CNR, UNIMI, UNINA, UNICT, UNIPG, IBF
The current political, social, and economic conditions place more than ever at the center of attention the need to supply nutrients for plant nutrition at sustainable costs. Integrating low-impact, crop-adapted, variable rate application fertilizer solutions is the focus of this task, which will foster the adoption of methods increasing nutrient use efficiency by developing fertilizers capable of controlled release of nutrients, in addition to devising precision distribution methods to bolster their efficiency. New solutions to improve the nutrient use efficiency (NUE) through fertilizers characterized by a controlled release using different methodology will be tested: coating with renewable materials (e.g., biofilms, bio-based materials, humic materials), organo-mineral products, nitrification and urease inhibitors, temperature-controlled release coating of nutrients (mainly nitrogen and phosphorus). The NUE of different kind of fertilizers (e.g., inorganic, organic and organo-mineral) will be tested from pilot to selected real environments, in different soil-plant systems. New crops tailor-made fertilizers will be developed, checked and then used at farm level on different soil-crop systems. Precision farming methodologies for the distribution of nutrients will be tested in this task and adopted at different levels (field and/or farm).
Methods: nutrient use efficiency, controlled release fertilizers, crop tailor-made fertilizers, precision farming methodologies.

Research Activity:
UNIBO: ***Innovative techniques for nutrient monitoring in soil and plant for optimal management of fertilizations.*** The aim of this research activity is to employ innovative techniques and sensors for monitoring soil availability of nutrients, with special emphasis on mineral N, to improve technical management of fertilizations and the consequent environmental benefits linked to a more efficient use of fertilizers. The employment of an *in situ* system for a continuous monitoring of soil porewater and measurement of nutrient concentration in plant tissues, will allow farmers to accurately adjust fertilizer-application regimes to maximize yields and reduce the potential for groundwater contamination by (i.e. nitrate-N). Experiments will be carried out on fruit trees, and the data collected will be compared with soil analysis to validate the reliability of the monitoring system.

UNIRC: ***Efficient organic fertilization management to provide nutrient (N & P) assimilable forms to support crop yield and limits losses.*** The objective of this action is to achieve a profitable trade-off between the short-term (crop nutrition) and medium/long-term (soil functioning) effects of organic

fertilization, combining green manure management with the use of biofertilizers as developers of the soil ability to support crop growth. Combining these two effects becomes very challenging when the soil available water and temperature become the main yield-limiting factors and when soil organic matter and nutrient dynamics are affected by the intensity of soil tillage (i.e., olive grove versus cereal rotational systems). Considering these aspects, the activity is aimed at evaluating, at experimental field scale, the short-term biofertilizer (BF) effects on crop yield and quality; their interaction with soil organic matter management practices, also accounting nitrogen and phosphorus losses and GHG emissions, will be assessed. The designed field experiments will also support the application of innovative and technological solutions focused on precision organic farming, under rain-fed and irrigated regimes.

CNR: ***Crop nutrient management and mitigation strategies*****.** Nutrient carriers will be developed so to incorporate microelements (Mn, Fe, Cu, Zn, etc.) and/or absorb/encapsulate nitrogenous compounds through various techniques (e.g. solid-phase mixing, adsorption in water, spray -dry etc.), and tested. Replicated open field trials - aimed at highlighting the overall Nitrogen Use Efficiency (NUE) - will be carried out at experimental farms to assess yield, GHGs emissions and nitrate leakage of selected crops. The simultaneous determination of N inputs and uptake will lead to assessing NUE. The rate of exchange of GHGs and VOCs will be measured with autochambers - in response to specific management operations and comparing traditional granular fertilizers with fertigation approaches. Upscaling of the results will be carried out by applying the APSIM (Agricultural Production Systems sIMulator) model.

UNIMI: ***Field monitoring and modelling analysis of the effects of agronomic management and pedoclimatic conditions on yield, nitrate leaching, and N_2O emissions with what-if approaches to offer optimised solutions.*** A user-friendly software tool, based on the ARMOSA cropping system simulation model, will be developed to quantify the environmental and productive sustainability of current and optimised agronomic solutions. Under field conditions (characterised by specific combinations of crop rotation, fertilisation, tillage, and crop residue management), a system for the continuous monitoring of target variables of the soil-crop continuum (e.g., N recovery, nitrate leaching, N_2O emissions, soil water content and drainage, yield, soil organic carbon stock) will be set up to compare contrasting agronomic treatments. The collected data will support the modelling analysis, particularly the calibration of the simulation model and its performance improvement. The model will be integrated into the software tool and used to simulate processes related to yield, nitrogen and carbon cycling in what-if scenarios in current and future climates.

UNINA: The task aims to elucidate the biostimulant action of novel biostimulants such as vegetal-derived protein hydrolysate (PH) (mixture of amino acids and small peptides obtained from the hydrolysis of protein matrixes). Moreover, in this task different bioproducts will be tested to produce amendments, substrates, fertilizers, corroborants and biostimulants. The biostimulant action will be evaluated on different crops in particular leafy vegetables in terms of effects on morpho-physiological traits, as well as molecular and biochemical processes. In addition, soil fertility, nutrient use efficiency, tolerance to abiotic stress (mainly salinity and nutritional stress) of crops and nutraceutical characteristics of products will be evaluated.

UNICT: ***Sustainable soil management and nitrogen fertilization techniques for control of greenhouse carbon emissions and fertility management in Mediterranean agroecosystems.*** The research will evaluate the effect on soil and crops (i.e. typical and new of Mediterranean agroecosystems, such as durum wheat, hemp and cactus pear) of soil amendment with sludges that provide nutrients and in particular nitrogen (N). The amendant will be derived from the processing of citrus peel as a result of obtaining juices and other co-products (eg pectins) used by the food industry. As part of this task, the following details are provided: (i) the protocols will be applied for durum wheat and hemp in open field conditions and in containers for all the three crops; (ii) on both the remodeled and fertilized soil (basic fertilization) and in containers, increasing doses of sewage sludge will be assessed against equivalent doses of mineral N and zero N.

UNIPG: ***Agronomic and environmental evaluation of Enhanced Efficiency Fertilizers.*** Lab and field experiments will be carried out to evaluate agronomic and environmental performances of Enhanced-Efficiency N Fertilizers (i.e. slow- and controlled- release N fertilizers; nitrification inhibitor-treated N fertilizers; urease inhibitor-treated N fertilizers). Experiments in controlled environment will be aimed at determining N release kinetics under different substrate and environment conditions (i.e. soil temperature

and moisture). Field experiments in wheat, tomato and olive will be aimed at determining Nutrient Use Efficiency, Apparent recovery, N balance in soil-crop system, N leaching risk. LCA and empirical models will be developed.

