Alliance for Internet of Things Innovation

Role of IoT in addressing the agroecological focus of the Green Deal

AIOTI WG Agriculture

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Content

Executive summary

The Green Deal presented in 2019 is one of the largest flagship initiatives launched by the European Commission in the recent decades, setting the vision of an efficient, competitive and low-carbon European economy. Agriculture and food systems are key elements to achieve the ambitious objectives of the Green Deal, as clearly reflected by the Farm to Fork and Biodiversity strategies, both presented in 2020. The recent reform of the Common Agricultural Policy (CAP) is also strongly aligned with the Green Deal targets. Overall, the trend is towards agriculture practices which are more sustainable and environmentally-friendly, pushing the concept of agroecology, yet ensuring fair economic return for the farmers.

ICT technologies, and IoT in particular, play a key role in supporting the transition towards this new model, leveraging on the use of data, analysis and monitoring tools. This paper delves into this relationship. First, the main contextual aspects of the Green Deal, the CAP, and their common objectives, are introduced along with the concept of agroecology. Then, the role of IoT and digital technologies in this new context is highlighted, and several case studies are described to show how practical implementations of IoT-based farming systems are contributing to support sustainable farming practices in line with the Green Deal.

Finally, the paper provides some recommendations to get the most of IoT-based smart farming. The focus is put on the need of quantifying/benchmarking the impact and full footprint of IoT and digital solutions in farming, as well as the need for reliable monitoring of target parameters and environmental indicators. Data issues (like compatibility and accessibility) and technology adoption are highlighted as transversal barriers that need to be overcome in order to unleash the full potential of digital solutions.

1. Context of agri-environmental policies within the Green Deal

On December 2019, the European Commission presented the European Green Deal [ECGD19], the 1st of six headline ambitions of President von der Leyen's Political Guidelines "to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use" [ECCWP20]. The Green Deal is one of the largest common efforts at EU level being accomplished so far, with an assignment of roughly one third of the EU's 21-27 budget, including the NextGenerationEU Recovery Plan [ECNGEU], and addressing numerous policy areas encompassing climate, environment and oceans, energy, transport, agriculture, and industry.

Agriculture and food systems are key intervention areas under the European Green Deal. On the 20 of May 2020, at the heart of the COVID-19 pandemic, the Commission adopted [ECPR20] a comprehensive Farm to Fork Strategy (F2F0) [ECFFS20], [ECFFSW20], which aims to ensure food security in the face of climate change and biodiversity loss. This general objective implies, on one hand, the need to strengthen the resilience and competitive sustainability of the EU food system, preserving the affordability of food whilst ensuring food safety, and fair economic returns for the actors in the food chain. On the other hand, the ambition of the F2F Strategy is to reduce the climate footprint of the EU food system, ultimately achieving a neutral or positive environmental impact of the EU food chain, from food production to consumption.

Also on the 20 of May 2020, the Commission adopted the Biodiversity Strategy [ECBDS20], [ECBDSW20], with the overall goal to put Europe's biodiversity on the path to recovery by 2030 for the benefit of people, climate and the plan. In particular, the strategy envisages measures to protect nature and reverse the degradation of ecosystems.

Both the F2F and the Biodiversity strategy set specific, measurable objectives for 2030 which impact directly on current agriculture practices:

1. Reduce by 50% the overall use of chemical pesticides and of more hazardous pesticides.
2. Reduce the loss of soil nutrients by at least 50% while ensuring no deterioration of soil fertility, resulting in a reduction of fertilisers of at least 20%.
3. Reduce the overall EU sales of antimicrobials for farmed animals and in aquaculture by at least 50%.
4. Achieve at least 25% of the EU's agricultural land under organic farming.
5. Ensure that at least 10% of agricultural area is transformed into high-biodiversity landscape features.

Other qualitative objectives are:

- Promote more carbon-efficient methods for agriculture, in particular livestock production, with the aim to reduce the GHG emissions due to the agriculture sector.
- Ensure a higher level of animal welfare, as this will improve animal health and food quality, reduce the need for medication and help preserve biodiversity.
- Significantly increase the uptake of agroecological practices.

In general a major focus is put on reducing agricultural inputs (including pesticides and fuel), while increasing efficiency, innovation capacity and resilience of farming processes, directly contributing to a resilient, sustainable and competitive agricultural sector, fully aligned with the above and in particular with the future Common Agriculture Policies (CAP) objectives (cf. next section), i.e. ensuring a fair income to farmers, increased competitiveness, climate change action, environmental care, preserving landscapes and biodiversity, vibrant rural areas, and protecting food and health quality. Here IoT and related technology advances, for example in the field of Artificial Intelligence (AI), are seen as key enablers to reach EU objectives. The case studies reported in Section 3 clearly demonstrate this.

In recent decades the concept of agroecology has emerged, which reflects a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. According to FAO[1], agroecology is considered a transdisciplinary field that includes the ecological, socio-cultural, technological, economic and political dimensions of food systems, from production to consumption. One of the main objectives of agroecology's practices is to optimize the interactions between plants, animals, humans and the environment towards sustainable agriculture and food systems. Agroecological transitions aim to support the simultaneous achievement of multiple sustainability objectives – economic, environmental, social, nutritional, health and cultural – holistically and in integrated manner at different levels and scales while being adapted for different environmental and cultural contexts. What makes agroecology distinct and fundamentally different from other approaches to sustainable development is that it is based on bottom-up and territorial processes, helping to deliver contextualised solutions to local problems. Agroecological innovations are based on the co-creation of knowledge, combining science with the traditional, practical and local knowledge of producers. Having as a starting point the work of [ALTIERI95] and [GLIESS15] and following a multi-actor synthesis process that included regional workshops organized by FAO the 10 elements of agroecology have been extracted [FAO18].

