WHITE PAPER AP14
TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE AND FOOD SAFETY AND SECURITY

EXECUTIVE SUMMARY

In the next future agriculture has to answer vital challenges: world population increase, reduction of availability and increase of costs of not renewable resources, and changes in climate, particularly in the Mediterranean area. The foresee climate change will increase the vulnerability of agricultural systems and abiotic/biotic stresses severely constrain yields in crop production. More food, fiber and row material are requested to be produced using natural resources (soil and water) in a more sustainable way, minimizing application of external input such as chemicals (fertilizers, pesticides) and reducing environmental pollution. Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social and economic equity. The digital technologies are recognized as tools to increase agriculture productivity assuring benefits for company, reduce its environmental footprint on not renewable resources and environment, assure healthier and safer food, and guarantee safer work environment and fair revenue for employees. This are the main goals politicians and regulators include in their programs striving for a more economically and ecologically sustainable agriculture. Passive and active sensors, able to collect data at different level at environmental, field, single plant or fruit scale can provide fundamental information for the sustainable management of agriculture crops. Assessment of water available in the soil and status crops at large (regional/continental) and site specific (farm/plant) level support solutions to improve productivity and reduce costs, minimizing environmental impacts. Modern, and even more, future systems for data collection made available large set of information that can be elaborated to predict pests outbreak, illnesses, and stressing conditions for plants and animals affecting the quantity or the quality of the production. More competitive and sustainable agriculture production is possible adopting highly automated processes embedded in more energy efficient and safer vehicles, machinery or processes. Innovative machinery or process are not limited to the production, but include the supply chain and the management of wastes, from agriculture to consumers. Particular attention is payed to the technologies capable of increasing the hygiene and the safety of food, to extend its edibility and maintain and increase the nutritional aspects, and recycling wastes into agricultural production processes.

1. STATE OF THE ART OF THE RELEVANT SCIENTIFIC AREA

The agricultural sector is facing important challenges due to several factors such as increasing worldwide food and feed demand, market globalization and food price volatility, and the needs for more sustainable farming systems in a changing climate scenario. In this framework, technologies can be exploited to contribute to all the value chain of the agro-sector from production to consumption including the overall reduction of waste and its recover. Sensors and GNSS, automation and robotics and other ICT solutions are converging into the so called “smart farming”, which encompasses precision farming (PF) and food safety technologies (handling, preparation, and storage of food). PF is aimed at site specific crop management in order to “produce more with less” by **identifying and handling** inter and intra-field variability in crops and **reducing** fertilizer and pesticides application (optimizing the timing, location and quantity). Technologies extend their application also to the post-harvest sector contributing to food quality assessment and to food safety implementation. Finally, innovation is devoted to **optimize** operator work and to **implement** healthier and safer working condition by exploiting autonomous or remoted operated machinery. Many of the technologies for “sustainable agriculture and food safety and security” involve disciplines existing and technological innovation developed in DIITET that cover 4 main domain (Figure 1).