IBF: ***Smart farming tool for precise fertilization.*** Activities will include: a) Set up of experimental platforms on a field scale for no more than 6 crops representative of a productive context; b) assessment of a precise fertilisation plan (prescription map) against (1) a nutrition plan compliant with EU & national rules; (2) no fertilisation; (3) no restriction in fertilisation; c) the experimental platforms, no more than two for each crop, will be digitally managed in order to interpret the cause-effect interactions of the factors that influence the cultivation system; d) plant tissue analyses to measure the concentration of nutritional elements during the most representative phases of the crop cycle; e) identifying the solution with the highest levels of efficiency in the use of production factors

***Initial TRL*:** 3
***Final TRL*:** 6

Task 3.2.3 *Smart and sustainable modelling and tools for agricultural water management optimization* **(M1-M36); task leader:** UNIMI [Claudio Gandolfi], **partners involved:** UNIBO, CNR, UNIBA, UNINA, UNICT, UNIPG, UNIPR, IBF, TEL
Water management interplays with many actors who contribute at different levels (farmers, irrigation consortia, district/regional water authorities). For this reason, a correct and sustainable management of this resource can only be achieved when all the components and end-users are integrated into a unified approach and vision. To this purpose, in this task we will develop and combine selected methods and tools to monitor and model agro- hydrological processes and hydraulic water distribution systems. Integration of proximal and remote sensors with digital platforms and smart control of water infrastructures will enable the optimization of agricultural water management, increasing water use efficiency and sustainability at different spatial (e.g., field, farm, district) and temporal scales. The results of this task will provide the basis to improve the strategies to plan and manage water resources towards a competitive agriculture and considering sustainable use and protection of the natural resources in a climate change context.
Methods: development of new advanced sensors and technology, agro-hydrological and hydraulic models, smart hydraulic networks, digital platforms and data analytics. Lab/pilot/field-scale implementation and tests.

Research Activity:
UNIMI: ***Agro-hydrological models for the improvement of agricultural water management and identification of adaptation strategies.*** The activities will be aimed to develop and integrate tools for the modeling of agro-hydrological and hydraulic processes in irrigated agricultural areas at different spatial scales: from field to district and basin. Building on the results achieved in previous studies, improved irrigation management strategies will be identified at the field scale and the impact of their application at the district and basin scales will be simulated in view of increasing efficiency adapting to climate change. Adaptation measures such as changes of irrigation methods and practices, or of crop types and agronomic practices will be considered. The implementation and validation of the models will exploit advanced technologies (e.g., geophysical methods, remote sensing) for soil characterization and derivation of phenology and crop parameters. Future climate patterns will be derived by applying state-of-the-art procedures for downscaling the projected regional climate change scenarios for Europe.

UNIBO: ***Integration of monitoring and modelling tools for assessing water resources and identifying best management practices in agriculture.*** The activities aim to improve and to integrate the monitoring and modeling of the hydrological processes at different spatial scales, ranging from field to regional scale, to support planning and management of the water resources in agriculture. Under this task, invasive and non-invasive sensors and observation systems will be integrated and homogenized to assess water fluxes from the atmosphere to the bedrock. Additional laboratory activities will also be performed to support the characterization of the systems. Hydraulic and agro-hydrological models will then be developed and set-up for the estimation of water fluxes at different scales and the collected data will be used to optimize and verify their performances. The integrated modelling tools will be the basis to develop adaptation strategies under

current and future scenarios. The integration of observed data and simulations through data assimilation techniques and within a single interactive and flexible digital platform is envisaged. Specifically, the integration of all these data-sets will be based on the design and development of a scalable sensory data management platform. The platform must be able to collect and aggregate heterogeneous data streams from multiple data sources to support data processing/analytics operations, and to provide data visualization for the end-users.

CNR: ***Identification of procedures for the optimized management of the water resource in vineyards.*** The research will adopt multidisciplinary approaches and methods to support irrigation optimization in the vineyard. The first step of the proposed activities is the identification of the functional homogeneous zones (fHZs) present in the vineyard through an environmental analysis based on the determination of the soil spatial variability, the micro-morphology of the vineyard (LIDAR) and the spatial variability of the crop response at different resolutions (satellite and drone). The second step will be based on the use and test of field sensors (commercial and experimental) to monitor plant and soil water status in the fHZs in order to define the optimal timing and volume of irrigation to achieve the desired field oenological goals while preserving the water resource.

UNIBA: ***Optimization of nutrient solution management in closed soilless cultivation systems.*** The aim of the research is to reduce fertigation inputs and water consumption, first in a greenhouse with a closed-cycle soil-less system. The specific aims are: i) to create an algorithm to calculate the composition of the nutrient solution; ii) to treat the circulate/drain nutrient solution to guarantee optimal chemical-physical and biological conditions during the whole cycle; iii) to improve the management of plant pathogens potentially contaminating the nutrient solution. Periodically, the nutrient solution composition, pH and electrical conductivity will be determined as well as the macro/micronutrients concentration in plant tissues. Potentially harmful substances, and the main biological parameters will be also monitored. Any deviation from optimal conditions will be corrected through the treatment of solutions with chemical-physical and biological methods. Finally, the possibility to use the drain nutrient solution collected at the end of the cycle for irrigation purposes will be evaluated, with or without final treatment.

UNINA: The two Sentinel-2 and the two Landsat 8 and 9 satellites are characterized by elevated acquisition frequency, excellent radiometric quality and suitable geometric resolution for precision agriculture. Their observations allow for a reliable and operational assessment of crop growth, evapotranspiration fluxes and related irrigation requirements. The present research aims at developing a system for producing real time maps of evapotranspiration and irrigation requirements at different spatial scales by combining observation data with robust agro-hydrological models and meteorological information. Observations in the short-wave infrared regions of Sentinel-2 and Landsat will be analysed for monitoring the water status of soil and crop, for detecting conditions of hydric stress. Starting from a TRL4, the research aims at reaching TRL 7 by means of validation and experimental activities at selected open field farms.

UNICT: ***Integration of satellite remote sensing with hydrological and crop modeling for smart irrigation and sustainable water management in order to increase the resilience in Mediterranean agroecosystems.*** Innovative solutions to improve the efficiency of water use in Mediterranean agro-ecosystems made fragile by climate change will be identified in the research activities, as follows: a) the integration of multi-source data (satellite, climatic and crop) to obtain accurate estimates of crop water needs and of the crop potential production features; b) the development of innovative and expeditious protocols for estimating biophysical indicators, characteristic of the crop water status, based on the monitoring of the reflective and thermal properties of the vegetation detected with proximal sensing techniques; c) the identification of response models of different species (herbaceous and woody) capable of adapting to water deficit regimes; d) the production of land suitability maps for herbaceous and tree species.

