Alliance for Internet of Things Innovation

IoT and digital technologies for monitoring of the new CAP

AIOTI WG06 – Smart Farming and Food Security

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Introduction

As part of its ongoing move to simplify and modernise the EU's Common Agricultural Policy (CAP), the European Commission is adopting new rules that will for the first time expressly allow a range of modern technologies to be used when carrying out checks for area-based CAP payments. This includes the possibility to completely replace physical checks on farms with a system of automated checks based on analysis of satellite-based data in combination with Internet of Things (IoT) and other digital technologies.

The present paper addresses this topic from the perspective of technical feasibility. An overview of the most relevant experiences, recently finished or ongoing, is provided, as a good basis on which further implementations in Europe can be built. Key considerations and recommendations for the future are finally presented.

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1. Overview of the strategic importance of digital technologies in CAP post-2020

As many other industrial sectors in Europe and globally, agriculture is undergoing a profound transformation where digital technologies play an essential role. New technologies, and ICT technologies in particular, are crucial for European farmers to address climate breakdown while optimising farm income, making farming more sustainable while competing in dynamic global markets. These are indeed objectives which are pursued by the European Commission with the current revision of the EU's Common Agricultural Policy (CAP).[1] In particular, the new CAP pursues the following specific objectives:

1. Support viable farm income and resilience across the EU territory to enhance food security;
2. Enhance market orientation and increase competitiveness including a greater focus on research, technology and digitalisation ;
3. Improve farmers' position in the value chain;
4. Contribute to climate change mitigation and adaptation, as well as sustainable energy;
5. Foster sustainable development and efficient management of natural resources such as water, soil and air;
6. Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes;
7. Attract young farmers and facilitate business development in rural areas;
8. Promote employment, growth, social inclusion and local development in rural areas, including bio-economy and sustainable forestry;
9. Improve the response of EU agriculture to societal demands on food and health, including safe, nutritious and sustainable food, as well as animal welfare.

As recognised by the European Commission, *"a smarter, modernised and more sustainable CAP needs to embrace research and innovation, in order to serve the multi-functionality of Union agriculture, forestry and food systems, investing in technological development and digitalisation, as well as improving the access to impartial, sound, relevant and new knowledge."*

[1] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans) [...] https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-cap-strategic-plans_en.pdf

The proposed CAP reform puts a strong emphasis in the role to be played by digital technologies to deliver the objectives above. Member States are required to devise and describe their strategies (in a "CAP Strategic Plan") for the development and use of digital technologies (in particular, smart farming) in agriculture and rural areas, in order to improve the effectiveness and efficiency of the CAP Strategic Plan interventions.

One of the key aspects where digital technologies are expected to make significant impact is in the modernisation of the policy implementation and the simplification of CAP support. The present paper focuses on one particular aspect: the use of digital technologies for monitoring area-based CAP payments, including the possibility of completely replacing physical checks on farms with a system of automated checks based on analysis of Earth observation data (in particular from Copernicus services) in combination with EGNOS and Galileo-based solutions, as well as other digital technologies.

2. Monitoring controls for area-based CAP payments

In order to have an idea of the dimension of the resources involved in the area-based CAP payments in Europe, here are some rough numbers:

- The utilised agricultural area (UAA) in the EU-28 amounts to almost 175 M hectares (about 40% of the total land area).[2] This is the surface subject to payment and controls.
- The total amount paid by the Paying Agencies is about 55000 M€ / year.
- Seven million farmers benefit from area-based CAP payments.

Those payments are performed on the basis of the data reported by the farmers, through a usually cumbersome process, which is labour-intensive and disproportionately impacts small/medium sized farms. It involves filling in off-line or on-line forms, which are subsequently revised by the Paying Agencies. The reported data, which is checked by the Paying Agencies, comprises among others:

- Measurement of admissible agriculture areas
- Verification of crops presence and/or livestock activity
- Counting of animals, hives, etc.
- Usage of phytosanitary products

These verifications are currently performed either by manual inspection (i.e. on farm) or by means of remote sensing technology relying on satellite and/or aerial imagery, always following the guidelines of the European Commission[3]. In the latter case, whenever the remote sensing data is of insufficient quality to verify compliance, on-farm inspections are performed.
It is interesting to note that in certain European regions inspections are still performed 100% on farm, usually by sampling a percentage of the total "inspectionable" land area.

Performing checks which are correct and accurate is of utmost importance in order to properly avoid full audits, and avoid financial corrections or penalties.

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[2] Eurostat. Agriculture, forestry and fishery statistics – 2013 edition. https://ec.europa.eu/eurostat/en/web/products-pocketbooks/-/KS-FK-13-001
[3] https://marswiki.jrc.ec.europa.eu/wikicap/index.php/Main_Page

3. Technical feasibility of automating monitoring through IoT and digital technologies

The new rules adopted by the European Commission, which came into force on 22 May 2018, will allow the data from the EU's Copernicus Sentinel satellites and other Earth observation data to be used as a primary evidence when checking farmers' fulfilment of requirements under the CAP for area-based payments (either direct payments to farmers or rural development support payments), as well as cross-compliance requirements, such as stubble burning. Other new forms of evidence will also be acceptable for the first time, as part of a broader shift towards a so-called "monitoring approach" that will lead to a decrease in the number of on-farm checks. These additional types of evidences include geo-tagged photos, information captured by drones (e.g. aerial imagery), and other digital data owned by the farmer (suitable for use for reporting purposes), such as:

- Data provided by automatic guidance systems with very high accuracy (less than 10cm) GNSS-based positioning or with RTK correction with 2 cm accuracy. This allows the creation of highly accurate field boundaries.
- Data provided by modern harvesting equipment which creates yield maps that are automatically uploaded to the cloud and can easily be shared with paying agencies. This data includes not only the area, but also the yield and which crop has been grown.
- As-applied digital maps of seed, fertilizer or pesticides are other highly accurate sources to prove the crop that has been grown and the field size.

Under current CAP rules, EU member states are currently required to carry out a number of checks on farms as part of the Integrated Administration and Control System, as a way to minimise the number of errors when delivering the payments made to the farmers. The move to a more widespread use of remote sensing technology and evidences obtained by digital means will significantly reduce the number of field inspections, which will only be necessary when the digital evidence is not sufficient to verify compliance. Several Member States have already indicated their intention to immediately start benefitting from the possibilities offered by digital technologies. It will benefit public administrations by reducing the costs of monitoring controls and checks, and also the farmers, by reducing the burden of the reporting process and avoiding subsequent on-farm checks. Several EU regions have already set out initiatives in this direction.