The objective of these 10 elements is to provide the countries with an analytical tool to guide the transformation of their food and agricultural systems, with the aim to mainstream sustainable agriculture on a large scale. The 10 Elements of agroecology are the following:

- Diversity; synergies; efficiency; resilience; recycling; co-creation and sharing of knowledge (describing common characteristics of agroecological systems, foundational practices and innovation approaches)
- Human and social values; culture and food traditions (context features)

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[1] http://www.fao.org/agroecology/overview/en/

- Responsible governance; circular and solidarity economy (enabling environment)

As illustrated in Figure 1, the 10 elements are interlinked and interdependent. The arrows highlight those elements where IoT technologies have a larger impact, as will be seen later in Section 4.

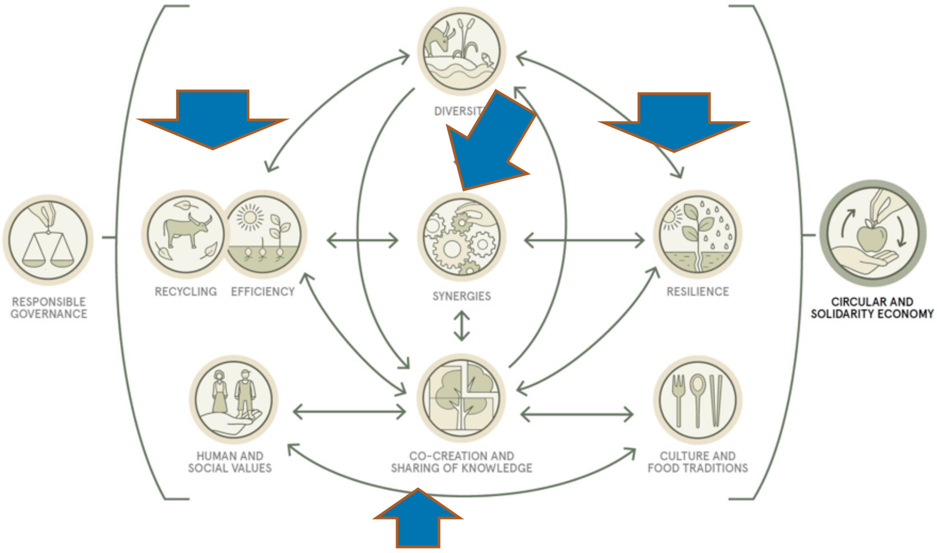

Figure 1: The 10 elements of Agroecology and their interdependencies. Source: FAO[2]

[2] http://www.fao.org/agroecology/overview/overview10elements/en/

2. Context of agri-environmental aspects in the new CAP

The Common Agricultural Policy was launched in 1962 [ECCAPG] and has defined since then the agricultural policy of the European Union. The CAP aims, among others, the improvement of agricultural productivity ensuring a stable supply of affordable food, the support to EU farmers, and the sustainable management of natural resources. The instruments of the CAP comprise market regulations, subsidies, and rural development measures. Overall, it currently accounts for roughly one third of the total EU budget.

The CAP has undergone several reforms through history in order to adapt to the evolving economic, social and environmental challenges. The future CAP, set to enter into force in 2023, is the result of a process that started with the legislative proposals presented in 2018 and all the negotiations taking place thereafter until reaching an agreement in June 2021 [ECCAPRef]. The future CAP is structured around 9 common EU objectives [ECCAP21], covering three dimensions: social, environmental and economic. As expected, the new CAP is strongly aligned with the principles of the European Green Deal with regard to the food chain, aiming to be more responsive to the challenges of climate change and generational renewal, while continuing to support European farmers for a sustainable and competitive agricultural sector. The CAP-Green Deal alignment comes clear from the following shared objectives [ECCAPGD20]:

- Increase the contribution of EU agriculture to climate change mitigation and adaptation.
- Improve the management of natural resources used by agriculture, such as water, soil and air.
- Reinforce the protection of biodiversity and ecosystem services within agrarian and forest systems
- Achieve effective sustainability of food systems in accordance with societal concerns regarding food and health on e.g. animal welfare, use of pesticides and antimicrobial resistance;
- Ensure a fair economic return and improving the position of farmers in the food supply chain.

As another proof of the strong CAP-Green Deal alignment, it should be mentioned the commitment by which Member States will earmark a certain amount of their CAP budget (up to 30%, depending on the CAP Pillar) to be spent on the improvement of climate and environmental performance of farmers.

The following table [ECCAPGD20] summarises the relationship between the specific indicators defined in the new CAP regulation and the Green Deal targets.

Green Deal targets (c.f. F2F and biodiversity strategies)	Impact and Context indicators (c.f. CAP Annex I and secondary legislation)	Output and result indicators (c.f. CAP Annex I)
1. Reducing by 50% the use and the risk of chemical pesticides by 2030 2. Reducing by 50% the use of high-risk pesticides	I.27 Sustainable use of pesticides: reduce risks and impacts of pesticides	R.37 Sustainable pesticide use: share of agricultural land concerned by supported specific actions which lead to a sustainable use of pesticides
Reducing by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030	I.26 Limiting antibiotic use in agriculture: sales/use in food producing animals	R.36 Limiting antibiotic use: share of livestock units concerned by supported actions to limit use of antibiotics
Reducing nutrient losses by at least 50% in 2030	I.15 Improving water quality: Gross nutrient balance on agricultural land	R.21 Sustainable nutrient management: share of agricultural land under commitments related to improved nutrient management
Achieve 25% agricultural area under organic farming by 2030	C.32 Agricultural area under organic farming	O.15 Number of ha with support for organic farming
Completing fast broadband internet access in rural areas reach		R.34 Connecting rural Europe: share of rural population benefitting from improved access to services and infrastructure through CAP support
Increasing land for biodiversity, including agricultural area under high-diversity landscape features	I.20 Enhanced provision of ecosystem services: share of UAA (Utilised Agricultural Area) covered with landscape features	R.29 Preserving landscape features: share of agriculture land under commitments for managing landscape features, including hedgerows