UNIPG: ***Smart and sustainable modelling and tools for agricultural water management optimization.*** An agro-hydrological (AH) forecasting model will be developed using thermometric data in data-driven approaches (Task 3.1.5) and employing crop status data as benchmark of irrigation management. Innovative contact (i.e. RFID of leaf temperature, vigour, steam flow, soil water) and remote (i.e. bowen ratio, thermal, multi/hyper-spectral) sensors for monitoring temperature and water status will be adopted. A calibration

protocol for AH models (adopted in DSS) will be defined. An advanced irrigation network control method will be tested based on real-time balance between actual and forecasted water volumes. The potential of remote sensors in mapping soil typological units and in quantifying irrigation will be assessed.

UNIPR: Development of digital twins for modelling and minimizing water consumption in the agricultural systems. Firstly, a monitoring of water consumption in a distributed network, by means of dedicated devices connected to a web application, will be carried out. Afterwards, the modelling of the water distribution systems will start in order to compare the model's outcomes with the real data taken from the field. The development then of digital twin models shall be done to optimize water management of hydrological processes and hydraulic water distribution systems, by increasing the efficiency and sustainability of water use at different levels (field, farm, district/basin). The developed models will be tested and validated within the Living Lab that will be developed during the project. The interconnection between simulation models and intelligent IoT systems and autonomous robotic solutions will make it possible to mechanize and manage the water resource in an advanced way.

IBF: ***Smart water management at district scale.*** Activities will include: a) DSS development for the efficient and automated management of an irrigation network (canals, pipes and mixed) in a large farm; b) automation of gates and other network devices based on actual crop water needs for each irrigate plot; c) development of a model to manage conditions of water scarcity (less than the demand) with simulated scenarios of water allocation to identify the best solution; d) case study at Bonifiche Ferraresi farm (Ferrara) with the cooperation of Consorzio di Bonifica Ferrara.

TEL: ***Drone solutions for monitoring and management of water resources in tomato plantations.*** The focus of this task is the design and demonstration of a service for the smart and sustainable management of water in tomato plantations. Data coming from drones and IoT sensors on-field will be integrated and elaborated to assess the water needs of the plantation and to manage the irrigation system accordingly. The aim is to devise and test a solution that could provide a periodical monitoring of the plantation during the whole life-cycle.

***Initial TRL*:** 3
***Final TRL*:** 6

T 3.2.4 *Strategic planning and technologies for water, wastewater and nutrients reuse and recovery* **(M1-M36) task leader:** IRR [Loris Franco]; **partners involved:** UNIBO, UNIBA, UNIMI, POLIMI, UNIRC**)**
In the view of climate change and consequent water scarcity, as well as pollution of water bodies, this task will develop, integrate, and adapt novel and sustainable technologies and strategies for water/wastewater treatment and reuse in agriculture, according to the new European regulation. Methods to assess the potential and the safety of wastewater reuse at district/basin level will be developed for a sustainable planning of this practice, based on water resources balance (available resources/irrigation water needs), available infrastructures, quality and quantity of treated wastewater, risk assessment. This can result in benefits in terms of both additional water availability for irrigation and nutrients recovery from treated wastewater (from cities, agro-industries, livestock production) and/or agricultural drainage water, according to circular economy approach. This task will develop and/or combine fit for purpose technologies (for treatment, irrigation, monitoring) that will be tested in pilot and/or real environment, taking into account their overall removal efficiency, costs, energy requirements and sustainability. Finally, the effects of the application of treated wastewater (e.g., on soil, groundwater, crops, irrigation materials) will be deeply assessed by field scale tests in pilot/relevant environment to ensure a safe use of non-conventional water resources.
Methods: spatial planning, lab/pilot/field-scale implementation and tests, technology assessment.

Research Activity:
IRR: Research and development of irrigation systems and filtering systems for Wastewater reuse.
The main goals of this research activity will be (i) Prototyping of irrigation systems and filtering systems for the use of unconventional water (wastewater, etc.), in order to increase the irrigation efficiency and the useful life of the irrigation systems. (ii) Prototyping of drip lines for sub-irrigation and prevention of damage from fauna and entomofauna with low environmental impact. The mechanical and hydraulic performance of

the prototypes obtained will be compared to the standard ones. Direct reuse of treated wastewater will be specifically investigated in view of the identification of innovative solutions to increase the useful life of irrigation systems.

UNIBO: ***Wastewater reuse planning and management from source to field application***. On a district/regional scale, wastewater treatment plant location and effluent quantitative and qualitative availability will be analysed together with position of agricultural areas and their water requirements. Those information will be used as an input for the development of methodology for overall assessing and planning of wastewater reuse potential, identifying also different risks present and the ways to reduce them. Moreover, the effects that treated wastewater has on soil, crops and irrigation equipment will be studied, to assess any negative effects and optimise the water and fertiliser consumption. Finally, UNIBO will also work on the development and optimisation of the technologies for treatment of polluted waters in order to reach effluent quality needed for irrigational reuse. The treatment will be performed with nature-based solutions (e.g. constructed wetlands) alone or in combination with more intensive technologies, focusing on the parameters required by the reuse regulations.

UNIBA: ***Multidisciplinary sustainable technologies and strategies for the quality of Reclaimed Water (RW).*** The main goal of this research activity will be the development and implementation of multidisciplinary sustainable technologies and strategies aimed at producing an acceptable quality of Reclaimed Water (RW) to be used for orchards/fields irrigation and fertigation, and the development of membrane technologies for nutrients and water recovery from agri-food liquid wastes. First, intelligent on-line fertigation equipment will be installed. At the tertiary treatment plant, peripheral stations sized for analog data acquisition and digital signals will be installed and calibrated for the remote management of all fertigation processes. Data on EC, nitrates, ammonium, phosphorous and potassium content, acquired by the control units using the appropriate probes will be sent to the Control Center. An innovative prototype, based on a physicochemical (PC) water treatment process, will be tested and validated for nutrient recovery and high-quality water production.

UNIMI: ***Smart solutions for the reuse of treated wastewater in agriculture.*** A set of analytical and modelling tools will be identified and applied to define the extent and benefits (in terms of water savings from primary water sources) of treated wastewater reuse in irrigation at the scale of an ATO (Ambito Territoriale Ottimale – Optimal Territorial Area). To demonstrate the application of the tools a case study area will be selected, where starting from the analysis of the current agricultural and irrigation practices and collecting data on the existing wastewater treatment plants (discharge, water quality observations and classification), the actual potential of irrigation water reuse will be assessed. Direct reuse of treated wastewater will be specifically investigated in view of the identification of innovative solutions that combine efficient irrigation infrastructure with advanced sensors and automation technologies.

POLIMI: ***Decision support tools and implementation of smart technologies for a sustainable reuse of waste water.*** The goal is to prepare an integrated platform to support the supply of crop water need and irrigation management according to difference irrigation systems able to combine traditional freshwater and wastewater according to the EU 2020/741 indications that will be operative in 2023. The platform architecture and the implemented water balance models will be able to manage different scenarios of meteorologic forcings due to climate changes and different water demands according to the increasing conflict in water use. The project will evaluate precision irrigation methods, for different soils and crops, improving the irrigation efficiency, the human health safety and reducing the environmental impact. This will be obtained thanks to an optimized reuse of wastewater purified with different technologies. The results will report measurable variables of the agricultural tradition and recent indicators identified through a participatory process with stakeholders (irrigation consortia, integrated water cycle managers, river district authorities, farms).