- In Spain and, in particular, Galicia, the regional Administration is fostering the use of Unmanned Aerial Vehicles (UAVs) and digital technologies such as remote sensing, image analysis, and big data to automate farm checks and exploit the collected data for an almost continuous monitoring of the exploitations resources, allowing a better decision making with higher precision, optimize crop yield, make predictions about the future to prevent the spread of pests and diseases.
- In Denmark, the objective of the paying agency is to completely eliminate by 2020 physical inspections for the requirement of agricultural activity, i.e. sowing, ploughing, harvesting etc. on arable land, and at least yearly grass cutting in areas with grassland and fallow land. Full monitoring of the basic payment scheme is starting to be introduced in 2019, still complementing it with physical inspections.
- Austria is currently running a pilot in the Austrian paying agency on automated area classification based on satellite imagery in different test regions called "automated detection of alpine forage area" to enhance the pro-rata-system for areas covered with trees or bushes. In a first approach (2017-2018) seventeen test regions were analysed based on PlanetScope data,[4] as well as the whole area of Austria based on Sentinel 2 data[5].

The benefits of this approach will be multiplied if this data collection process occurs in synergy with other digital technologies, such as crop monitoring and yield forecasting, bringing greater efficiencies to farms.

Recent advances in Artificial Intelligence and Machine Learning -especially, with the widespread use of Deep Learning- permit the automatic segmentation of farms, classification of the type of crops, and even the detection of objects/structures from aerial imagery, all of which provide data relevant for measuring, determining payments to the farmers and performing additional monitoring checks.
For example, using commercial UAVs, images with a resolution around 10cm/pixel can be acquired, and such resolution has been proven to be enough to detect most types of crops and to meet the requirements needed by the EU´s Common Agriculture Policy (CAP).

The potential benefits are clear but it is important to understand the potential technological limitations, along with the respective imposed requirements. The following list identifies the most crucial points.

[4] https://www.planet.com/products/planet-imagery/
[5] https://www.copernicus.eu/main/sentinels

1. Accuracy and measurement tolerance

Accuracy of the monitoring is a key parameter to ensure both compliance and trust in the system, and this depends to a large extent (but not only) on the accuracy of spatial measurements. The combined use of certain technologies, such as EGNOS[6] (for augmentation of geolocation accuracy) can help to overcome limitations related to positioning accuracy. However, another potential limitation comes from the resolution offered by current Earth observation technology. The free images offered by the Copernicus program through the Sentinel satellite constellation fulfil in many cases the requirements for performing the checks with the required accuracy, but in certain European territories the size of the parcels to be monitored is quite small, as witnessed by the recent experience in the Austrian pilots mentioned above. To overcome this limitation, other imaging sources would be necessary:

- The use of commercial satellite imagery with higher resolutions. Indeed, in the Austrian case a countrywide classification is planned for 2019 on the basis of PlanetScope data as well as on Worldview data[7] in several regions.
- The use of UAVs for obtaining aerial imagery, as is being done in the Galician case.

However, the viability of these alternatives will greatly depend on the costs compared to classical inspections, and also on the regulations regarding the use of drones in non-segregated air space. Progress is being made in both directions, as witnessed by recent trials in Europe.[8]

On the side of field equipment/devices, especially those with a yield monitor or crop/soil/water sensing device, calibration is needed to get accurate results. Calibration is usually done in the field before the work is started. If the machine or measurement device is not set up properly, data will be skewed. While automatically calibrating systems are available, in most cases the calibration is a variable that has to be managed. Data from measurements involving calibration have to be treated in an appropriate way.

2. In relation to Machine Learning technologies

To build machine-learning expert systems, specially deep neural network-based engines which are able to accurately segment farms, classify crops, etc. it is mandatory to take into account the following requirements: 1) Large datasets are needed, 2) these datasets should be representative of the problem at hand, 3) creating these datasets requires experts who provide accurate manual annotations (labels) for the training data, and 4) those experts should be familiar with the EU´s Common Agriculture Policy context.

[6] https://www.gsa.europa.eu/egnos/what-egnos
[7] https://earthdata.nasa.gov/worldview
[8] https://www.vodafone.com/content/index/media/vodafone-group-releases/2018/mobile-tracking-and-control-technology-for-long-distance-drone-flights.html

If these requirements are not met, the neural network will be trained on incomplete or "wrong" data and results will not be as accurate as it could be expected. For instance, in the task of aerial image analysis for crop classification, this involves having a "training dataset" of aerial images where, ideally, each pixel should have been manually labeled with the type of crop it represents, which is a highly time-consuming task. It is expected that curated open datasets can be available soon for that purpose, as a result of on-going work in Europe. Moreover, available data platforms (e.g. Copernicus WEkEO DIAS[9]) should be considered for exploitation by the agriculture digital ecosystem to efficiently perform analytics and machine learning on very large volumes of data.

3. Semantic Interoperability

There is an obvious need to formulate with common semantics the digital evidence collected by a farm that will be shared with the Paying Agencies. Given the heterogeneity of the deployed smart farming technologies (e.g. farm management information systems, farm machinery systems, intelligent decision support systems, environmental monitoring platforms) it is expected data will be expressed with diverse custom information models particular to each proprietary platform. In addition, protocols currently utilised for exchanging these data are also not following a common approach (e.g. for the processing of satellite imagery). To this end, there is a need for the definition of common and if possible standardised syntactic and semantic information models along with the appropriate technological tools (e.g. data translators) that will act as interoperability enablers. However, information modelling approaches tailored to the agricultural domain are still somewhat fragmented while standardisation efforts are not yet given enough visibility.

Apart from the data generating side, also parties on the receiving side have to be ready for complying with standards. Otherwise, not only technology providers would need to multiply their efforts in supporting multiple methods to report data, but it would also make reporting more prone to errors, with higher difficulty to implement quality controls and data alignment for consistent interpretation. Thus, the collaboration of the different stakeholders is mandatory to develop ontologies and smart data exchange mechanisms.

4. Seamless integration

Existing smart farming deployments tend to be complicated by including various customised engineering approaches. It is not realistic to expect that already deployed proprietary smart farming solutions to radically change their mode of operation in order to adapt to the changes imposed by the desire of digital evidence sharing. Hence it is the interoperability enabling solution that need to be versatile and easy to adapt to the legacy systems applying Plug-n-Play technologies and light-weight software components with standard interfaces. This also relates to the issue of semantic interoperability mentioned above.