Table 1: Relationship between CAP indicators and Green Deal targets. Source: [ECCAPGD20]

Overall, the new CAP reform introduces major changes that shift the model from compliance and pre-defined rules to results and performance. The new CAP envisages several measures and mechanisms to support such a results-oriented model aligned with the Green Deal:

- Higher use of high-quality data and analysis. Emphasis will be put on developing common approaches to data collection and sharing in order to ensure proper coordination between policies (agriculture, climate, biodiversity, etc.). At the same time, Member States will be obliged to provide the EC with the data necessary to perform monitoring and evaluation of the CAP.
- A new system of conditionality including the implementation of mandatory environmental standards, such as crop rotation, soil protection, or maintaining permanent grassland.
- Voluntary measures, in particular the eco-schemes, an instrument to incentivise farmers to adopt or maintain practices that benefit the environment, climate and biodiversity. The eco-schemes are expected to contribute to the wide take-up of sustainable practices, such as precision agriculture, agroecology (including organic farming) and agroforestry, or carbon farming.

- Stronger support to Agricultural Knowledge and Innovation Systems (AKIS), together with farm advisory services, in order to support farmers in their decision-making related to the most appropriate tools and mechanisms for implementing sustainable farming practices.

The implementation of the required measures will require stronger investments in digital tools and technologies. In addition, Member States will have to prove the implementation of their Strategic Plans and their performance, and how they are reaching their specific target values, which in turn will require new digital monitoring tools and mechanisms [AIOTI19] (for instance, for benchmarking of the effectiveness of new measures such as the eco-schemes).

3. IoT as an enabler of sustainable farming and agroecological practices in the CAP

This section includes several (non-exhaustive) case studies showing the role of IoT solutions on the support of more sustainable farming practices.

Case 1 – Disease prediction and supply chain transparency for orchards/vineyards (a DEMETER Pilot)	
Direct relationship to Green Deal objectives and CAP indicators (c.f. Table 1)	• IoT-enabled spraying equipment can help to reduce the amount of pesticides used.
Other benefits	• IoT-enabled spraying equipment can also document actual pesticide usage, which in turn can be linked to CAP payments.
Maturity level	The solution described is currently in TRL 7/8 and has been deployed in Plantaze (Montenegro) in collaboration with FEDE and DunavNET.
Case study description	
Fresh fruit production is dearly needed to nourish the growing world population, with the World Health Organization (WHO) attributing approximately 1.7 million deaths a year to low fruit, and vegetable intake [WHOFV], while studies highlight the risk of serious food shortages by 2050[3] [GRETHE11], [SIEGEL14]. However, crops are susceptible to pest and disease outbreaks that would cause far over 20% yield loss if not stopped, according to the Food and Agriculture Organization of the United Nations [FAO15]. Unfortunately, conventional farming still relies on applying pesticides based on experience instead of relying on facts/measurements and available prediction models, resulting in suboptimal adjustment of spraying equipment. This leads to usually overusing of pesticides and spray drift, and losses of pesticides into surface waters and the environment, which in the sequel is a serious blow to biodiversity, with now "1 000 000 species threatened with extinction" [UNIPBES19]. Thus, conscious Fruit farmers are desperately longing for a solution that lets them sustainably and environmentally friendly achieve high quality yields, while keeping outbreaks at bay. A solution is offered by IoT systems developed in the EU DEMETER Project [DEMPW], precisely by the pilot "Disease prediction and supply chain transparency for orchards/vineyards" [DEMP20], which focusses on holistic farm management in vineyards and orchards, from providing a decision support system (DSS) for pest and disease management, over machinery control, all the way up to enabling an integer and transparent supply chain. Decision support relies on data gathered from installed IoT devices, which provide inputs into pest and disease prediction models. Therewith the DSS is able to guide farm managers on the right time and place for pesticide usage. Accordingly, Work Orders are scheduled and are wirelessly conveyed to the field operators and IoT enabled field machinery, with an example of a cloud-connected sprayer	

[3] According to the Food and Agricultural Organization of the United Nations (FAO), to meet food demand to feed a global population projected for over 9 billion by the year 2050, a 60% increase in global agricultural production is necessary relative to 2005, http://www.fao.org/home/en/

in Figure 2. Once a Work Order has been executed, results are automatically fed back into the Cloud with precise information on where pesticides have been applied and in which quantity.