UNIRC: ***Testing an automated and optimized aerated lagooning system for agro-industrial wastewater depuration.*** The objective of the task is the optimization of an aerated lagooning pilot plant for depuration of wastewater from the agro-food industries. The system consists of a tank for wastewater storage throughout a period of 2-3 months under intermittent aeration at low flow rate. The performance of the system will be

measured by the depuration efficiency (percent removal of the Chemical Oxygen Demand - COD, percent reduction of pH, variation of C/N ratio) as well as the energy consumption per unit of COD removed. This system is designed to overcome the common drawbacks of agro-industrial wastewater (e.g., olive oil mill and citrus processing wastewater) shown by the activated sludge depuration plants (that are commonly used for other types of wastewater), such as the low efficiency and stability, and high energy costs.

***Initial TRL*:** 3
***Final TRL*:** 6

T 3.2.5 *Nature-based solutions for natural resources and environment protection* **(M1-M30); task leader:** UNICT [Giuseppe Cirelli]; **partners involved:** UNIBO, CNR, UNIBA, UNIMI, UNINA, POLIMI, UNIPG, UNIRC
Nature-based solutions are sustainable and low-cost technologies and practices that can contribute to a better protection of ecosystems, with a huge potential to be exploited in agricultural context. This task will develop, test and plan their tailored and integrated application at farm or district/basin level with multiple purposes, such as water availability (by retention, storage, infiltration) and water quality (by pollutant removal) increase, phyto/bioremediation of soils, ecosystem and biodiversity protection and value-enhancement, sustainable land use and planning. Therefore, this task will identify, select and test nature-based solutions (e.g., natural and constructed wetlands, swales, buffer strips, green infrastructure, green systems and environmentally-friendly land management practices) that can contribute to: i) a better reduction and control of non-point sources of pollution from agriculture, ii) the sustainable use of natural resources in agricultural systems, and iii) the overall environment protection, especially in rural areas. Finally, an integrated planning for some scenarios of agricultural areas will be developed taking into account the overall state of environment, different pollution streams and types of solutions that can be applied, focusing on the better environmental quality.
Methods: spatial planning, real/field-scale implementation and tests, technology assessment.

Research Activity:
UNICT: ***Evaluation of substrates and innovative technologies for the implementation of NBS for wastewater treatment and reuse in Mediterranean conditions.*** The overall goal is the optimization of constructed wetlands (CW) for wastewater treatment and reuse in agriculture, reducing the environmental footprint and increasing the lifespan, for full scale application in medium-large settlements. The specific objectives are to: (i) evaluate the suitability of innovative filter substrates; (ii) evaluate the effects on soil and vegetation of CW effluents. The CW performance and the effects of irrigation reuse will be evaluated through microbiological indicators, some selected emerging contaminants (EC) and antibiotic resistant microorganisms. In particular, the following will be studied: the interaction mechanisms between the CWs and the target EC; EC phytoextraction processes in CW and herbaceous crops; the hydraulic and ecological role of CW vegetation; the bio-agronomic reuse effects on herbaceous crops; the exposure effects of beneficial insects of agroecosystems to target ECs; the antibiotic-resistant genes persistence; the LCA and LCC of some selected CW technologies.

UNIBO: ***Nature-based solutions for agricultural pollution control and planning.*** A screening of NBS that can be applied at a farm/irrigation district level will be compiled, based on their potential to improve water quality and provide ecosystem services. The selected types will be tested and monitored, at pilot or full scale, in order to optimise their performance and enable their wider application. They will be analysed for water availability, estimating water budget during intensive rain events and over a longer time periods. Moreover, the capacity of NBS to remove pollutants and improve agricultural drainage and irrigation water quality will be evaluated. The removal of different compounds will be studied also during single events (e.g. intensive precipitation) in order to estimate the ability of NBS to deal with high and intermittent loading rates. These activities will be used for a spatial analysis that will enable better site selection and definition of integrated scenarios at the regional scale.

CNR: ***Innovative strategies for nature-based solutions*.** The research will adopt innovative multidisciplinary approaches, such as safe-by-design materials based on calcium phosphate and calcium carbonate, the conjugation with biostimulants, nutrients and bioeffectors, assessing their effectiveness on

model crops. Concurrently, activities will be focused on the design, production, characterization and application of biomolecules of natural origin for crop protection. Further work will focus on the identification of bioactive molecules against plant pathogens based on natural molecules. Natural bioactive substances from plants and microorganisms for the control of weeds will be evaluated, as well as the promotion of plant growth and tolerance to abiotic stress using mycorrhizal fungi, endophytic and/or rhizocompetent microbial strains. Finally, the reduction of inputs from nitrogen fertilizers and the improvement of Nitrogen Use Efficiency (NUE) through investigations in controlled conditions on legume plants will be assessed.

UNIBA: ***Nature-based solutions for agro-ecosystems restoration.*** The research activity will focus on improving the quality of the degraded agro-environmental ecosystems. Different Nature-based solutions (NBSs) able to improve and restore ecosystem functions will be modeled on some specific areas (e.g., polluted and/or subject to erosive and soil instability phenomena). Specifically, integrated intervention strategies will be hypothesized and modeled at the farm level both for natural and agricultural areas (e.g., buffer strips, soil-bioengineering techniques, renaturalization interventions). The management of the agro-environmental ecosystems will be integrated by specific actions aimed at the management of pathogens, the analysis of the soil microbiota, and the bioremediation of soils, such as the development of integrated fertilization systems (use of organic amendments, inorganic fertilizers, resistance inducers, bio-stimulating substances, and microorganisms). The final aim of the activity will be to provide an agro-forestry environment management methodology (study-monitoring-modelling interventions of protection and restoration) applicable to degraded agro-environmental areas.

UNIMI: ***Hydrological modelling for the design and assessment of Nature-based solutions in peri-urban and agricultural areas.*** A large-scale rainfall simulator will be designed, built and instrumented with the purpose to implement a shared facility to conduct research into sustainable management of stormwater runoff in agro-urban environments. In particular, different types and configurations of infiltration/retention-based green infrastructures such as infiltration basins, permeable pavements and green roofs will be implemented and tested for a comprehensive evaluation of their performances in storm water quantity and quality control. The platforms will be instrumented with rain gauges, soil moisture, temperature sensors, water level devices, flow rate meters, automatic water samplers for the monitoring and collection of runoff and percolated water from the infiltration/retention-based green infrastructures. The collected data will be used for implementing and comparing new and existing green infrastructure modelling tools useful for designing and planning stormwater mitigation measures at different spatial scales.