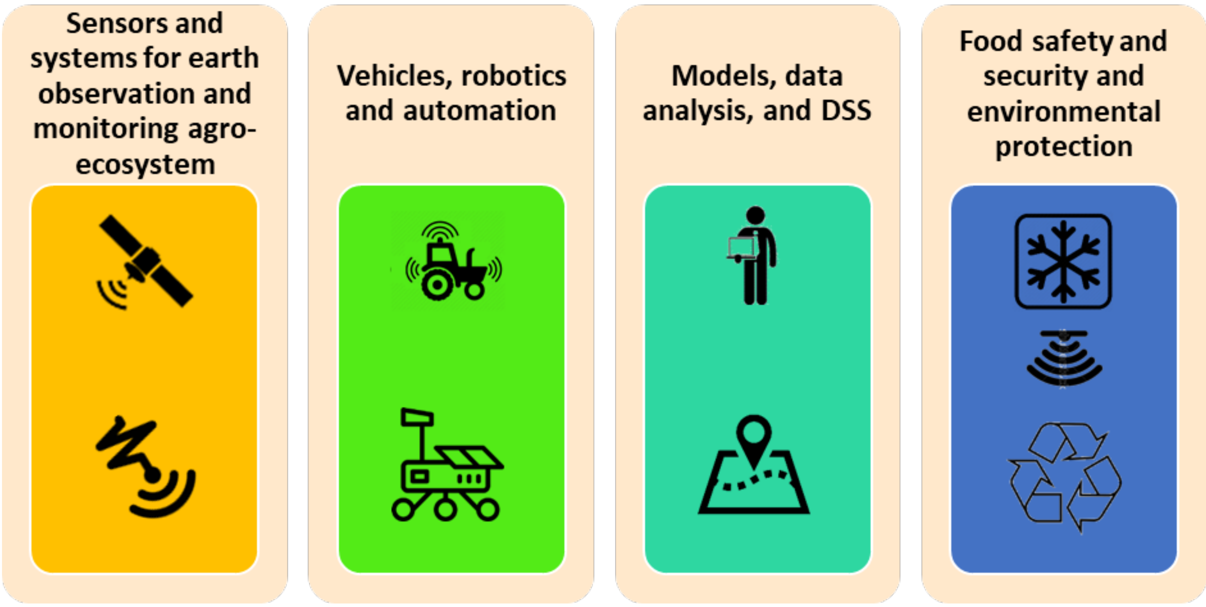

Figure 1: The four domains of "TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE AND FOOD SAFETY AND SECURITY"

Sensors and systems for earth observation and monitoring agro-ecosystem

Sensors and monitoring devices make available high-quality information concerning spatial and temporal variability of crops' distribution and status to perform large scale (regional/continental) and site specific (farm) monitoring to support solutions focused on improving productivity and reducing costs, while minimizing environmental impacts.
Large scale information can be derived from the integration of high-quality geospatial data (e.g., remotely sensed images, soil and meteorological maps). The recent availability of Sentinel-1 (S-1) and 2 (S-2) systems with their improved spatial/temporal resolution, radiometric accuracy and acquisition plan enables the systematic retrieval of crucial information, such as seasonal crop and soil tillage change maps, time series of Leaf Area Index (LAI), crop biomass and soil moisture content (SM), that are fundamental for improving agricultural monitoring and crop yield forecast.
On the opposite, detailed, in-situ information can be collected by non-destructive and non-invasive sensors acquiring data from proximal distance or directly on plants. Optical sensors are attractive since they can be exploited to record continuous measurements of plant status on the same location. Fluorescence-based sensors are developed to estimate the leaf N content and can be embarked on moving vehicles allowing to cover large areas within relatively short times. In vivo sensors are able to detect in continuous and in real time physiological changes related to stress condition hence are useful to identify in advance dangerous status such as pathogens presence or resource (water, nutrients) shortage.

Vehicles, robotics and automation

In the last few years, robotics technology has been increasingly employed in agriculture to improve productivity and efficiency of farm machinery. Main objective is to increase the level of driving automation of machinery on farms. Semi or fully automated vehicles, fitted with sensor and connected in real time to the farm data network can lead to save labor time and to perform more efficient farming applications, including regular monitoring of plant growth and precision plant treatments.
GPS-based navigation systems have been in practical use for some years allowing auto-guided agricultural machines but underexploited to, since now, to provide information on the dynamics of the environment and crops status.
Future challenges in machine industry include i) development of smarter vehicles that can operate safely in semi-structured or unstructured dynamic environment ii) the introduction of alternative fossil fuel (LPG, Methane) and electricity as source of energy and electrical actuators and implements. Furthermore advanced perception, and cognitive systems, and human-machine interfaces are required for clear understanding of

surrounding world and controls of such enhanced machines. Standards and validation processes have to be developed to assess safety and environmental compliance and performance of such new machines and devices. The interest in such technologies is not limited to the final users, the farms, but it is extended to the sector of manufacturers of agricultural equipment.