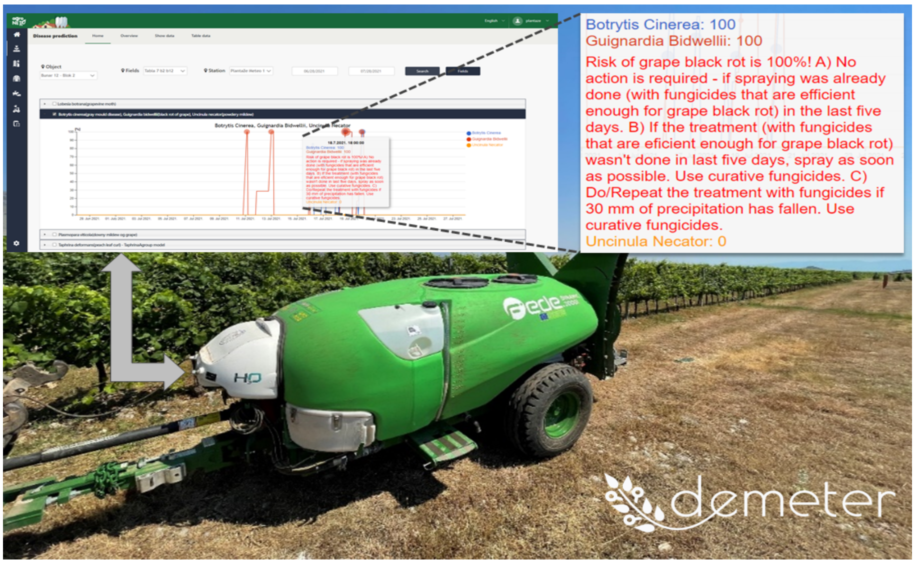

Figure 2: Decision Support System (DSS) and IoT enabled sprayer used in DEMETER Pilot during field tests in Montenegro vineyards

With this information a blockchain-based Product Passport is produced. e.g. to allow traceability, each wine bottle receives its own QR-code, providing different information (e.g. name of producer, production type, pesticide used, transport conditions, advice on product usage). Scanning this QR-code with their smartphones, consumers are able to retrieve bottle specific information, while, if desired, supply chain information can also be shared with retail, certification organizations, or to serve CAP implementation.

The DEMETER Pilot [DEMP20] therewith meets several objectives, on the one hand bringing out pesticides with DSS and high-end machinery (so called Smartomizers as shown in Figure 2) only where and when absolutely required, contributing, thus, to the EUs objective of 50% hazardous pesticide reduction by 2030.

On the other hand, the pilot shows that IoT systems in agriculture are ready to establish supply chain transparency in line with end-consumer demands, retail demands, industry certifications like Global G.A.P., or upcoming CAP requirements.

Moreover, using efficient high-end IoT enabled agricultural machinery has the side effect to also significantly reducing on the amount of tractor fuel and spray water, and is therewith fully aligned with the EU's Green Deal, the Biodiversity and the Farm to Fork strategy, as well as the UN's Sustainable Development Goals in the quest for a sustainable future where "nobody is left behind".

Case 2 – Integrated Plant Protection and decision support systems	
Direct relationship to Green Deal objectives and CAP indicators (c.f. Table 1)	• Information provided through an IT platform gives farmers support for a more sustainable use of pesticides
Other benefits	• Improve sustainable practices by sharing of data across multiple farming domains (e.g. crops and bees)
Maturity level	• The solution described is currently in TRL 7 / has been deployed in PSNC Data Center/Poland
Case study description	

Integrated plant protection is one of the key factors determining the efficiency and quality of agricultural production. Agricultural producers expect efficiency improvement, while society expects high-quality and health-promoting features. Project eDWIN[4] aims at creating a national IT system for plant protection, a system that will significantly affect the quality and quantity of food produced in Poland. The project is supporting the implementation of the EU directive on the obligation to apply the principles of integrated pest management. It aims at rationalizing the use of plant protection products by agricultural producers and supporting decision-making in plant protection by introducing 20 new models (for plants such as wheat, barley, potatoes or beetroot). To achieve that, the project deploys in Poland an IoT network of Agro-meteo stations (upgrading to over 600), equipped with different types of sensors. In addition there are planned automatic observation phenological stations (to be combined with AI image recognition of pests).

As a result of the project implementation, four new e- services will be made available to recipients

- Virtual farm.
- Tracing the origin of agricultural products and plant protection products used.
- Risk reporting
- Sharing of meteorological data

The virtual farm e-service (see Figure 3) is an entry point for a wide group of farmers. The main goal of offered functionalities is to help farmers with planning and management of their plant production, collecting necessary data for reporting and subsidies documentation, while minimizing usage of plant protection products by suggesting only necessary treatments and doses. Users are constantly informed about the presence of both observed threats as well as predicted ones, by the way of pest mathematical prediction models. Moreover, the farmer is able to report own pest observations to alarm other users within the region or to contact his advisors for more information.