UNINA: ***Precise solutions for the sustainable forest management.*** The growing importance of Mediterranean forests requires suitable strategies for their protection and management to minimize the impact of climate change on trees' health and functionality and the ecosystem services they provide. In this framework, innovative ICTs enable (i) spatial analyses of forests, and environmental data in a guided and cost-effective manner; (ii) timely monitoring of tree health; and (iii) support of decision-making and ensuring the current objectives of sustainable forest management. In this task, the shift from traditional to precision forest management consists of monitoring, conservation, and restoration of the forest stands subjected to natural or anthropogenic disturbances through (i) in situ approaches for characterization of forest stands using proximal survey technologies; (ii) combination of spatial data on tree growth and status from multi-platform proximal sensing, biomass yield, eco-physiological tree performance, and environmental conditions for granular prescription protocols. In disturbed forests, the implementation of such technologies coupled with remote sensing serves as a basis for the management of multifunctional, resilient, and sustainable natural forest ecosystems.

POLIMI: ***Natural solutions for the protection of environmental resources in agriculture.*** This Task will develop a taxonomy of natural solutions (NBS) and test its application through a multi-objective perspective of sustainable urban and territorial planning, with reference to economic, environmental and social issues. Different types of NBS will be studied, evaluating their effectiveness for the retention, storage or infiltration of water resources, for the improvement of water quality and for the protection and enhancement of soils, ecosystems and biodiversity. The effectiveness of the different types will be assessed with respect to: i) potential for reducing and controlling non-punctual sources of agricultural pollution, ii) sustainable use of

natural resources in agricultural systems, iii) production of goods and services from an economic perspective circular, iv) environmental protection.

UNIPG: ***Buffer strips for water and soil protection.*** Greenhouse, lab and field experiments will be carried out to identify most suitable herbaceous and tree species to set up buffer strips aimed at: i) phytoremediation of aqueous solutions; ii) soil erosion prevention; iii) ecosystem service improvement. Greenhouse/lab experiments will include: soil-less bioassays to study agrochemical absorption efficiency; olfactometer bioassays, EPG, volatilome analysis to study attractivity and suitability of plants with regard to natural enemies and insect pollinators. Field plot experiments will be focused on mitigation of soil and water pollution by buffer strips with different species composition and width. Also buffer strips at whole field level will be monitored.

UNIRC: ***Monitoring and use of useful organisms to enhance restoration strategies for compromised environments.*** This activity will focus on the use of nature-based solutions (NBS) to protect agricultural and natural environments from the threats of global changes, and to restore damaged ecosystems. These solutions will be based on leveraging the manipulation of the environmental microbiome and arthropod biodiversity to protect the environment and our natural resources. We are currently able to characterize the plant-microbiome interaction able to positively influence plant communities. Similarly, we are currently able to characterize the arthropod biodiversity, mainly pollinators and natural enemies, and its role in maintaining the environmental homeostasis. At the end we will be able to exploit the environmental microbiome and arthropod biodiversity to restore damaged systems and to protect natural resources. The achievement of this objective will be verified by the successful use of our NBS to reduce the impact of agricultural practices on the environment.

***Initial TRL*: 3**
***Final TRL*: 6**

Deliverables
D3.2.1.1 Screening of suitable strategies to ensure and improve soil quality (M6)
D3.2.1.2 Final report on implemented solution for soil quality protection and amelioration (M30)
D3.2.2.1 Mid-term report on implemented strategies to improve soil fertility (M18)
D3.2.2.2 Final report on implemented strategies effectiveness (M36)
D3.2.3.1 Overall development of smart architecture and models for water management improvement (M12)
D3.2.3.2 Final report on testing and field validation of agricultural water supply modelling and tools (M36)
D3.2.4.1 Screening and piloting of suitable strategies and sustainable technologies for water/wastewater reuse and valorization (M18)
D3.2.4.2 Final report on planning, testing and field validation of smart solutions for water/wastewater irrigational reuse (M36)
D3.2.5 Report on design, implementation, technological enhancement, and validation of NBS for environmental impact reduction in agricultural systems (M30)

Milestones
M3.2.1 Experimental protocols and pilot activities planned (M12)
M3.2.2 All planned lab/pilot/field activities ongoing (M24)

Interactions with other Spokes
Innovative strategies to protect natural resources and reduce agriculture environmental impact will be coordinated and synergic with those in Spoke 2 (*WP2.1 - Agroecology and landscape management to reinforce ecosystem services; WP2.2 - Alternatives tools and strategies to reduce the use of synthetic pesticides and fertilizers*), Spoke 5 (*WP5.2 - Livestock management for improving resilience to climate change)*, Spoke 6 (*WP6.1 - Farm management models to enhance* sustainability and resilience in different agricultural scenarios; *WP6.2 - Circular management models for better exploitation of waste materials*), Spoke 8 (*WP8.3 -Nutrient and organic matter recovery from wastes to reduce the use of agrochemicals and closing waste cycle*), Spoke 9 (*WP9.1 -Data Hub integrating new data and metadata on origin and sustainability*). The activity of WP 3.2 addressed to optimized water and soil management in agricultural systems, will be carried out considering also the activities of Spoke 4 (*WP4.2 - Smart-climate and resilient*

agriculture and forestry: from sustainable products to the bioeconomy, T4.2.2) on resilient climate and multifunctional agriculture.

Work package number	3.3	**Lead beneficiary**	UNIBO
Work package title	Evaluation and demonstration for stakeholder engagement and innovation exploitation		
Start month	1	**End month**	36

WP Leader: Davide Viaggi [UNIBO]

Objectives

- to evaluate new solutions for smart agricultural systems from an economic point of view
- to provide an integrated multidisciplinary assessment of solutions for smart agricultural systems
- to identify policy needs and support governance solutions through engagement and animation of stakeholders
- to set up a coordinated network of living labs and demonstrate innovative solutions

Description of work

T3.3.1 *Economic analysis for the evaluation, uptake and supply chain valorization* **(M1-M36) task leader:** UNIPR [Davide Menozzi]; **partners involved:** UNIBO, POLIMI, UNIPG, IBF, ISP

This task will evaluate new solutions for smart agricultural systems according to economic and social criteria. The analysis will run on different levels. Firstly, it will use advanced economic analysis of consumers and farmers' behaviour related to the newly developed technologies using combinations of surveys and econometric analysis. The result will explain (potential) acceptance, attitude, intention and uptake mechanisms according to cutting-edge concepts of innovation adoption and diffusion, as well as related perceived value, measured through the Willingness to pay (WTP). This will feed the use of a cost/benefit framework and its extensions to evaluate the expected economic impact and profitability of technology and suitable organisational options for their use (e.g., considering different value chains or contractual mechanisms). The results will be translated into solutions for the innovation diffusion and enhancement through the value chain.

Methods: Cost-benefit analysis, statistical and econometric techniques, surveys, behavioural experiments, advanced data management, contractual solutions.