Models, data analysis, and DSS

The large amount of data from sensors made possible to design models able to simulate and forecast the effects of environmental conditions and resources availability (water, nutrients) on crop development, pests outbreak, and final yield, and to adjust operations and chemical applications accordingly.
Soil characteristics, nutrient availability and status of plants are important parameters to make better decisions for an optimized management of crops. Fertilization is one of the agronomic practices that most influences both yield and quality of products, with significantly different responses in relation to the species and cultivar and climate conditions. Moreover, this practice is extremely related to environmental issue in particular in relation to nitrate leaching in water (Directive 91/676/EEC).
The knowledge of the dynamics and the diffusion of a pest is important to define management strategies in areas where pest is already present and/or to tackle the diffusion in new areas .
Sustainable pest management is a key component in farming as requested by the European guidelines (Directive 2009/128/EC) that encourage a rational use of pesticides. Decision Support Systems (DSS) developed on pest population dynamics and trophic interaction models describing dynamics in the agro-ecosystems and on crop nutrients and water demands are extremely relevant for a sustainable crop and pests management.

Food safety and security and environmental protection

Food supply chain faces several challenges to guarantee safe and quality food to meet the growing consumers demand. In food industry different technologies are adopted to contamination and packaging failures control, or identification of items with below standard characteristics. Non-destructive optical tools exist to estimate *in situ* antioxidants, such as flavonoids and carotenoids allowing for rapid and inexpensive monitoring of compounds in the vegetables. The spectrometric devices can be used when the fruit are still on the plant for fast selection during harvesting, differential storage and processing. A promising technique is the exploitation of low temperature plasmas that has shown anti-microbial capability on food processing in addition to increase seed germination.
Refrigeration are fundamental in the food chain, in terms of safety, keeping temperature of the goods under control to prevent microbial proliferation, and reduction of post-harvest losses. They are however responsible for high environmental footprint, due to energy consumption and GHG direct emissions related to refrigerants, thus, requiring introduction of new gasses and related systems less impacting.
Consumer and regulators are more aware about environmental problems such as soil degradation processes, water overexploitation, decline of biodiversity, carbon emission and pollution from chemicals used in farm processes and organic compound from wastes. Technologies and practices including the post-harvest waste management, are adopted to protect natural resources, reduce impact on environment and increase sustainability of the agricultural system.

2. CONTRIBUTION TO THE RELEVANT SCIENTIFIC AREA

Figure 2 represents schematically the solution developed by research unit of DIITET, the list of specific innovation are reported in Table 1