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[9] https://www.wekeo.eu/

5. User acceptance of technological solutions

A common challenge that needs to be addressed in the years to come is to keep a balance between deploying technologies for monitoring every-day farming activities and these mechanisms being considered as hostile and out of farmer's control. End-users' acceptance and familiarisation with the employed smart-farming technologies being used is a crucial requirement that affects not only the successful realisation of the new CAP's procedures, but it is also a key enabler towards the digitisation of the agriculture in general, especially in a EU context with an aged farmers' community. A key limitation that needs to be addressed is that relatively complicated procedures related with the overall operation of the deployed monitoring solutions need to be interfaced to the end users in a simplified and efficient way as much as possible, leveraging also on support to enhance the digital skills of farmers. For user acceptance it is important that the farmer can see and feel the benefit of new means of control in the form of simpler rules, smarter rules, more guidance etc.

Another issue to be considered is the affordability of the digital solutions. For the farmer any new technology to be used means an investment which has a cost. Typically the greatest economic difficulties to access flagship equipment with all the data features will be for small and medium-sized farmers.

6. Information flow control and privacy protection

Advances on sensing technologies and data collection mechanisms make feasible the deployment of vast monitoring networks capable to record and process sensitive information elements endangering the confidentiality of personal and/or financial interests and that even can potentially violate established regulations (e.g., GDPR). Smart farming platforms and monitoring technologies must enable and facilitate trusted and secure sharing based on automated and robust controls evaluating the legal rights protection of data owners.

The data receivers need certainty that the data is captured using the right methods and that the data during the following processing flow is not tampered with. Specific methods to ensure the right implementation of the EU Code of Conduct on agriculture data sharing by contractual agreement are necessary.

7. Connectivity and the digital divide

Good infrastructure, services and high-performance broadband are crucial for the uptake of ICT and IoT technologies in rural Europe. According to the latest European Commission study on broadband coverage in Europe, although 92.4% of rural EU homes had access to at least one fixed broadband technology in mid-2017, less than 50% (46.9%) had access to the high-speed connectivity that is necessary to enjoy the benefits of next generation e-services. The situation nowadays is that still there are many rural areas where broadband connectivity is minimal or poor, and this is true even in the wealthier EC states.

While satellite images may be easily obtained by remote EO, drone images may be difficult to transmit if locally produced, or farmers may not benefit from this kind of EO and thus object to the adoption of this technology. Emerging technologies, like Narrowband-IoT,[10] should be considered for filling the existing gap of cost-effective connectivity solutions for rural areas. In any case, limited ease of access for data upload will be a major impediment for the deployment of these technologies in an effective manner.

[10] https://www.gsma.com/iot/news/smart-agriculture-nb-iot/

Furthermore, CAP monitoring via remote sensing or direct data collection will need to avoid creating a digital divide between those farmers who benefit from reduced costs for monitoring and those who for reasons outside their control do not have access to appropriate technology including uplinks.

4. Overview of related projects and initiatives

The automation of CAP monitoring controls has been gaining attention during the last years not only at the European policy level but also by the innovation ecosystem. Although the number of related experiences is still quite low and with a limited exposure, there are a few initiatives worth to mention.

4.1. RECAP

RECAP is a commercial platform supporting Paying Agencies (PAs), Agricultural Consultants & Advisors, as well as Farmers to respond to the CAP monitoring challenges. It was developed by DRAXIS Environmental (GR) in close collaboration with end users, within H2020 funded project RECAP—Personalised Public Services in Support for the implementation of the Common Agriculture Policy (CAP), Grant Agreement 693171.[11] The platform builds upon different components (as presented in Figure 1) integrating satellite remote sensing and user-generated data (admin data; geotagged and timestamped photos, etc.) into added value services for a cost-efficient, transparent and reliable remote CAP monitoring.