Research Activity:

UNIPR: Economic assessment of smart agricultural systems. The work aims to evaluate new solutions for smart agricultural systems according to economic and social criteria. The analysis will run on different levels. Firstly, it will use advanced economic analysis of consumers and farmers' behaviour related to the newly developed technologies using combinations of surveys and econometric and statistical analyses (e.g. structural equation modelling, agent-based modelling). It will be possible to explain (potential) acceptance, attitude, intention and uptake mechanisms according to cutting-edge concepts of innovation adoption and diffusion, as well as related willingness to pay (WTP). These results will inform scenario analysis able to evaluate and quantify the expected impact on farm's profitability of new technology and suitable organizational options for their use. This assessment procedure and simulations will also consider the environmental dimension (e.g. carbon and water footprint), and will be translated into solutions for valorisation of innovation through the value chain.

UNIBO: ***Analysis of consumers and famers' behaviour related to the newly developed technologies*****.** UNIBO will conduct advanced economic analysis of consumers and famers' behaviour related to the newly developed technologies using combinations of surveys and econometric analysis. The result will explain (potential) acceptance, attitude, intention and uptake mechanisms according to cutting-edge concepts of innovation adoption and diffusion, as well as related Willingness to pay (WTP). Results can be used in a cost/benefit framework expected economic impact and profitability of new technologies, considering different value chains or contractual mechanisms.

POLIMI: ***Analysis of costs, benefits and acceptance of intelligent solutions for agriculture.*** The activities will involve: a) investigating the main drivers and barriers (D&B) that influence the adoption of Smart Agriculture Technologies and Systems (SATS) for farmers, including defining and assessing the propensity / acceptance of other stakeholders in the supply chain; b) investigating the main organizational and process innovations and collaborations to integrate SATS; c) defining a framework for cost and benefit analysis of SATS for farmers and other stages of the supply chain; d) measuring and evaluating the expected costs and benefits of SATS.

UNIPG: ***Economic analysis for the evaluation, uptake and supply chain valorization.*** Analysis will be performed by using different research methodologies with an integrated and coordinated approach: structured questionnaires; cost-benefit analysis; behavioral experiments; econometric models. Ongoing and preliminary results will be discussed by a participatory Multi-Actor approach.

IBF: ***Food chain platform to support the Life Cycle Assessment.*** Activities will focus on the development of a food chain platform for the econometric analysis of the impacts in the adoption of smart farming techniques through cost-benefit analysis and survey of farmers' behaviour. The platform manages the farm crop plan and the related field operations, recording labour efforts, input costs and fixed costs. The aim is to support the Life Cycle Assessment and provide farmers with the operating results. The platform will be implemented, as a case study, on an agro-industrial chain to evaluate the economic impacts and profitability of the adoption of smart technologies and quantify the management requirements in terms of work organization.

***Initial TRL*:** 5
***Final TRL*:** 7

T3.3.2 *Multidisciplinary technology assessment* **(M1-M36) task leader:** UNIPG [Antonio Boggia]; **partners involved:** UNIBO, UNIBA, UNINA, POLIMI, UNIPR, UNIRC
Integrated multidisciplinary evaluation of selected new solutions for smart agricultural systems will be performed according to economic, social, and environmental dimensions, also considering innovative sustainability concepts, such as resilience. The task will build on technical data collected in WPs 3.1 and 3.2, that will allow to estimate a range of performance indicators. These will be integrated using economic results of task 3.3.1 as well as stakeholder preferences identified in tasks 3.3.3. Techniques for multi-criteria analysis will be used to compare different solutions taking into account different evaluation criteria. The choice of the precise technique among the many available will be decided depending on the problem structure, with preferences for hierarchical approaches more suitable for complex multidimensional issues.
Methods: assessment indicators; multi-criteria analysis; advanced data management and statistical analysis.

Research Activity:
UNIPG: ***Multicriteria evaluation model for sustainability assessment of smart agriculture***. The activity will encompass: i) selection of most suitable analysis methods as related to problem structure, number and type of variables; ii) method testing; iii) construction of an Indicator System based on technical data from WPs 3.1-3.2 and task 3.3.1 and stakeholder preferences from task 3.3.3; iv) model calibration and validation to evaluate performance of the innovative smart agricultural systems studied in the project.

UNIBO: ***Technology assessment applied to new technologies.*** UNIBO will perform integrated multidisciplinary evaluation of selected new solutions for smart agricultural systems according to economic, social, and environmental dimensions, also considering innovative sustainability concepts, such as resilience. This will build on the estimation of a range of performance indicators and on the use of multi-criteria analysis to compare different solutions. The activity will rely on primary data collected in task 3.3.1 and 3.3.2 as well as on the outcome of the other WPs.

UNIBA: ***Evaluation of the impact of smart systems for precision agriculture on the quality of selected products and by-products.*** The main objective of this research activity will be the evaluation of the impact that innovative management technologies, developed and implemented in the previous WPs 3.1 and 3.2,

have on the nutritional and organoleptic quality of agricultural production and on the nutritional/functional characteristics of wastes and by-products in order to identify potential new uses or more suitable methods of disposal. The performance of the smart solutions and the innovative strategies proposed will therefore be evaluated according to the nutritional/compositional units of the products obtained through their use, compared to conventional production, with a particular focus on the quality and quantity of the protein of the productions, minor components (e.g., mineral elements) and sensorial characteristics (Depending on the studied agricultural product and by-products). Wastes and by-products of selected supply chains will be analyzed for the content of bioactive molecules and the comparison between innovative and traditional approaches will allow defining the potential for the valorization of the waste/by-product.

UNINA: The research will focus on the analysis and modelling of energy flows for both outdoor and indoor cultivation, with parametric analysis of scenarios, including: use of renewable energy sources, use of new technologies for building, energy conversion systems (air conditioning, artificial lighting, cooling), defining appropriate KPIs for estimating environmental impact, energy consumptions and economic factors (productivity and/or total costs). The method is based on calibration of white-box case-specific models based on experimental data or well assessed data from literature, and numerical simulations; also, some artificial intelligence models (machine learning) could be used if white-box model predictions do not fit well available data. Results in terms of parametric analysis and multi-criteria optimizations will be produced.

POLIMI: ***Measurement and evaluation of the sustainability of Smart Agriculture Technologies and Systems.*** After identifying the developed Smart Agriculture Technologies and Systems (SATS), sustainability KPIs will be identified: i) from established frameworks, such as GRI, SAFA, SDGs, LCA, S-LCA, and ii) from a bottom-up survey of the state of art.