[4] https://www.psnc.pl/edwin-project-awarded-at-intelligent-development-forum/

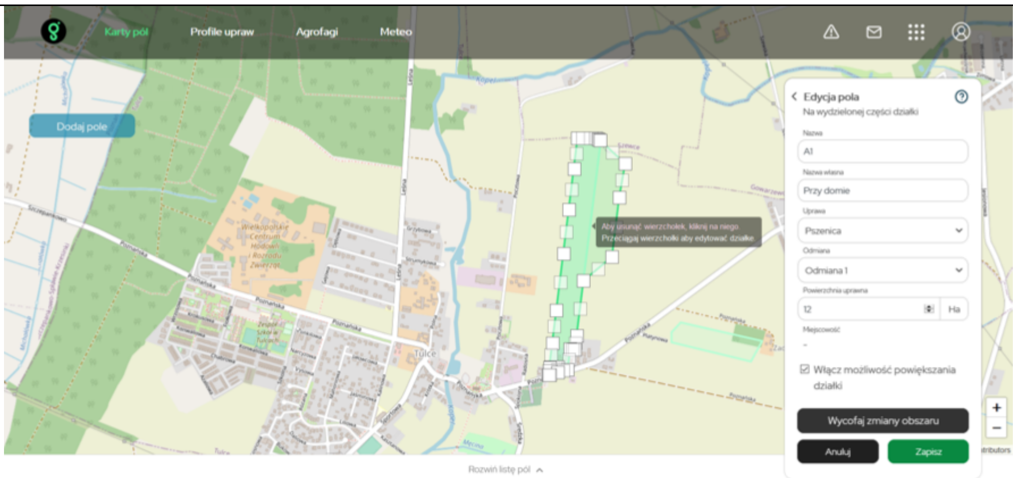

Figure 3: screen capture of the virtual farm e-service of the eDWIN project

eDWIN is aggregating a large number of spatial, meteorological and contextual data that can also be used by other, external e-services such as traceability of food for production batches or public entities. Data sharing is one of the main goals of the eDWIN project. To provide the farmer with knowledge various external information systems have been integrated, such as e.g. plant species and types, plant protection products catalogue, possible plant pest threats. eDWIN also is integrated with the H2020 DEMETER Pollination pilot, the main goal of this integration is to create and establish the common platform for cooperation and to share important information between apiary owners using IoT Apiary Management systems and farmers. This functionality provides farmers with a tool to report a need for pollination. In response, beekeepers may answer with offers, from which farmers may choose the best one. In result, an association between beekeeper and farmer is established in a win-win model in which a farmer is assured that his field will be pollinated, and hives will be placed in the correct spot to collect nectar from appropriate plants, but also in the safe situation for bees (no plant treatment indicated by farmer).

The eDWIN project is coordinated by Wielkopolska Agricultural Advisory Center in Poznań, that invited other partners including the PSNC, the Institute of Plant Protection - National Research Institute, the CDR in Brwinów and the rest of regional agricultural advisory centers (in total 19 partners).

Case 3 – Digitalising the smart agrifood sector in the Balearic Islands	
Direct relationship to Green Deal objectives and CAP indicators (c.f. Table 1)	• IoT to reduce the use of pesticides • IoT to increase the quality of production and ensure the traceability of organic food
Other benefits	• Strengthen the link between agri-food and other sectors such as tourism, contributing to maintain the landscape • Convergence of technologies to increase the digitalisation of the agri-food sector
Maturity level	• The solution described is currently in TRL 7 / has been deployed in Mallorca, Spain
Case study description	

The Balearic Islands' agricultural sector represents less than two per cent of its GDP, but at the same time this sector also manages 85 per cent of the whole land surface. The Balearic Islands base their economic activity on a very busy tourism sector (with a population of one million inhabitants, the Balearic Islands welcome around 16 million tourists a year). The islands' economic, social and environmental sustainability depend on the balance between these sectors (tourism and agriculture). The core idea of "Tourism not being able to exist without Agriculture" finally seems to be leaving a mark on large companies and tourism operators which are starting to look towards the agricultural sector. And this due to several reasons:

- The islands' landscape is a great tourism attraction that is becoming more and more popular and a growing attraction for tourists. It also offers new immersive tourist experiences related to nature and the culinary sector that also attract better quality tourists.
- "Km0" and local products are also becoming more and more popular within the tourism market, but although this is the case, the number of farmers and people working in the agricultural sector is dropping (this is due to a lack of incentives and this sector not being made to look like at attractive career option or young workers)

In this context, the Spanish company Anysolution is participating in two EU projects.

The first project is the use case of the Ploutos European project[5] in the Balearic Islands, that intends to demonstrate how the introduction of innovative technologies could increase the competitiveness of agri-food companies as well as generate synergies between the agri-food and tourism sectors. This use case is deployed in a greenhouse for tomatoes. Sensors are set up inside, outside and on the ground to continuously monitor the greenhouse's different parameters. The person in charge sets up the optimal parameters to maximise production. The sensors send the data to the cloud where it is analysed so that the system takes autonomously the decision to irrigate, to open the windows for airing, etc. Thanks to this digitalization process of the primary sector, we will be able to generate synergies with Mallorca's top driving sector (tourism), linking both activities.

[5] https://ploutos-h2020.eu/

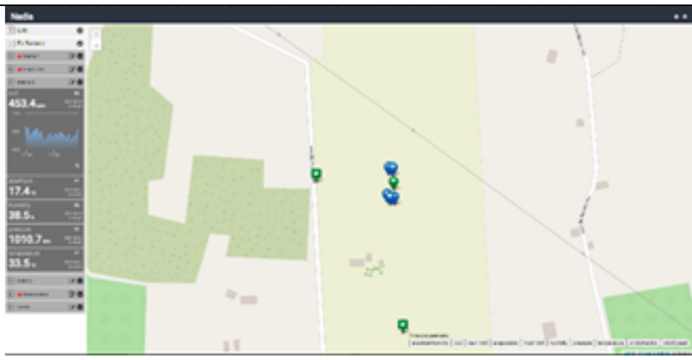

Figure 4: Nadia platform map screen and sensor deployed in the Ploutos project

The generation of synergies is related to the identification of joint activities in the tourism and agricultural fields and other kinds of activities that complement and improve the farmer's role in agri-food value chains and relate their activity with the world of tourism, for example by organising meetings in which the hotel chains visit the agri-food exploitations, or the products use a traceability solution that allows them to fulfil the quality criteria of hotels and restaurants, etc. This pillar will also include all scaling-up activities related to the solutions of the islands' different cooperatives, reaching the farmers' directly as well as showing them what technological developments are available that could improve their productivity and competitiveness.

The second project is CPS4Agri[6]. The participants of the project are AnySolution, Camp Mallorqui (an agri-food cooperative), and Turistec (a Digital Innovation Hub). The goal is to attract and improve digitisation in the agri-food world by applying CPES (Cyber Physical Systems) knowledge with IoT in land of Camp Mallorqui and increase productivity, by being able to quickly detect diseases in crops and manage facilities with autonomous intelligence. Data will be studied to help the system identify crops in danger of catching diseases and automatically warn the platform.