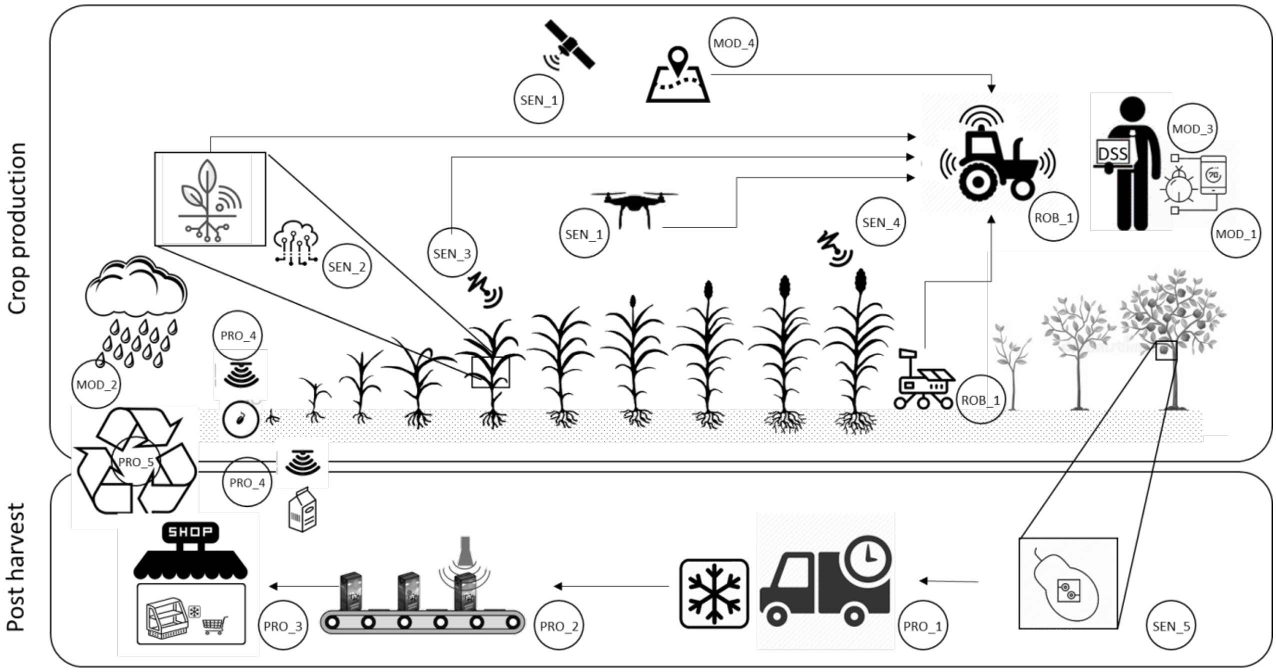

Figure 2: interconnection of DIITET applications in the "TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE AND FOOD SAFETY AND SECURITY

Table 1: Synthesis of DIITET competences by sectors

SENSORS AND SYSTEMS FOR EARTH OBSERVATION AND MONITORING AGRO-ECOSYSTEM
SEN_1: Remote sensing and geo-information for crop and pests monitoring (IREA)
SEN_2: OECT based in vivo sensors (IMEM)
SEN_3: Non-destructive fluorescence-based sensors (IFAC)
SEN_4: Non-destructive optical tools (IFAC)
SEN_5: Multi-energy scanners (IMEM)
VEHICLES, ROBOTICS AND AUTOMATION
ROB_1: Ground-based agricultural robots and autonomous vehicles (STIIMA, IMAMOTER)
MODELS, DATA ANALYSIS, AND DSS
MOD_1: Pest Population Dynamics Models and Decision Support Systems (IMATI)
MOD_2: Soil and water management and conservation in agriculture (IMAMOTER)
MOD_3: Ergonomics, human factors and safety and health in agriculture (IMAMOTER)
MOD_4: data fusion and geo-processing to support Variable Rate application (IREA)
FOOD SAFETY AND SECURITY AND ENVIRONMENTAL PROTECTION
PRO_1: Refrigerated transport and storage (ITC)
PRO_2: Food item monitoring during production (IREA)
PRO_3: Commercial Refrigeration (ITC)
PRO_4: Low Temperature Plasmas: transversal technology from pre-sowing treatment of seeds to food sanitization (IGI)
PRO_5: Wastes recovering (IMAMOTER)