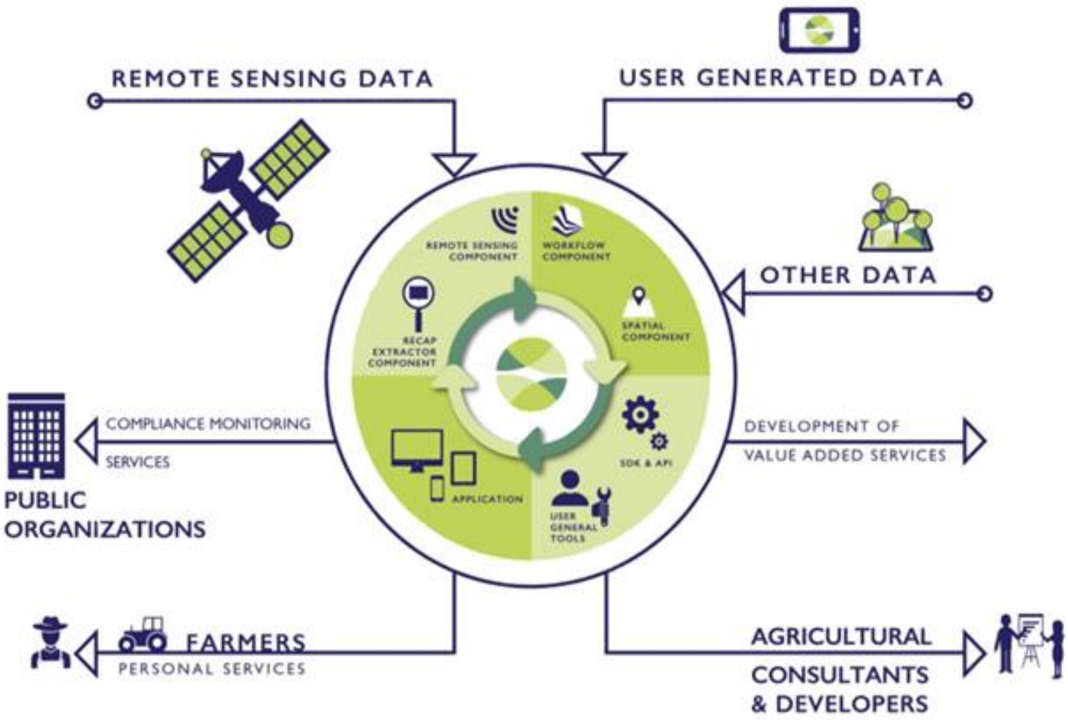

Figure 1: RECAP digital components

[11] https://www.recap-h2020.eu/

Through the combination of advanced manual and fully automatic hybrid Earth Observation techniques and user-generated data, RECAP has achieved to offer a remote compliance control system supporting PAs to increase the effectiveness of risk-based analysis, and reduce overall cost, time and admin burden for the CAP monitoring. The RECAP Remote Sensing (RS) methodology is founded on the accurate crop type classification via machine learning application on a time-series of combined Sentinel-2 imagery and relevant vegetation indices. The monitoring of compliance algorithmically addressed, covers the following requirements for Greening and Cross Compliance: Greening 1 – Crop Diversification; Greening 2 – Permanent Grassland; GAEC1 – Buffer Strips; GAEC 4 – Minimum Soil Cover; GAEC 5 – Minimising Soil Erosion; SMR 1 – Reducing water pollution in Nitrate Vulnerable Zones (VNZs) and GAEC 6 – Maintaining the level of organic matter in soil. The RS component comprises of three principal processing chains, namely the crop type mapping, the runoff risk analysis and the identification of stubble burning. The relevance of the developed RS solution to the CAP monitoring challenge is essentially relied on the accuracy of the crop type classification. A traffic light system is introduced, enabling a smart sampling approach for targeted inspections. The RS component has been pilot tested in 3 sites (Greece, Spain, Lithuania) showing an overall accuracy higher than 85% (validated results) for the discrimination among 8 to 11 different crop types (depending on the pilot case) that explain more than 90% of the different pilot sites.

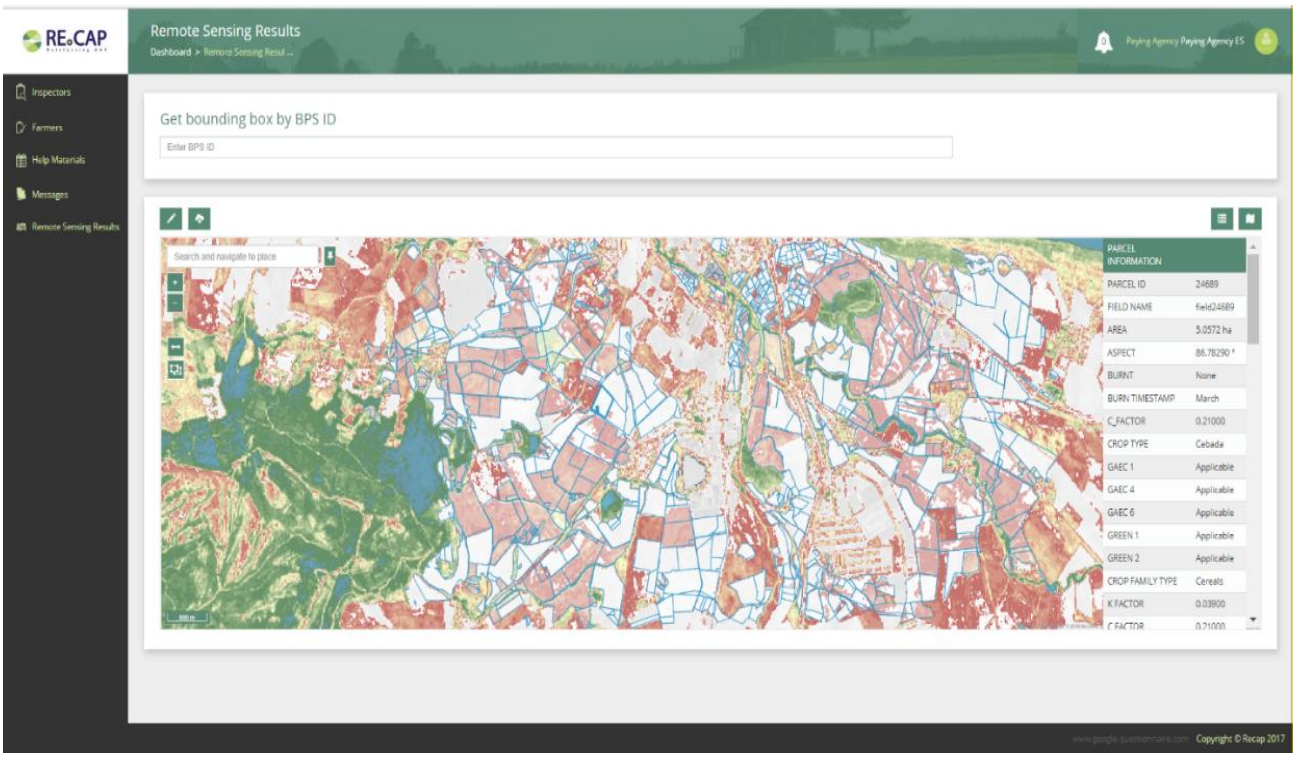

Figure 2: Paying Agency view of Remote Sensing results in the region of interest, with the relevant parcel information.

Through RECAP farmers are provided with a system of personalised services responding to their individual needs and farm characteristics. It is based on workflows, checklists and personalised alerts, transposing complex CAP rules applying to each farm's specific characteristics, to an easy to understand guidance ensuring farmers' compliance. Such collaborative approach also encourages proactive participation of farmers in the overall monitoring procedure, giving them an active role in the data collection process, enhancing close communication and cooperation with public administration. This innovative framework sets up a monitoring system that informs, guides and notifies farmers on their obligations towards the CAP rules, instead of penalising them for non-compliance when inspections take place. Additionally the RECAP platform works as a repository of data for farmers (as well as inspectors; platform users), where they are able to store data, records, and documents to which they can have continuous access within a secure and transparent framework and will be In position to obtain or retain during an inspection. Further, complementary user generated data can be uploaded to the platform by farmers (same for inspectors and agr. consultants; advisors) that could be used to rectify non-compliance, or prevent such a case occurring in the future, or seek assistance on specific issues.
The RECAP platform stimulates the development of new added-value services by agricultural consultants and developers, allowing them to create add-ons to the main platform and make use of the data collected. Provided with the Software Development Kit, developers are offered certain functionalities allowing them to search and use data stored in the RECAP platform; to integrate search results into their applications supporting farmers' claims; as well as to manage RECAP configuration and objects. In overall RECAP is facilitating the day-to-day work of agricultural consultants and extension services to provide valuable e-advice to farmers.