Figure 5: Area for developing CPS4Agri project in almond trees field

An intelligent system designed to automatically act on the crops will be deployed: level 1 for analysis (at the Edge) and level 2 for prevention (through a remote platform). The CPES will be distributed between the autonomous system and the crops, interacting when necessary. Data sources in real-time will help to detect diseases and infestations early. These will also be prevented thanks to data records already collected and the information stored in the system. This will lead to novel concepts

[6] https://dih4cps.eu/experiment-13/

and approaches related to the introduction of CPES and to the combination of local knowledge with data received from heterogeneous sources improving productivity in farming. Cloud and Edge latest disruptive technology is used in both projects. Traditional farming techniques are combined with the latest computer vision and artificial intelligence technologies, joining ancestral and modern techniques.	
Case 4: CAP indicators landscape monitoring	
Direct relationship to Green Deal objectives and CAP indicators (c.f. Table 1)	• ICT mechanisms for data collection and integration in support of Green Deal and new CAP indicators monitoring.
Other benefits	• Support IACS in data collection for subsidies
Maturity level	• The solution described is currently in TRL 6
Case study description	
In recent years, Earth Observation (EO) data products have been introduced for agricultural assessment supporting the collection of environmental and agricultural related variables on a large scale and in an efficient and cost-effective manner. However, EO based monitoring comes with various limitations as it is mainly applicable for large parcels, it is affected by meteorological conditions, and it is not feasible to monitor important sustainability related parameters in detail (e.g., applied chemicals, use of water, yield quantity/quality). In order to mitigate these limitations and given the continuous adoption of ICT and IoT technologies in support of everyday farming activities, it is now feasible to enrich EO data products with farm-level data generated by in-situ data sources. For example, the Digital Farmer's calendar, also called Farm-Book, represents a valuable source of information, as it contains detailed insights on agricultural inputs and outputs. It should be noted that specific type of chemical applications like the recording of the applied pesticides is currently a mandatory process based on Directive 2009/128/EC and should be followed by all farmers. In addition, and given the continuous adoption of integrated systems like Farm Management Information Systems, farmer's calendar records can be escorted by ground-truth digital evidence generated by the use of various agricultural technologies (e.g., logs generated by tractor's navigation services, Variable Rate Application services, soil moisture sensors, integrated pest management services, milking-robots). Within the H2020 NIVA project[7] the "CAP markers and data signals monitoring" tool has been developed which aims to realise landscape monitoring through the collection and integration of heterogeneous agricultural data. The tool follows an interoperable by design implementation approach incorporating as much as possible the use of standards in data exchange processes aiming to realise syntactic and semantic interoperability. The main objectives of this tool are: a) To provide easy-to-use mechanisms for agricultural data collection. The tool offers the necessary mechanisms for individual data providers (e.g., farmers, advisors or FMIS services) to be able to provide, view, update and remove datasets referring to their farms and the applied cultivation practices. b) To make available the collected data from different sources through interoperable APIs in an integrated and controlled manner. The envisioned users of the data collections are	

[7] https://www.niva4cap.eu/

regional administration authorities, IACS officers, CAP monitoring services, National Statistics Office, FADN.

In order to avoid reinventing the wheel – and implement another data platform, defining new data models and APIs - this tool reuses and builds on top of GeoServer (http://geoserver.org/). As it is stated by GeoServer creators: "GeoServer is an open-source server that allows users to share, process and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards". It should be noted that GeoServer facilitates data exchange through the robust OGC standard (WFS/WMS). Data import to Geoserver is realised through a simple RESTfull API called "Geo-Importer". Currently different functionalities are supported for importing and managing farm calendar records, EO data products and (geotagged) photos of the cultivation. However, the data import API is easily expandable to support the management of additional data types. Access control and security mechanisms are implemented as an external service supporting the federation with existing authorization systems, e.g., OAuth.

Data providers can perform view, update and remove operations on their datasets. Figure 6 illustrates the functional components of the "CAP markers and data signals monitoring" tool.

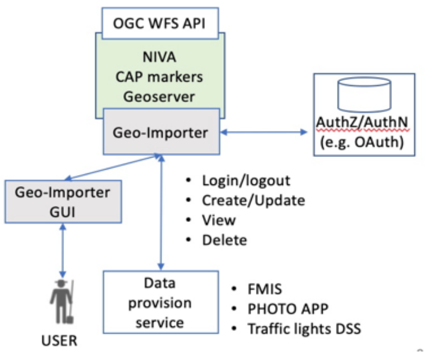

Figure 6. The "CAP Markers and Data signals monitoring" architecture

An additional benefit from the re-use of GeoServer and the respective standard OGC-WFS-WMS is that the same technology is currently utilised by various entities for sharing geographical data. Hence, it is feasible for end users (regional administration authorities, CAP monitoring agencies) to use the "CAP markers and data signals monitoring" tool in a federated manner supporting concurrent distributed queries to various OGC compliant repositories with agro-enviromental related data. Figure 7 illustrates the federated use of GIS systems which are all utilising the OGC standard.