Sensors and systems for earth observation and monitoring agro-ecosystem

Even though from the technological and instrumental point of view (satellites, drones, sensors, agricultural machinery, software, etc.) development is nowadays very advanced the full exploitation of these solution in real farm condition is the last mile to be addressed.
Satellite sensing technologies are a fundamental input to provide spatio-temporal information about soil condition, crop status and dynamics. Multi-spectral and multi-temporal data from satellite (e.g S-1 & S-2) make possible to i) produce regional scale (e.g. Mediterranean basin) seasonal crop maps by using classification methods, ii) estimate crop fresh biomass, LAI and soil tillage change maps at field scale, and iii) create time series of SM maps with a spatial resolution ranging between 100m and 1000m (See figure 2 Sen_1).
Coping with climate change in agriculture requires the development of frameworks to address food production and security under limiting environmental conditions. A net of smart sensors with different characteristics with specific applications can significantly increase the efficiency of agriculture management and governance, specifically, measurably, and time-bound. Many sensors are nowadays available. Optical sensors based on fluorescence detection can detect the crop/plat physiology status to be translated into plant nutrient and water requirements. The use of non-destructive optical sensors to evaluate in situ plant antioxidants represents a significant innovative tool that can be used on vegetables and fruits to optimize and monitor cultivation practices and postharvest elicitor treatments (See figure 2 Sen_3 and 4). A particularly advanced technique is in vivo sensors, sensors integrated in the plant and able to retrieve directly information on physiological processes, that allows the development of the so call “Internet of Plants”. (See figure 2 Sen_2). Finally, spectroscopic detectors are able to collect at one time several images at several energy bands. CdTe and CdZnTe detectors are the most promising solutions for novel multi-energy x-ray scanners able to assess the quality and status of products in a non-destructive real time (See figure 2 Sen_4).

Vehicles, robotics and automation

An important aspect of the research deals with the development of smart agricultural vehicles and ground-based robots that, designed or retrofitted with multi-sensor perception systems, are able to accurately monitor the operating environment on a local narrow scale to perform precision farming tasks, such as plant by plant inspection and treatment. In this respect, accurate and robust environmental perception systems is a critical requirement to address unsolved issues including safe interaction with field workers and animals, obstacle detection and situation awareness recognition devoted to increase process automation and safety. Specific objectives of the research in automation dedicated to agricultural machinery and robots are: increased operator safety through multimodal and multichannel sensing; improved persistency under compromised visibility or sensor failure; augmented surround and lateral view for the driver; scene interpretation; obstacle detection; crop assessment and phenotyping (See figure 2 Rob_1) Another important research activity is the development of multi-sensor systems and methods to assess the terrain properties related with the terrain ability to support vehicular motion, to improve vehicle performance and predict the risk of soil compaction by farm machinery.
Self-propelled agricultural vehicles are currently equipped with Diesel engine but, as in other sector of the automotive industry, energies alternative to the liquid fossil fuel are emerging. LPG and methane tractors are proposed by manufacturers but electricity is on the way as it is the adoption of actuators and implement electrically powered.
Increasing attention is paid to the adoption of user-center design and ergonomics in agricultural machinery design. It is based on qualitative, quantitative and mixed-methods research to assess performance, safety, comfort and usability in the human-machine/task/environment interaction, considering both physical and cognitive components of the interaction. The discipline requires anthropometric and biomechanical measurements of the individuals and measurements of targeted technical features of the machine to assess the potential physical mismatch between the two components. The process identifies critical issues that may benefit from user-oriented interventions, in terms of both a user-centered (re)design of tasks, machinery and technology, and of targeted information campaigns and training actions, to lead to a better usability and reduction of occupational risks.

Models, data analysis, and DSS

Mathematical models are fundamental to know and forecast the temporal dynamics of many natural phenomena. Pests outbreak and soil management are examples of application of such model in DSS. Spatial diffusion of pests in a selected area and environmental risk evaluation due to pest invasion are based on the knowledge of the pest dynamics formalized in simulation model. Evaluation of risk and population pressure can be used to take on decisions on the control of the pest to avoid the invasion of an area or to manage the presence of the pest in a crops. In the last case, probabilistic methods can be used to construct a decisional tool able to optimize the chemical application only when needed and not on schedule time taking into account the predicted abundance of the pest on the crop. Software for the decision support system can be developed to assist the farmer supplying useful indications on the time and methods to treat crops with pesticides (See Figure 2 Mod_1 and Mod 3).
Effects of different agricultural management practices including impact of tractors traffic on soil hydrologic characteristics, erosion and soil compaction processes, especially in sloping area can be evaluated by models based on data collected on long term observations.