The RECAP services are provided through a web cloud-based Software as a Service platform (provided under public licence), as well as a mobile and tablet application. There are two mobile interfaces developed; a smartphone optimised interface dedicated to the farmers' needs and another one focusing on the inspectors' needs. The mobile application is mainly for the data collection on the farmer's field either from the farmer or from the inspector during on-the-spot checks. An offline mode has been integrated within which all data collected will be uploaded to the RECAP database once connected to the Internet.

4.2. Advanced Platform for Intelligent Inspections

The **Advanced Platform for Intelligent Inspections** (APII) is a technological solution in development by a partnership between two companies (Seresco,[12] Proyestegal[13]) and a RTO (Gradiant[14]), under the framework of the PRIMARE programme[15], a Public Procurement of Innovative solutions (PPI) by the Galician Agency for Technology Modernisation (AMTEGA[16]) in cooperation with the Galician Ministry of Rural Affairs, in the context of improvement of the CAP management based on the use of digital technologies. The development and validation are expected to be completed by the end of 2019.

The APII proposes a change of paradigm in the way CAP controls are carried out by providing a set of tools that dramatically improve performance and reduce costs over existing approaches, introducing the highest degree of automation to all processes involved in CAP management, from the request of inspections to the execution and supervision of controls. The area of application of the APII is Galicia, Spain, where the area subject to CAP controls amounts to 650.000 hectares.

The APII ingests and processes data from different sources, encompassing:

- High-resolution imagery (resolution around 50 cm): high-resolution satellite imagery (such as Worldview or GeoEye) and UAV imagery acquired with different payloads: RGB, multiespectral, LIDAR and different camera configurations (nadir, oblique).
- Open data from the Copernicus program (Sentinel-2 imagery), PNOA (Aerial Ortophotography National Plan) and Cadastral Information.

The integration of all the above data sources allows for accurate collection and documentation of evidences over a certain area, thus ensuring reliable results for CAP inspections, bringing to a minimum the number of required field visits and making the whole process more transparent.

[12] https://seresco.com/en
[13] http://www.proyestegal.com/
[14] https://www.gradiant.org/en/
[15] https://amtega.xunta.gal/es/programa-primare
[16] https://amtega.xunta.gal/

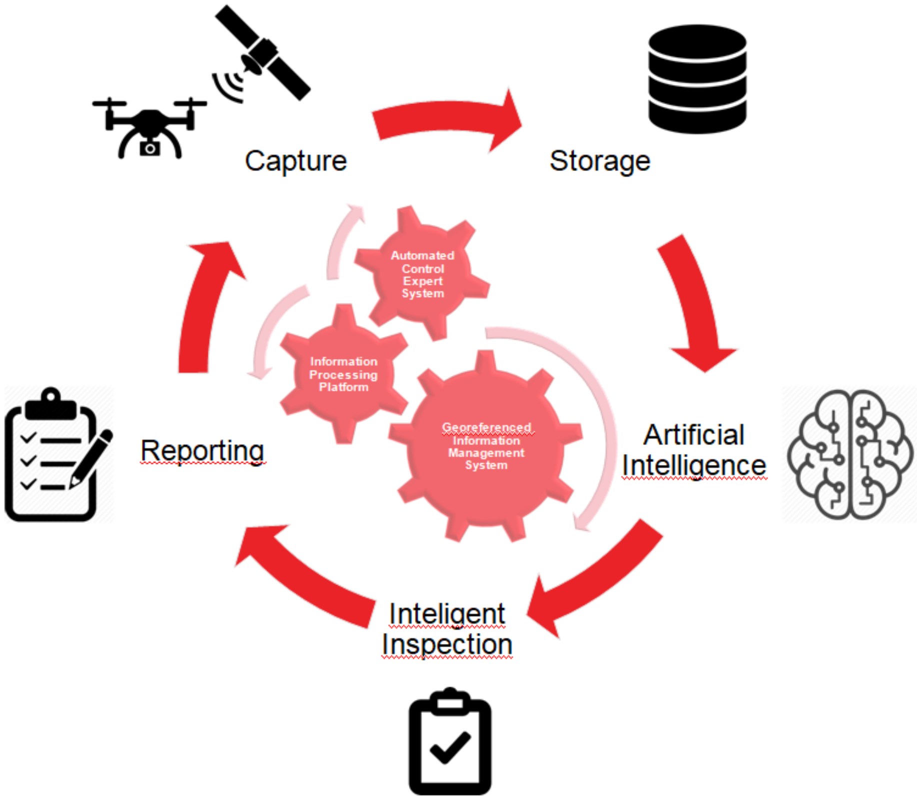

Figure 3: Advanced Platform for Intelligent Inspections

The APII is a modular system formed by three different subsystems working together, as illustrated in Figure 3:

- A **Georeferenced Information Management System (GIMS)** which is responsible for both the capture and storage of the data required for the inspections.
- An **Information Processing Platform (IPP)**, which is where the data acquired by the GIMS module is processed for classification. The IPP will be capable of classifying more than 10 different crop types, including grassland, shrub grass, wooded pasture, corn, raygrass, vineyard, potatoes and fruit trees. Types of agriculture activity supported by the classifier are grazing, mowing, land-clearing and cultivation. The IPP will also be capable of identifying landscape features such as hedgerows, group of trees, fields margins lower than 10 meters, ponds and lagoons, stone walls, and isolated trees.
- The final module, the **Automated Control Expert System (ACES)**, is a decision support and analysis system and, as such, is responsible for carrying out the intelligent inspection of the farmers' fields, verifying compliance with the requirements of EU's Common Agricultural Policy (CAP).

The Advanced Platform for Intelligent Inspections will provide the Public Administration with accurate information for the automation of processes related with the EU's Common Agricultural Policy (CAP) thus facilitating decision making. The platform will benefit farmers too, as requests will be dealt with faster and with less room for error. Moreover, it will provide both the administration and the farmers with very valuable information on agricultural holdings such as that included in maps associated to fertilization needs, which will help in continuous and remote monitoring farming activity

Beyond CAP subsidies, the APII platform also enables tools for management and monitoring of agricultural and farming activities, as well as for forestry monitoring. This is the case of a web application that will be made available to farmers for helping them in decision making that will result in greater efficiency and cost reduction. One of the functionalities provided by this application will be the generation of advices for the most suitable irrigation and harvesting times, based on the observation of the crops.