UNIPR: Integrated multidisciplinary evaluation of new solutions for smart agricultural systems. An integrated evaluation of new solutions for smart agricultural systems through a multidisciplinary approach considering economic, social, and environmental dimensions, including the theme of supply chain resilience will be applied. A range of performance indicators will be defined across the three dimensions to assess the economic (e.g. value added), social (e.g. employment), and environmental impact (e.g. carbon footprint) of new solutions for smart agricultural systems. Primary (e.g. interviews) and secondary data will be collected and analyzed by applying widely recognized methodologies (e.g. LCA, LCC, S-LCA, Delphi, etc.). As far as LCA is concerned, it will use several LCIA impact categories adopting internationally recognized indicators. Multi-criteria analysis techniques will finally be used to compare different solutions taking into account different evaluation criteria and dimensions.

UNIRC: Multidisciplinary technology assessment. This task aims to carry out an integrated analysis and sustainability measurement of the new solutions for smart agricultural systems implemented within WP 3.2 and, particularly, in the frame of UNIRC-Task 3.2.2 and UNIRC-Task 3.2.4 in order to compare and evaluate different practices for soil management in organic farming, as well as for wastewater reuse from the agro-food industries. The activities will entail the implementation of specific Life-Cycle based methodologies for stressing and quantifying the potential environmental, economic and social impacts derived from the innovative solutions fulfilment.

***Initial TRL*:** 5
***Final TRL*:** 7

T3.3.3 *Policy supporting innovation, engagement, animation and exploitation* **(M1-M36); task leader:** IBF [Pier Luigi Romiti], **partners involved:** UNIBO, CNR, UNIBA, UNIPR
The task will involve and engage stakeholders and animate a network of interested parties suitable to provide orientation of research, exploitation of the research results and policy advice. This will primary be complementary to task 3.3.4 that will run the demonstration activities. In addition, stakeholders will be involved in workshops and other participatory activities supporting the identification of policies instruments suitable to support the exploitation and uptake of innovations. Attention will be particularly devoted to instruments compatible with the Italian PSN implementing the 2023-2027 CAP, but also to innovations in policy design in a longer-term perspective. In parallel, economic models will be used to provide simulation

of the performances of these policy instruments and identify innovative policy design options, policy, with a focus on interaction between policy and market scenarios.
Methods: stakeholder involvement techniques such as participatory workshops; policy modelling and simulation.
Research Activity:
IBF: ***Dissemination and stakeholders' involvement***. Thematic workshops and conferences will be organized for the dissemination and support to the adoption of innovative strategies. The BF group will provide its contribution both through the activation of the stakeholder network and by organizing conference activities at its locations.

UNIBO: ***Policy analysis and participatory stakeholder engagement.*** UNIBO will conduct an analysis of policy instruments suitable to support the exploitation and uptake of innovations. Attention will be particularly devoted to instruments compatible with the Italian PSN implementing the 2023-2027 CAP, but also to innovations in policy design in a longer-term perspective. The analysis will be based on a combination of economic simulation models and stakeholder workshops. It will aim to both estimate performance of different instruments and identify innovative policy design options under different scenarios. The activities will be supported by the engagement of a network of stakeholders in connection to task 3.3.4

CNR: I*nnovative strategies and networking instruments for involving interested parties about Plant Protection and Biological Invasion's risks*. The research will aim to: a. inform, train and raise awareness and knowledge on plant sustainable protection, risks/impacts of biological invasions by pathogens, parasites and other alien plants/animals; b. identify limits and needs for research and innovation; c. the direct networking participation of citizens and the improvement of the synergistic interaction between research/stakeholders for the sustainable management of crop production and environment protection. The activities will: a. develop a pilot online platform, containing a digital application of Citizen science, for description/territorial surveillance/reporting of alien organisms, and an interactive section to identify knowledge/technology gaps, legislative limits and training, research and innovation needs; b. produce informative/communicative and training materials tailored to different stakeholders and groups of interests.

UNIBA: ***LAB2IND: from experimentation to active communication.*** LAB2IND has as its main objective the transfer, communication and active dissemination of the technological solutions tested and developed in the previous WPs 3.1 and 3.2 to the various stakeholders of the regional territory. Profiling (in relation to the respective activities, missions, tasks, and skills) and the identification of possible stakeholders through screening on the territory will be the first objective of this task. This will be followed by the drafting of a communication and dissemination plan for the results, developed and drafted with the help, in agreement, of specialized companies. The realization, among others, of workshops, demonstration days in the field, and community of practice meetings, will constitute the core of this activity and will allow an effective transfer of the innovations developed throughout the Spoke.

UNIPR: Policy supporting innovation, engagement, animation and exploitation. The research activities will include the creation of the "Stakeholder Map" constructed as a two-axis graph with the stakeholder's level of influence along the x-axis and level of interest along the y-axis. The quadrant of the map that stakeholder occupies determines the intensity, frequency and types of engagement required. To construct the Map, stakeholders as input providers, farmers, decision makers, traders, will be involved in workshops and other participatory activities. The MAP will later be discussed in a Citizen Jury to help the identification of policies instruments suitable to support the exploitation and uptake of innovations. Attention will be particularly devoted to instruments compatible with the Italian PSN implementing the 2023-2027 CAP, but also to innovations in policy design in a longer-term perspective. Workshops in Living Lab at the campus of the University of Parma will be organized in order to understand/discuss innovations policies pro and cons.

***Initial TRL*:** 5
***Final TRL*:** 7

T3.3.4 *Establishment and operation of coordinated, large-scale, living labs and demonstrators* **(M6-M36); task leader:** UNIBO [Attilio Toscano]; **partners involved:** CNR, UNINA, POLIMI, UNICT, UNIPG,

UNIPR, CNH, TEL
This task will focus on the creation of a coordinated network of large and on-field living labs where a selection of the designed and developed smart technologies, sensors, tools, machines, vehicles, robots, practices, models, platforms, prototypes will be tested, assessed, and demonstrated at full-scale in diverse environments, representing some Italian production districts. The ambition is to build a research and demonstration diffuse infrastructure able to become a recognised and outstanding reference point at national and European level for precision, sustainable and modern agriculture, where researchers, farmers, industry, and all relevant stakeholders can meet and collaborate to overcome the challenges of future agricultural systems. Therefore, this task will cover all the aspects of agricultural production considering different crops, cultural practices and farming systems, overall input and outputs, infrastructures and machinery that will be designed and operated to achieve sustainable national production increase and to ensure food security, even more needed due to pandemic and recent Ukraine war scenarios.
Methods: design, construction, operation and demonstration of full-scale living labs.
Research Activity:

UNIBO: The AGRITECH research plots and infrastructure deployed mainly at the Experiment Farm and within the research labs of the University of Bologna will double up as field and lab demonstrators of the state of the art technologies implemented and tested, which will be the focus of dissemination activities aimed at growers, field technicians, scientists, the press and other interested stakeholders. Specific attention will be given to more developed technologies and/or those that show higher potential for adoption, also taking into consideration the participatory involvement of stakeholders.