Calibrated and validated models allows to identify the most correct management solutions in relation to soil mechanical processing, traffic optimization, and planning of farm operations, to improve soil protection, biodiversity conservation and water availability, that are three major ecosystem services that should be provided by agricultural land in addition to crop production (See Figure 2 Mod_2).
UAV are a new innovative flexible solution to acquire Very High Resolution (VHR) data as a support for strategic decision in precision farming application. On the other hand, thanks to the European Copernicus program free of charge, decametric and multi-sensors (Optical multispectral and SAR) satellite data open a new era for the exploitation of Earth Observation imagery in operational workflow devoted to agro monitoring and support for field level agro management. In this context, proper methodological tools are required for a full exploitation of VHR UAV and satellite time series data to extract information and provide that in time for a real user exploitation. Downstream services addressing specific user requirements must be developed exploiting advancement in geo data management by developing algorithm able to extract information from EO data and producing added value decision support products by model assimilation (See Figure 2 Mod_4).

Food safety and security and environmental protection

The electromagnetic technologies for the multi-resolution assessment of product quality within the food-production chain has the unique feature of exploiting the interplay among different portions of the electromagnetic spectrum (microwaves and terahertz). This interplay enables an integrated/simultaneous inspection of foreign bodies, packaging damages, and surface texture and internal properties assessment. (PRO_2) The low temperature plasmas (LTP), generated at atmospheric pressure by different devices, can directly expose or indirectly put in contact, with water or liquids . LTP technology still requires laboratory studies with multidisciplinary approach for its application on the food chain (PRO_4).
Energy efficiency and reduction environmental impact is a priority for refrigeration systems. The replacement of high GWP fluids with low GWP or natural fluids is one of the priorities. For commercial refrigeration, the market is going towards CO_2 as a refrigerant but studies are still needed to improve efficiency and to monitor actual performances. In refrigerated transport, the transition to low GWP or naturals fluids has just started and the gap needs to be rapidly filled. Integration with renewables is also under investigation, tests are approached with numerical and experimental thermos fluid dynamics to study the heat gains and air flow optimization inside the container. The same techniques are applied also to display cabinets and cold rooms. Finally, the control of components and remote monitoring for operation optimization and fault detection is a cross and key topic in refrigeration (PRO_1 and 3).
Wastes for agriculture and agrofood-chain can be submitted to processes for production of fertilizer to be reused in the same sector (circular-economy). This processes requires special procedure to reduce the contribution to GHG emission. This fertilizer can be activated with microorganisms to enhance their nutritional features and biological activity and densified to increase the possibility of storage, transport and distribution when applied with variable rate technology machines. Such fertilizers improve the biodiversity

and the carbon content of the soil, and are able to reduce the soil erosion and compaction. Long-term observations are required on fields or large plots to detect soil degradation processes, particularly important in the Mediterranean area where the effects of the climate change jeopardize agriculture production, farmers revenue, and food secure (Pro_5).