4.3. Gaiasense and the H2020 DataBio Big Data Lighthouse project

Gaiasense[17] is a technological solution, developed and operated by NEUROPUBLIC S.A.[18], offering a range of innovative smart farming services which, among others, are contributing to the realisation of the proposed CAP reform. As illustrated in Figure 4 the gaiasense solution implements a holistic approach which combines data collected directly from the field by stationary IoT environmental monitoring sensors along with earth observation images from aerial (UAV) or in-orbit platforms. Additional information sources are incorporated such as weather forecasts and field information provided by the farmers and advisors. gaiasense solution is currently deployed in 26 pilot sites in Greece covering > 60.000 ha and 17 different crops, offering services on fertilisation, irrigation and pest management/hazard warnings to 15.000 Farmers.

[17] http://www.gaiasense.gr/en
[18] https://www.neuropublic.gr/

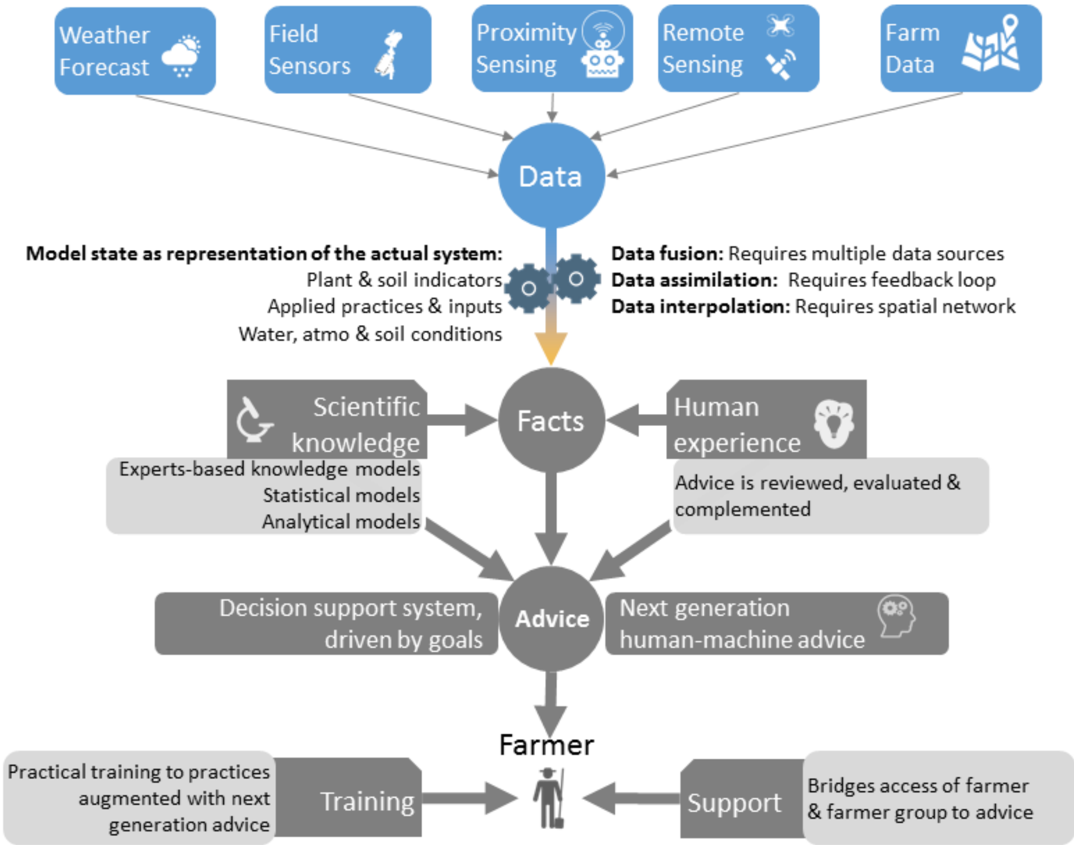

Figure 4: The gaiasense workflow

Under the umbrella of the H2020 Big Data Lighthouse project DataBio[19], NEUROPUBLIC and GAIA Epicheirein have launched a highly ambitious pilot in Northern Greece in an area covering 50000 ha, targeting towards the evaluation of a set of EO-based services designed appropriately to support specific needs of the CAP value chain stakeholders. The pilot services rely on innovative tools and complementary technologies that will sustain the interconnection with IoT infrastructures and EO platforms, the collection and ingestion of spatiotemporal data, the multidimensional deep data exploration and modelling and the provision of meaningful insights, thus, supporting the simplification and improving the effectiveness of CAP. The gaiasense smart farming solution has a key role towards the realisation of this pilot as it provides the appropriate means for combining EO data analytics outcomes with field data derived by IoT information sources.

The ambition of the launched DataBio pilot is to deal effectively with CAP demands for agricultural crop type identification, systematic observation, tracking and assessment of eligibility conditions over a period of time. The pilot activities are fully aligned with the main concepts of the new agricultural monitoring approach which will effectively lead to fewer controls, will facilitate and expand the adoption of technology to the farmer communities, will promote the penetration of EO deeper into the CAP line of business and raise the awareness of the farmers, agronomists, agricultural advisors, farmer cooperatives and organizations (e.g. groups of producers), national paying agencies on how new technological tools could facilitate the crop declaration process.

[19] https://www.databio.eu/

Towards that direction, the pilot provides EO-based services that support key business processes including the farmer decision making actions during the submission of the "Greening" aid application (proactive control). The basic use case scenario involves batch processing after the declaration period closes and protects the farmer in order to receive the payment. The farmers that could benefit from the methodology are the ones holding parcels of > 10 ha that are eligible for checks for "Greening" requirements related to crop diversification.

A series of steps comprise the backbone of the pilot's methodological framework and involve:

- Crop type modelling using machine learning methodologies and EO historical data as training features (a priori procedure)
- Automatic EO product generation and assignment of generated EO-based indices (e.g. NDVI) for each agricultural parcel (continuous procedure)
- Collection of data related to the farmers' aid application for "Greening". Crop type declaration for each agricultural parcel.
- Classification of each parcel after the farmers' declaration period closes and comparison against its declared label. Finally, a monitoring "Greening" compliance outcome is produced for all the declared agricultural parcels of a farmer and is depicted using a traffic light system (batch procedure)
- Farmer receives request for follow-up actions in case of crop type discrepancies that jeopardize its Greening eligibility. At this point, additional evidence collected from the IoT field sensors along with information related with the various cultivation related activities performed by the farmer, can be provided to the Paying Agency as proof. Since traffic lights are updated, the farmers are informed in regular intervals until the final decision for the payment is made.

