CONSOLE

CONtract Solutions for Effective and lasting delivery of agri-environmental-climate public goods by EU agriculture and forestry

Research and Innovation action: H2020 - GA 817949

D1.6 Report on technological aspects

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1 Summary

Technology has been applied in agriculture as a tool to reduce labour effects and improve labour efficiency. However, they also provide valuable information that provides both the farmer and other users with a better understanding of other assets provided by a farm. In this document, the different technologies applied in the agricultural sector are analysed, differentiating them between compliance technologies and monitoring of agri-environmental public goods (AECPGs) based on scientific publications, reports from relevant entities, meetings with key stakeholders and actions carried out in the CONSOLE project and in other Research and Innovation projects.

For this, the CONSOLE project partners have provided relevant information on the actions carried out in their case studies as well as national and / or local developments. Subsequently, the information received has been classified and categorized according to the type of technology used.

This document reflects the variety of technologies available in the sector that allows and favors the development of new contractual relationships that increase or promote AECPGs following the objectives set by the new CAP Farm to Fork, Green Deal and the objectives of sustainable development of FAO.

However, to favor the implementation of the technology and therefore the development of new contractual relationships, an incentive from the responsible parties can be crucial to achieve the objectives set for Horizon 2030.

For that, this document reflects the perception from key actors to analyze current technologies and their feasibility to be implemented under different contractual relationships and AECPGs promoted.

2 Introduction

The aim of this report is to provide a portfolio of current technologies available for the design and the implementation of innovative contractual relationships which promote the agri-environmental public goods.

The CONSOLE project has identified four types of contractual relationships (Result-based, Collective implementation, value chain and land tenure). The purpose of this document is to identify the suitability of each of the types of technologies to be applied in each of the contractual relationships.

Each of the types of contractual relationships claims a series of specific parameters to be monitored according to the nature of the contractual relationship. From a monitoring technologies point of view, it is easy to relate to the type of indicator-based. However, the rest of the typologies also require technologies that allow them to know if the land has been tilled or not, if the implementation of any management is being carried out properly throughout the territory or if the management of the crop has been carried out according to the indications of the contract.

The CONSOLE project includes more than 60 case studies of different typologies in which there are examples of the use of different technologies.

The technology is and has been applied in the agriculture sector to eliminate or reduce efforts and increase efficiency in agriculture (sensors, datalogger, autonomous tractors, etc) . The main advantages are increased production, improved nutrients in food, reduced pressure on the environment, improved quality of life, etc. (Wiggins, 2004). Furthermore, the technology could allow additional functions as monitoring, designing new contractual relationships and reducing costs and time in compliance tasks.

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However, different regulatory measures can affect the application of one or another technologies in the agricultural sector. For instance, the Biotech directive dealing with genetic innovation and the current CAP provides incentives based on the digitalization of the sector.

The innovations on the widespread internet in the last two decades allowed the capability to the producers and consumer services in real time such as crops monitoring, pest controls, livestock monitoring, etc. Artificial Intelligence, drones/sensors, and genetic engineering are emerging technologies which play an important role in revolutionizing agriculture (Ryan et al, 2018). The advanced technologies provide benefits for farmers and public administration, increase the profitability of the plots and reduce the costs of monitoring. This will make it easier for farmers to monitor their environmental and other obligations in a timely manner and thus avoid penalties for non-compliance with the rules of the CAP. In the CAP framework, the application of advanced technologies could reduce the number of on-the-spot checks, and significantly reduce the time spent by farmers with inspectors in the field. Farmers will also be able to benefit from synergies with other digital technologies, such as crop monitoring and yield forecasting, to manage their farms better. Paperwork can also be reduced through the improved automation of activity recording (EC, 2018).

The advances of technology will benefit citizen science in agriculture and food research converting data into usable information, particularly for those collecting the data. In addition, a variety of algorithms coupled to camera phones allow plants, and soon pests, pathogens, and pollinators to be identified in the field in near real-time for identification projects (Ramcharan et al, 2018)

Other technologies, such as drones and genetic engineering also present opportunities, but may be more limited in their capacity depending on government regulations. Similarly, genetic engineering and gene editing (e.g. CRISPR/Cas9) technologies are becoming cheaper (Ryan et al, 2018)

Currently, the utilised agricultural area (UAA) in the EU-28 amounts to almost 175M hectares subject to payment and controls. Seven million farmers benefit from area-based CAP payments achieving a total amount paid by the Paying Agencies of 55000 M€/year.

Recently, the European Union Green Deal created a new food security strategy called the "Farm to Fork Strategy" (F2F) the main goal of which are: ensuring sustainable food production; ensuring food security; stimulating sustainable food processing wholesale, retail, hospitality and food services practices; promoting sustainable food consumption and facilitating the shift to healthy, sustainable diets; reducing foods loss and waste and; combating food fraud along the food supply chain. This strategy is in line with the Sustainable Developments Goals and reduces the greenhouse gas emissions.

As well as, the F2F Strategy is related to the new CAP, to reduce the negative impacts on environmental health and sustainable production.

The main features of the Commission’s proposal for a modernised and simplified CAP include:

- A focus on strategy and objectives
- A fairer subsidy system
- A focus on environmental and climate actions

Member States will have more flexibility to design measures targeting national and regional needs, and more flexibility when agreeing strategic plans with the EU for the application of controls.