3. IMPACT

Sensors and systems for earth observation and monitoring agro-ecosystem

Combining a higher agricultural productivity with the protection of natural ecosystems is one of the key United Nations (UN) Sustainable Development Goals (https://sustainabledevelopment.un.org). It requires the support of Earth Observation systems and of algorithms for a full exploitation of different sensors data (UAV or satellite, multispectral or SAR) to i) provide spatially distributed information on wide area (i.e. crop distribution, crop practices, phenological developments, risk alerts) as a basic component of agriculture monitoring platform (Regional level downstream) and to ii) retrieve crop related information (e.g. biophysical parameters, plant nutritional status, stress condition) in order to generate added value information useful in supporting within field crop management (Local level downstream).
Regional downstream services are fundamental to develop reliable forecast of agricultural production and to create early warning system able to alert on anomalous situations and to support decisions for managing the food security risk. Local downstream services can be exploited directly to support crop management with a direct economic impact for growers and the food industry: farmers can take advantage from the cultivation of well-balanced plants, less susceptible to diseases, reducing the request of chemical application and, consequently labour and pesticides costs hence increasing farming profitability.
In this sector, proximal sensing non-destructive methods can be used to assess nutrients content avoiding destructive sampling and leaf chemical analysis cost. The main impact of such innovation is on the possibility to perform precision fertilization exploiting sensors information and variable rate machineries. According to IOF2020 consortium (https://www.iof2020.eu/trials/arable/precision-crop-management) there is a potential market of 59 million Euro thanks to the expected profitability of about +3% due to increase in nitrogen use efficiency, reduction of water use (-10%) and optimisation of labour (efficiency +5%). Furthermore, the control of the nutrient supply can limit plant diseases and then, indirectly, reduce the use of pesticides contributing to environmental preservation.
The possibility to monitor in vivo and in real time physiological mechanism occurring during plant stress response will reply to the increasing demand of a more sustainable use of resources. Moreover, the implementation of in vivo sensing technology can also contribute to national and international plant phenotyping infrastructures and networks.

Vehicles, robotics and automation

The development of highly automated vehicles will reduce effort and working hours with positive impact on costs. Vehicle and robots equipped with multi-sensor systems will be able to perceive and understand the surroundings. This will result in an increased safety for people and animals, and will reduce the risk of damages to crops or to machines. Automated agricultural vehicles and ground-based robotic platform will also be able to accurately monitor the operating environment on a local narrow scale to improve precise plant treatments such as precise application of fertilizers or herbicides and plant growth monitoring. In addition, sensing real-time terrain properties the vehicle will be able to adapt to the site-specific environment by varying its velocity or tire pressure, or adjusting the parameters of onboard control and stability systems.
The understanding of the role played by different variables related to both the farming system and to the operators (i.e. subjective evaluations, physical and behavioral human variability, and objective characteristics of working conditions and machinery) promotes operators' health, safety and well-being, and can suggest possible solutions in terms of policies, user-centered (re)design of tasks, machinery and technology, and/or operators' training, to support and promote a more sustainable agriculture.
Self-propelled vehicles equipped with alternative propulsion system to Diesel engine contribute to the reduction on air pollution in addition to introduce agriculture in network of the smart grid for the use of electrical power.

DIITET structures are accredited as official testing station for safety and performance of agricultural equipment while DIITET representatives participate as expert at national and international level at technical (INAIL) and standardization forum (CUNA, UNI, CEN, ISO, OECD), and supports the manufacturers for the development of new products.

Models, data analysis, and DSS

Mathematical models are useful for many agricultural operations to pass from information to decision. One of those application is for pest population dynamics used to manage the presence of pests by national and international organizations and enterprises. For instance, EFSA uses mathematical models for pest dynamics to promulgate directives for the EU members to control the diffusion of the pest. A mathematical model to describe the dynamics of the grape berry moth has been used in a European project to construct a decision support system for vinegrowers.

Food safety and security and environmental protection

Sensors for food quality and safety should be easy to use, have low impact in the food production chain, be rapid and high-throughput for in-line food monitoring and low-cost. Optical sensors help identifying aspect involved in quality and more profitable products, multi-energy scanners are useful in the field of in-line food safety control, broadband EM diagnostic technology are applicable to the detection of foreign body contaminants in food products along the production chain. An emerging technology in agriculture and food treatment is the low temperature plasma.
In refrigeration technology DIITET representatives assure the Italian presence in the food chain technology projects and supports the national industry, offering scientific collaboration and technology transfer. In transport refrigeration, DIITET representatives acts as expert at national and international level, at political and standardization forum (CTI, CEN, UNECE).
The soil conservation and waste treatments research aims to understand and promote the best agricultural management practices, to optimize the use of natural resources (water and soil), to improve sustainability and performance of the Mediterranean agroecosystems, by promoting solution to make it more resilient to climate uncertainties, also with application of innovative techniques. Regarding soil, considering the climate trend of recent years (changes of rainfall pattern, extreme events causing relevant runoff and soil erosion processes, and, on the opposite, increasing water scarcity) different management solutions should be selected and evaluated, to preserve essential resources and secure yields under future climate scenario. Concerning wastes technology treatments the densification processes are able to overcame the low density condition of products, recognized as the most important obstacle for transport, handling, storage and application in agriculture.
Many of the scientific work force belonging to this AP transfer their knowledge in university lecturers, hosting and supervising trainees, thesis and PhD students from the university in their own specific field of study as well as technology transfer initiative are ongoing with well establish collaboration with industry and business service sector.