As illustrated in Figure 5 the pilot focused on the greater area of Thessaloniki, Greece and targets towards the EO-based identification and monitoring of annual crops with an important footprint in the Greek agricultural sector (rice, wheat, cotton, maize, etc ~20% of the total cultivated area). Agro-climate IoT telemetry stations provide ancillary data to support noise removal decision from the satellite imagery. The main stakeholders of the pilot activities are the farmers in the pilot area and GAIA Epicheirein that has a supporting role in the farmers' declaration process (maintaining a valuable error checking tool for assessing "Greening" compliance).

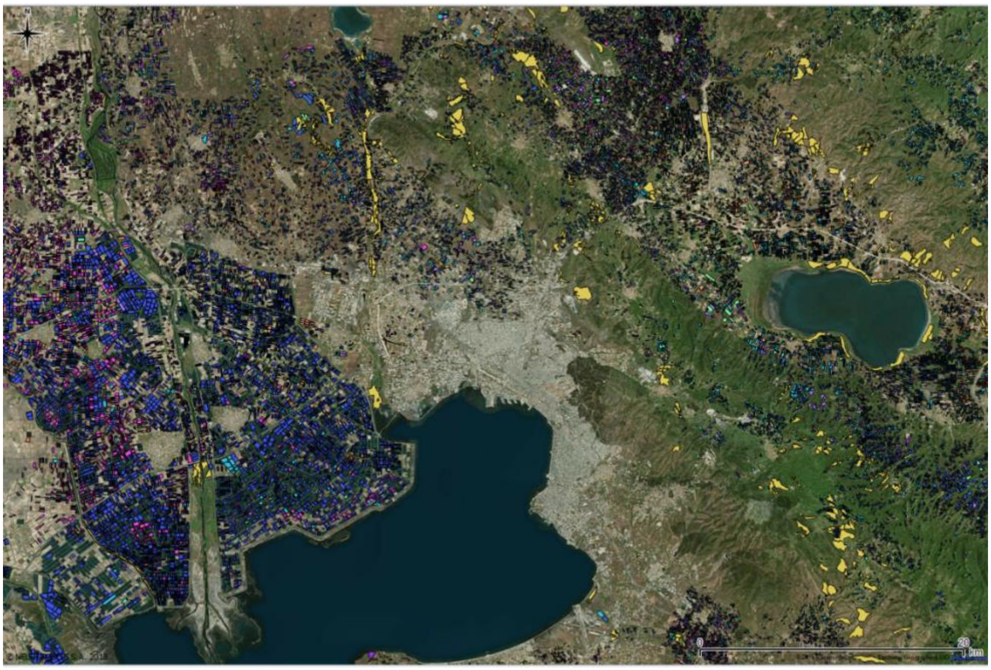

Figure 5: Satellite image of the greater area of Thessaloniki. Coloured field parcels correspond to various identified crop types

4.4. The NIVA project

The "New IACS Vision in Action (NIVA)" is a H2020 project that will start in 2019 and aims to contribute in the modernisation of the Common Agricultural Policy through the provision of a suite of digital solutions, e-tools and good practices for e-governance.

Administrative bodies from 9 EU Member States join forces to realise a new vision on the Integrated Administration and Control System (IACS) – the instrument for CAP governance. The project aims to support the acceleration of cost-effective administration of CAP payments, to stimulate data (re)use for monitoring the societal benefits of agriculture towards climate, environment and rural development and thus to improve the sustainability and competitiveness of the sector. NIVA strives for maximum impact by involving all other European Paying Agencies in a Reference Group that will be actively involved. NIVA will exploit the ongoing operationalisation of the Copernicus satellite programme and the use of Earth Observation data but also will specify the appropriate mechanisms towards the increased interoperability between different subsystems, like open data, farm management and information systems, telemetry on farm machinery and local sensors.

5. Conclusions and recommendations

The CAP's efforts to promote the use of new ICT technologies should be welcomed. The European Commission and Member State authorities are encouraged to explore voluntary and innovative ways to use modern ICT technologies supporting farmers and agri-cooperatives, in order to simplify inspections and make them less costly and less bureaucratic, bringing benefits to all stakeholders and demonstrating its sustainability for CAP beneficiaries. The farmers would not only benefit from streamlined reporting, and the government from less paperwork and better input, but the farming community would also benefit from digital tools for more efficient and sustainable farming. From this point of view, this is also an element that can contribute to wider uptake of digital services by farmers, thus supporting farms resilience, mitigation and adaptation to climate change, and eventually improving the competitiveness of European farms which in turn derives on EU rural growth and jobs, opening the doors to new data-driven business models, and eventually contributing to show to a new generation of entrepreneurs that agriculture is a modern and highly interesting profession.

Nevertheless, as made evident throughout this paper, there are certain aspects which are worth careful consideration.

1. Farming activities across different regions in EU are highly diverse. Thus, solutions for performing automated CAP controls need to be adapted to satisfy the requirements stemming from such variety of cases. If technology evolves isolated from the understanding of actual on-farm realities, then there is a large risk that it will not be useful and remain unused. A number of pilot experiences have been (or are being) carried out in Europe, but having covered yet a limited territory and a limited variety of farming cases.

2. Different technologies for performing automated CAP controls have been tested so far, especially those relying on free-access Earth observation data. Other technologies exploiting complementary data sources (e.g. images captured by drones or field-data captured by farmers' devices) are being explored, but still with limited validation for the moment. Technical validation must address especially aspects such as accuracy/tolerance of measurements, calibration, training, etc. which are essential to ensure validity of the controls.