CNR: ***Field demonstration activities at DEMO farms and Living Labs*.** The establishment of DEMO Farms and Living Labs will strengthen the knowledge exchange between researchers and farmers through workshops and field demonstrations, multimedia products, webinars, lectures, participation in scientific meetings, and continuous updates through social networks and media. The CNR will make available the DEMO Farms of S. Paolina in Follonica and in collaboration with Terre Regionali Toscane, Tenuta di Alberese (Grosseto), Tenuta di Cesa (Arezzo), and Donna Elvira winery (Montemiletto, AV), where numerous field demonstration activities of digital agriculture have already been implemented. Additionally, student classes, social groups, and communities will use experimental cereal fields as Living Labs. Thanks to the DATI project (EU-PRIMA), a link will be established with international DEMO Farms.

UNINA: Volumes and types of environmental data have increased enormously, entering in the everyday life of billions of people using digital devices such as smartphones and portable computers. Farmers lack access to data and information for adjusting their crop management whilst Earth Observation -based services provide the necessary data and information ("diagnostic") for mapping of yield potential and within field variability (soil, crop and water status). However, the penetration of EO-services among farmers is still rather low in comparison to the potentialities, mainly because of a low perception of potential business improvements by farmers and the difficulties in adjusting every-day operations according to the information received, which is seen as a complication and/or a waste of time.
In this research we will develop an irrigation advisory service with a cloud-based infrastructure and real time processing of different sources of data (Earth Observation, meteorology, if available in-situ sensors). Although being science-driven, the platform service will be transparent for its users, with the concept of facilitating the up-taking of digital services within the farmers community.

POLIMI: ***Integration of robots in a large-scale indoor environment.*** The task concerns the creation of an indoor Living lab that allows to: a) develop and test cultivation practices in vertical farming, introducing a very high degree of mechanization and automation that makes possible to make all processes replicable, fully measurable, standardized and automated; b) develop a coordinated control and management environment for autonomous multi-platform or tele-operated systems in environments with the aim of controlling irrigation water quantity and quality, carrying out complex tasks in the presence of environmental and crop constraints; c) integrate the vertical farming system with robotic systems of soft and precision picking for the automated sowing / harvesting of agricultural products and modules for the analysis of their quality; d) define and test the characteristics and performance of a micro-grid (TRL4-6) to experiment in the agricultural sector predictive optimization algorithms for the optimal planning of multi-level energy systems / applications and

guarantee their safe and efficient operation even in the presence of a high penetration of renewable generators.

UNICT: ***Social networks, living labs and research infrastructures for agro ecological transition.*** The task aims to facilitate the integration of research and innovation processes in natural environments in order to: i) recognize the main forces in the adoption of innovations by stakeholders operating in different supply chains; and ii) identify potential barriers that could hinder the diffusion of such innovations on a local scale. This objective will be by the following activities: a) Creation of a living lab structure, in which stakeholders are involved and made bottom-up co-constructors of innovation needs; b) Methodological construction of an integrated approach based on frameworks such as social network analysis, life cycle cost and life cycle assessment, data mining based on artificial intelligence algorithms, and choice experiments; c) Survey of a representative sample of cases; d) Animation on the territory, dissemination of results and best practices. The results of this task will be used to improve processes, support policies, and provide a sound basis for informed decisions.

UNIPG: ***Establishment and operation of a large-scale living lab***. A Living Lab will be developed within a large farm [Azienda Agraria of the Fondazione per l'Istruzione Agraria di Perugia, Casalina di Deruta (PG), about 1500 ha] with an adequate level of digitalization (i.e. soil and crop mapping; tractors equipped with guided systems; recording technologies; Variable Rate Technologies). Thematic living labs and a multimedia platform will be developed. Thematic living labs, linked with crop cycles, will be at fixed sites. Activity scheduling will be shared by the platform with users and stakeholders.

UNIPR: Construction of the living lab and demonstrators. The methodology adopted provides for an initial phase in which the living lab infrastructure will be created and where intelligent technologies will be installed. The infrastructure created will be the "container" of the intelligent technologies developed in the project. Subsequently, a network between actors of the various agricultural supply chains will be created. The aim of the network will be to connect the various realities to the project and start a process of strong diffusion of the innovation, with a look to sustainability. Inside the living lab, in fact, various activities will be organized, precisely to strengthen the link between Stakeholders, research and innovation.

CNH: Autonomous living lab. In this task, CNHi will support the definition and design of a living lab to support autonomous Vehicle testing.
In addition, CNHi will support the definition of the auxiliary infrastructures needed to properly operate them, e.g. 5G connectivity, GPS-RTK base-antenna correction, … Furthermore, CNHi will help in the definition of the the safety systems needed to operate and test Autonomous Vehicles prototypes in a safety manner

TEL: ***T-DROMES exploitation for Drone solutions in agriculture.*** For this task Telespazio will put the T-DROMES service platform at disposal of the Living Lab activities that will involve acquisition of data from drones. The T-DROMES platform will allow to plan and manage all the operative workflow connected to a geo-information service based on drones, from the planning and scheduling of the flight to the flight execution and data collection; finally T-DROMES will allow the provisioning of the info-product data to the farmer. In the frame of this task, the platform will be enhanced to interfacing the specific drone system used in Task 3.2.3.

Initial TRL**:** 5
Final TRL**: 7**

Deliverables
D3.3.1 Report on results of the economic analyses (M30)
D3.3.2 Report on results of the multidisciplinary technology assessment (M36)
D3.3.3.1 Screening of policy issues, relevant stakeholder, and engagement plan (M12)
D3.3.3.2 Report on engagement activities and policy analysis (M30)
D3.3.4.1 Planning and design of demo platforms (M6)
D3.3.4.2 Presentation materials and video documentary of implemented living labs and demonstrators (M36)

Milestones
M3.3.1 Methodologies for analysis and stakeholder engagement plan ready (M6)
M3.3.2 Demo platforms established (M30)

Interactions with other Spokes
Analysis carried out in tasks 3.3.1-3 will mainly cover technologies developed/studied in Spoke 3, but also those developed in other spoke when suitable synergies may be envisaged (e.g. using the same methods and/or benefiting from cross-Spoke comparisons). Cost-benefit analyses (T3.3.1) and technology assessment (T3.3.2) will possible benefit of results of monetary and non-monetary evaluation of ecosystem services carried out in Spoke 4 (*WP4.2 - Smart-climate and resilient agriculture and forestry: from sustainable products to the bioeconomy, T4.2.4*). The results of evaluations in tasks 3.3.1-3 will be used to feed management models addressed in the Spoke 6 and collaborations are envisaged in identifying suitable business models for sustainable agricultural systems taking into account technical, economic and organisational perspectives. Technology evaluation carried out in tasks 3.3.1- 3 will be also developed in a synergic way with Spoke 9, in order to ensure results are consistent with traceability strategies identified. The policy instruments developed in T3.3.3 will benefit of common brainstorming and exchanged with other tasks addressing policy or policy support (e.g. T4.3.1).