4. EMERGING RESEARCH CHALLENGES

Sensors and systems for earth observation and monitoring agro-ecosystem

Data acquisition from sensors (proximal, UAV and satellite), data processing and management to derive crop related information to be included in DSS to create value-added information useful for site specific management by the final operators.
Development of specific sensors for agricultural and food chain processes such as high energy resolution and high spatial resolution x-ray scanners or OECT based in vivo sensing platform.

Vehicles, robotics and automation

Advancement in perception systems based on multi-sensor platforms and on the fly processing algorithms integrated on-board agricultural vehicles for highly automated driving and information processing of sensor data in real time field conditions. Users' acceptability, attitude toward adoption, and ease of use of new technologies.

Models, data analysis, and DSS

Development of algorithms, models and DSS for pest population dynamics and control, for long term soil degradation prevention, and crop water management to increase resilience and sustainability of agriculture.

Food safety and security and environmental protection

Development of broadband EM technology for monitoring food quality along the production chain and of LTP for seeds, plants or food treatments.
Efficiency and environmental improvement, and integration with renewable in refrigeration.
Investigation on tree and cover crops system and their connections with climatic characteristic and hydrologic response, and livestock waste processing and its application with precision agricultural tools.

5. CONCLUSIONS

Sensing technologies devoted to earth and crop observation are fundamental for agriculture to collect spatio-temporal information about soil condition, water and nutrient availability and demand, crop status and pests dynamics to be fully exploited at different levels to significantly increase the efficiency of use of non-renewable resources and reduce the environmental footprint of agriculture. Significantly innovative tools for agricultural applications are non-destructive sensors based on fluorescence detection for crop and plant physiology. Sensors directly integrated in the plant (in-vivo) are the next challenge in agricultural sensor application. Optical sensors and multi-energy x-ray scanners are promising techniques to assess the fruit and vegetables nutritional characteristics. Data collected by sensors can be exploited developing algorithms and models for resource management and sustainable chemical application and for pest monitoring and control. Smart agricultural vehicles and ground-based robots, together with drones, are the best platforms to be equipped with sensors for crop and plant observation and inspection and to perform precision farming tasks. These vehicles require accurate and robust environmental perception systems for an effective and safe interaction with the environment and should be able to detect the terrain properties to improve vehicle performance and reduce the risk of soil compaction by farm machinery. Adoption of alternative fuels to the fossil one is the challenge for the future of the agricultural vehicles.
In the food supply chain electromagnetic technologies enables an integrated/simultaneous inspection of properties of product and packaging damages while the low temperature plasmas is a promising technique for food sanitization. Energy efficiency and reduction environmental impact, adopting natural or low GWP fluids and renewable energies all along the food supply chain, are the priority investigation in refrigeration technologies. Intensive land use focusing solely on production results in the decline of agricultural ecosystems, therefore, future agricultural land use should be evaluated considering the trade-offs between food production and the provision of the different ecosystem services. Preserving natural resources from degradation and promoting circular economy paradigm promoting appropriate agricultural system waste management make possible to achieve UN targets for a more sustainable agriculture.

PROJECT AREA 14: TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE, FOOD SAFETY AND SECURITY

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