3. An increasing dependence on technology brings a higher risk in the enlargement of the digital divide among different EU Member States, because of an unaffordable increase in the technological requirements (and associated cost) for farmers or new barriers for the use of public services. A key challenge is to favour simplicity over complexity (too much information may be more confusing instead of clarifying). Likewise, the lack of digital infrastructure (e.g. reliable Internet connectivity in rural areas) might hamper the development of new CAP monitoring measures in less digitised EU regions.
4. The availability of data captured for CAP monitoring purposes opens the door to provide new personalized services of interest both for the farmers and the public administration. A recent study[20] indicates that the value of agriculture machine-generated, non-personal data in the EU by 2027 (given the forecasted IoT penetration) is expected to reach 50 billion €, of which 40 billion would be attributable to data sharing. Indeed, there is a big potential in the exploitation of sinergies between the CAP monitoring tools and other digital tools, such as

[20] https://www.vodafone.com/content/dam/vodafone-images/public-policy/reports/pdf/Realising_the_potential_of_IoT_data_report_for_Vodafone.pdf

crop monitoring, yield forecasting, etc. One clear example is the Farm Sustainability Tool for Nutrients (FaST[21]) which is under development by the European Commission for facilitating the sustainable use of fertilizers and encouraging the digitisation of the farming industry. However, standardized and interoperable data representation/exchange schemes are still not widely implemented in practice, thus preventing stakeholders from realizing the full potential of data sharing. Data security issues as well can hinder the development of services built on data if aspects such as data ownership, IP rights, privacy of farmers, and trustworthiness of data, are not properly addressed.

[21] https://ec.europa.eu/info/news/new-tool-increase-sustainable-use-nutrients-across-eu-2019-feb-19_en

Recommendations

1. Before wide deployment of automated controls, the technical and economic viability of replacing on-farm controls must be ensured. To this end, the large-scale piloting and validation of technologies should be accelerated, building on the hands-on experience by recent and on-going initiatives (such as the ones reported in Section 4 of this paper), in order to promote the use of cost-effective, validated in operational environments and widely available technologies. Developments must be driven by the needs of paying agencies and regulators to guarantee workable solutions. Farmers and agri-cooperatives must be involved in the process from the very beginning to ensure wide acceptance. It is highly advisable that an exhaustive validation phase is put in place, where automated controls can be carefully benchmarked against existing on-farm controls to ensure fulfilment of performance and expectations.

2. In order to ensure a level playing field across the EU, the European Commission may provide support to the Member States in the design of the different technological tools and the required supporting services, as well as democratizing access to essential infrastructures (i.e. for data transmission, storage and processing). Ideas in this direction would range from subsidies for the acquisition of digital equipment to the set up of public data processing facilities and provision of high bandwidth connectivity in rural areas, without neglecting the importance of actions for improvement of the farmers' digital skills as users of these new digital technologies, as this is nowadays one of the key reasons why digital technology adoption in EU agriculture is being relatively slow.

    a. Digital infrastructure, e-services and high-performance connectivity in rural areas are crucial to the competitiveness of rural areas, to enable full digital transformation of agriculture, and in particular to guarantee that all farmers across Europe can benefit from the investments being made by paying agencies and the European Commission in ICT systems and tools (Galileo and Copernicus programmes, agriculture tools such as FaST,[22] etc.) for improving the management and monitoring of the CAP. The connectivity gaps in rural and remote areas must be properly addressed. Particular attention must be paid to the deployment plans of optical fibre and future 5G networks in rural areas as an opportunity in this regard. EU, national and regional public investments should target those territories where the private sector alone will not close the gap. By looking at the level of digital infrastructure investments required in rural areas as of today, it appears that a better coordination framework between public funds will be necessary.

    b. There is a need for more integrated and focused digital training and educational programmes coordinated with advisory services, ensuring that farmers have the skills needed to participate and benefit from the digital economy, supporting upskill and re-skill during their working lives. This in turn needs to be considered in the context of a wide diversity of practices, production environments, and socioeconomic conditions on farms.

[22] https://ec.europa.eu/info/news/new-tool-increase-sustainable-use-nutrients-across-eu-2019-feb-19_en

3. The combination of different data sources (e.g. aerial data and field-data) entails a huge potential and should be encouraged, not only from the point of view of the CAP monitoring, but also from the perspective of providing additional, innovative value-added personalized services to farmers, and services of interest to the managing authorities. To realize the full potential and avoid data silos, sharing of data and open data schemes should be encouraged. Solutions for ensuring interoperability of data, as well as its secure management respecting ownership, farmers' privacy and trustworthiness of data, leveraging the EU code of conduct,[23] should be promoted.

4. In view of the greater emphasis on environmental issues in the new CAP, and the far greater awareness of impact of agriculture on climate breakdown, the range and type of measurements made by digital technologies need to expand. This presents a challenge and opportunity for the manufacturers of sensors and for the analysis of EO data. Most digital measurements for CAP have focused on type of crop, spatial measurements and little else. If crop and natural biodiversity is to be significantly monitored and enhanced, more sophisticated and subtle measurement techniques need to be developed both to support appropriate decision support systems and to enable monitoring of biodiversity, environmental pollution, water usage and other aspects. While great technical progress is being made in these areas, significant investment is needed at a European wide scale.

5. It comes clear that a close collaboration between the public and private sectors is needed to fill the existing gaps. It is recommended that EC and Member States build on public-private collaboration programmes. Instruments such as Pre-Commercial Procurement and Public Procurement for Innovation (in particular the latter) look very appropriate since the relevant services, as discussed in this paper, are not yet widely available neither in a commercial basis nor fully tested in operational environments.

[23] https://copa-cogeca.eu/img/user/files/EU%20CODE/EU_Code_2018_web_version.pdf

6. Finally, the new technological solutions should not end up being seen as a form of surveillance. It is crucial to ensure that the new monitoring systems based on data will not be introduced to penalise farmer more easily for non-compliance, but rather to inform and guide them on their performance connected to the CAP rules and objectives as well as providing them a better decision making with less bureaucracy. In this regard, it is advisable to clarify all the uses that public authorities will give to all the information generated through monitoring. There is an opportunity to increase trust and reduce costs for all stakeholders by improving transparency and access to information of common interest (databases of soil maps, water maps, etc). In general, the recommendation can be summarised as "create substantial benefits and incentives for the farmer through smarter regulation, simplification, higher tolerances, smaller penalties and more guidance and correction, adding value for all stakeholders."

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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.

AIOTI is a member driven organisation with equal rights for all members, striving for a well-balanced representation from all stakeholders in IoT and recognizing the different needs and capabilities. Our members believe that we are the most relevant platform for connecting to the European IoT Innovation ecosystems in general and the best platform to find partners for Real Scale Experimentation.

AIOTI WG06 is the key meeting point of EU-based stakeholders interested in developing and exploiting the benefits of IoT (technologies, ecosystem and infrastructure) in the domains of farming for food production and food safety, from farm to fork. The scope of the working group encompasses precision farming (IoT devices, data management tools and issues) applied to multiple farming modalities, food traceability and safety, considering the business, policy and societal dimensions.