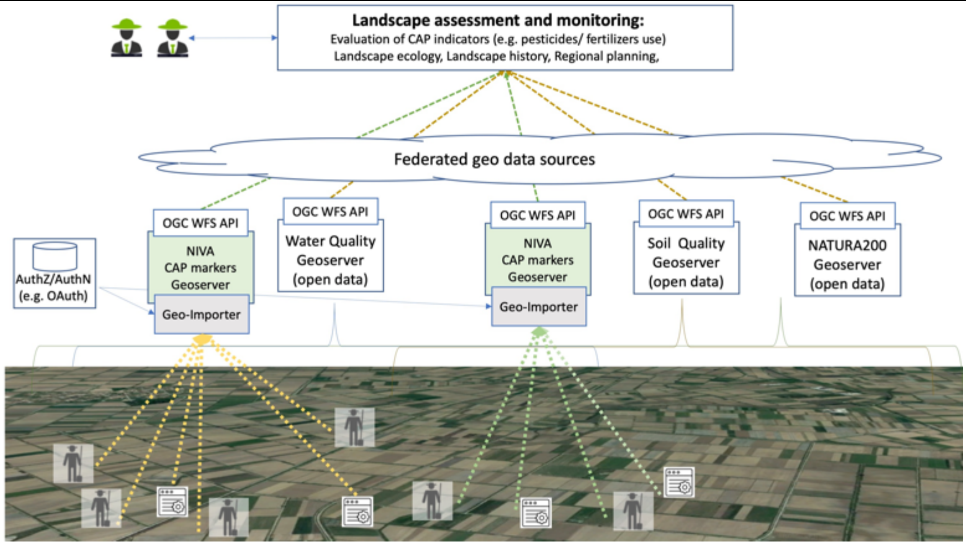

Figure 7. Federated and distributed use of GIS systems in support of landscape monitoring

Categories of landscape information that are of interest for agro-enviromental monitoring and are available in open geographical formats are the following: Surface waters and water courses, Nitrate Vulnerables Zones, Natura2000 Areas, Soil type/quality data, Wildlife sanctuaries, Transportation network, Air and water quality. Some examples of available OGC based GIS systems with open environmental data in EU are provided in the Annex of this document.

The first release of the "CAP markers and data signals monitoring" tool is available here: https://gitlab.com/nivaeu/WP4_cap-markers-data-signals_ogc_api

Currently the tool is under evaluation and testing by various Paying Agencies in the EU in the context of H2020-NIVA project. Based on the received feedback the tool is continuously being refined.

Case 5 – Smart Farming Techniques for Climate Change Adaptation in Cyprus	
Direct relationship to Green Deal objectives and CAP indicators (c.f. Table 1)	• Advice provided through the gaiasense smart farming service can reduce the need of pesticides use
Other benefits	• Reduction of irrigation needs • Reduction of farming ecological footprint
Maturity level	• The solution described is currently in TRL 9, and it is being deployed in Greece, Poland, Spain, Cyprus, and Portugal
Case study description	
It is projected that Cyprus will be highly affected by climate change impacts, such as increased temperature and decreased precipitation which will increase irrigation water demands, reduce yields, and increase soil degradation. These adverse effects might cause considerable loss in agricultural production and income [STYLIANOU20]. Added to these challenges is the fact that the Cypriot agricultural sector still lags behind in terms of the adoption of new smart farming technologies and agriculture digitalization in general, which is a strategic goal of the next	

programming period (2021–2027). The small and fragmented farm holdings, the high input costs (e.g., pesticides, fertilizers, irrigation), the ageing and the low education level of farmers, the absence of skilled workforce, the land degradation and water scarcity, as well as various marketing problems, are only some of the several structural and chronic problems that the Cypriot agricultural sector has to deal with [STYLIANOU20] .

Innovative technologies such as smart farming, are necessary for both adaptation to, and mitigation of, climate change. On this aspect, research in progress (smart farming techniques, telemetric stations, and soil sensors), in crop fields in Cyprus, aims to provide valuable insights applicable to the whole Mediterranean region. One such example, is the pilot entitled "Data-Driven Potato Production (IoT4Potato[8])" which is part of the H2020-IoF2020[9] project.

Among the key innovations of this pilot was the implementation and evaluation of the gaiasense [KALATZIS19] Smart Farming as a Service (SFaaS) solution which is adapted to the southern Mediterranean region and small-scale farmer. Having under consideration the small and fragmented holdings of farmers in southeast Europe and the limited capacity of technological investment, gaiasense follows an innovative approach where the farmer(s) gets an annual subscription with a charging fee which is proportional to the area of their holdings and to the type of farming advisory services that they are subscribed (e.g., pest management, irrigation recommendations, and fertilization optimization). The objective is to support the farmers by taking over the technological investment burden and offer next generation farming advice through the combined utilization of heterogeneous information sources. This approach has the potential to further increase the impact of data-driven cultivation practices by extending the implementation of smart farming technologies in a larger number of farmers covering wider areas of cultivated land.

The gaiasense incorporates a set of information sources that include IoT-enabled agro-environmental sensing stations, Earth Observation services, farmer's digital calendar, and on-the-field observations of the cultivation. The IoT telemetric autonomous stations collect data from sensors installed in the field and record atmospheric, soil, and plant parameters (e.g., temperature, relative humidity, precipitation, atmospheric pressure, wind speed/direction, soil moisture, leaf temperature, humidity, and wetness).

In the context of IoT4Potato the gaiasense system supported the cultivation of potato in 6 fields in Cyprus for two cultivation periods (2019-2020). During the pilot, IoT devices collected time series of environmental, soil, and crop performance data, that were analyzed to forecast and compute recommendations and deliver critical information to farmers in real time. A detailed analysis on the achieved results is available in the scientific article in [ADAMIDES20]. The overall results of the pilot demonstrate a potential reduction of up to 22% on total irrigation needs and important optimization opportunities on pesticides use efficiency. As it is stated in the article there is significant potential for innovations through the use of advanced agricultural technologies that can mitigate climate change effects and help farmers reduce their ecological footprint.

[8] https://www.iof2020.eu/trials/arable/data-driven-potato-farming
[9] https://www.iof2020.eu/

4. Identified gaps and recommendations

The case studies addressed in Section 4 are just a minimum sample among the large number of examples that can be found nowadays on the application of IoT and digital technologies to farming. Actually, all examples provided above are focused on plant farming, but examples can be easily found as well in the animal farming domain, which exemplify the impact of IoT on improving animal welfare, reducing the need for antibiotics, and increase farm productivity. In fact, there is a vast amount of technical literature, reports, etc. describing farming pilots and use cases, and the benefits of IoT in relation to the Green Deal objectives (c.f. Table 1). However (with some exceptions), those studies are still being mostly performed at a qualitative level, hence there is no precise knowledge about the real benefit of IoT on the ecological footprint of farming activity, and more in particular for organic farming.

Recommendation #1: concentrate efforts in quantifying and benchmarking the impact of IoT and digital solutions in the ecological footprint of (organic) farming. A roadmap for "replicable benchmarking" must be established, including the definition of common metrics and methodologies. Given the complexity of the task (long-term testing needed, influence of a large number of external conditions), it is advisable to make the most of computational models and digital twins that can facilitate/accelerate quantification and benchmarking through simulation.

The scientific literature has been focused in showing the positive impact of IoT in farming. However, it is necessary to look at the wider sustainability picture and take into account the full ecological footprint.

Recommendation #2: define a framework for quantifying the full ecological footprint of IoT-based smart farming solutions, taking into account the balance between positive and negative impacts:

1. Positive impact in productivity increase, reduction of pesticides, fertilisers, etc.
2. Negative impact of ICT technology: AI models training and blockchain (high computational/energy cost), IoT devices lifecycle including electronic waste, etc

Many of the objectives set out in the Green Deal are quantitative by definition: % use of pesticides, antimicrobials, antibiotics, nutrient losses, water quality… Likewise the CAP objectives, especially those related to environmental performance, require measurement tools/mechanisms which are either not yet (widely) deployed or do not have yet a clear implementation. Monitoring technology is crucial to support policy makers and advisors to collect the necessary information items in order to design and monitor agro-environmental related policies.

> **Recommendation #3:** Strengthen the investments to develop, pilot and validate at large scale digital tools and technologies to enable reliable (and certified) monitoring and measurement of target parameters and environment indicators ("digital evidences"). Research on agricultural IoT should also focus on developing robust solutions for recording -on a farm level- environmental related parameters and indicators that are affected by agricultural activities e.g., population and type of pollinators in agricultural land, soil fertility, quality of air and water.
>
> Those data items should be feasible to be combined with existing environmental data repositories in order to achieve area-based environmental monitoring.

Since all the potential improvements brought by IoT-based smart farming will be data-driven, data issues like data sharing or systems interoperability must be addressed before reaping the full benefits.

> **Recommendation #4**: promote the use of interoperability mechanisms and accessibility of data, e.g.
>
> 1. Use of existing data standards (c.f. Case Study #4)
> 2. Re-use of geo-tagged open data (c.f. Case Study #4).
> 3. Creation of data spaces to facilitate the access and sharing of data, as well as other useful resources like validated AI data models.

Farmers are being pressed to implement more environment-friendly agricultural practices, in particular to comply with the new CAP regulation. Both improving the environmental performance and proving it is something that will require the adoption of digital technologies. However, farmers and other agri-food stakeholders usually are not aware of smart farming solutions existence or believe that they are too expensive, do not trust them yet, lack the (digital) skills to follow them, and most of them lack investment capability because of the small size of the family farms, which account for the majority of the agricultural holdings in Europe. This bottleneck in technology adoption will hinder the expected benefits of IoT technologies in farming.

Recommendation #5: implement actions at a large scale to facilitate the adoption of IoT technology in farming

1. Raise awareness at large, reaching out to farms of all sizes, in particular to small family farms. Design schemes involving intermediary agents (advisors, cooperatives, etc.) to reach the whole community.
2. Make the business cases and ROI (Return On Investment) clear to all stakeholders (esp. end users).
3. Design public-private mechanisms (including Digital Innovation Hubs and Testing&Experimentation Facilities) to facilitate the testing, benchmarking and subsequent adoption of digital solutions.

On a more general plane, the low degree of digitalisation of farming and the lack of connectivity in rural areas are important issues that must be addressed before advanced solutions can deliver any positive impact.

Annex – Examples of available OGC-based GIS systems with open environmental data in the EU

1. European Drought Observatory - https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1160
2. Natura2000 areas in Greece - https://geodata.gov.gr/en/dataset/to-diktuo-natura-2000-kai-prostateuomenes-periokhes/resource/e5245870-f99b-453c-b42f-a416bd882f05?inner_span=True
3. Wildlife sanctuaries in Greece - https://geodata.gov.gr/en/dataset/kataphugia-agrias-zoes/resource/ab1fd2f3-7658-44cf-874c-d0d6314b69fe
4. National Parks & Wildlife Service in Ireland - http://webservices.npws.ie/arcgis/services/NPWS/NPWSDesignatedAreas/MapServer/WMSServer?request=GetCapabilities&service=WMS
5. Open Data WMS of the Finnish Meteorological Institute - http://openwms.fmi.fi/geoserver/wms

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About AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT Innovation in Europe, bringing together small and large companies, start-ups and scale-ups, academia, policy makers and end-users and representatives of society in an end-to-end approach. We work with partners in a global context. We strive to leverage, share and promote best practices in the IoT ecosystems, be a one-stop point of information on all relevant aspects of IoT Innovation to its members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of IoT Innovation in society.

AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies. We also put them in practice in vertical application domains with societal and economic relevance.

AIOTI is a partner for the European Commission on IoT policies and stimulus programs, helping to identifying and removing obstacles and fast learning, deployment and replication of IoT Innovation in Real Scale Experimentation in Europe from a global perspective.

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