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The Integrated Administrative Control System (IACS) has been subsequently developed and tailored across the EU, introducing specific regulatory requirements (RDPs, Greening, etc) and technological tools (LPIS, Geo Spatial Aid Application etc). The current IACS incorporates different databases (farmers' register, animal register, LPIS, entitlement register, claims databases) with cross-checking of the integrity of data. Under IACS, Member States are required to use computerised databases to administer the annual claim and control cycle, covering aid application, administrative and (where applicable) on-the-spot checks (OTSC), and payments, incorporating (where applicable) penalties and deductions.

The draft IACS legislation, which retains the key elements of the current system, includes the requirement to introduce an area monitoring system that allows regular and systematic observation, tracking, and assessment of agricultural activities and practices on agricultural areas using Copernicus Sentinels satellite data or equivalent.

A specific topic of interest is whether advanced versions of the current technologies are in use or being considered by administrators, beneficiaries and tin the wider market that have the potential to reduce administrative burden and allow monitoring Agri-environmental public goods. In this report, we will describe the current technologies available regarding their targets. The information shown has been collected from scientific manuscripts, EC and project reports and the experiences reported from CS from the CONSOLE project.

3 Methodology

In May of 2019, the CONSOLE kick-off meeting (KOM) was carried out in Seville (Spain). During the KOM, the strategy to achieve milestones and objectives were discussed. Three steps were identified: state of the art based on scientific manuscripts, technological and report manuscripts; Community of Practice members experts on technology and policy through workshops and; CONSOLE partners and their entities due to the expertise in the area and their advances in the CONSOLE Case Studies.

The first step designed was the identification of current technologies available through the compilation of knowledge. In fact, a close collaboration between UNIBO and EVENOR was designed in order to facilitate the goals of task 1.6. For that, Dr. Davide Viaggi, from UNIBO led a stay of three months (10/06/2019) of a one researcher from Evenor-Tech focused on the identification of different categories of technologies as a support to the implementation of result-based and collective agri-environmental schemes. During the stay, a through review of current technologies was carried out to focus on the current compliance technologies available for the agro-forestry sector. For that, several scientific manuscripts, project and technology reports and projects were consulted in order to collect all knowledge available. Every week, a progress meeting was organized in order to analyse advances achieved. At the end of the stay, before the 1st project meeting, the advances were discussed internally to show preliminary results.

During the project meeting, the second step "involvement of the Community of Practice" in this task was discussed. In light of the points discussed, the preliminary results had been shown with them in a workshop scheduled to the end of M18. However, the pandemic situation affected the normal development of the workshop. For instance, the workshop was designed as a virtual workshop in order to collect their feedback. Nevertheless, the key members of the CoP had not attended the meeting due to their availability. According to the lack of time from the CoP to participate in the participatory activity, the workshop will be set at the end of the project in order to validate the results obtained.

Finally (third step), CONSOLE partners were consulted to provide new technologies and solutions not identified in the preliminary results. In addition, the several case studies described

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in WP2 were reviewed to nurture the current report. CONSOLE partners provided information about several technologies and tools associated with their entities or case studies. The information provided was classified according to the categories identified previously.

Furthermore, several interviews with stakeholders and, finally, members of the CoP, were carried out to communicate information about the project, their objectives, and promote their involvement and the exchange of their knowledge. Several entities showed interest in the CONSOLE project, sister and related projects, ICT entities, research centers, universities, public administration, etc. The participation in virtual congress and conferences allowed them to increase their interest in the advances on this topic. Entities such as IFAPA (Andalusian Institute for Research and Training in Agriculture, Fisheries, Food and Ecological Production), LifeWacht-ERIC and Joint Research Center as tool developers focus on monitoring environmental and crop variables.

In the end, a workshop was carried out in 1st December 2021 in order to evaluate the technologies analyzed and their impacts on public goods and current contract solutions.

4 State of art on monitoring compliance technologies

Land Parcel Identification System (LPIS) is a software that allows geolocate, display and spatially integrate its constituent data (Article 70 of Regulation (EU) No 1306/2013 and Article 5 of Regulation (EU) No 640/20143). It contains diverse spatial data sets from multiple sources which together form a record of all agricultural areas (reference parcels) in the relevant Member State and the maximum eligible areas under different EU aid schemes in Pillars 1 and 2 of the current CAP. LPISs comprise alphanumerical and graphic elements (EC and ECORYS, 2019).

From 2018, all aid applications must include pre-populated and amendable geo-spatial information including the location and size of ecological focus area (EFAs). LPIS is maintained using aerial or satellite orto-photos (imagery), national mapping systems, validated farmers notifications, and results of on-the-spot controls. Based on this kind of technology, different additional technologies can be related. Following, the information included is based on EC and Ecorys, 2018

4.1 Geo-Spatial Aid Application (GSAA)

GSAA could be the most frequent technology applied due to the long application. Some Member States adopted electronic claims with a geo-spatial component before GSAA became a requirement. This technology provides several attractive features, not only for public administration, for farmers, such as on-line cross checks with paying agency databases and instant anomaly warnings that could minimize the number of mistakes in declarations. It also reduces the number of errors and checks the paying agency needs to undertake between the receipt of the application and making payment.

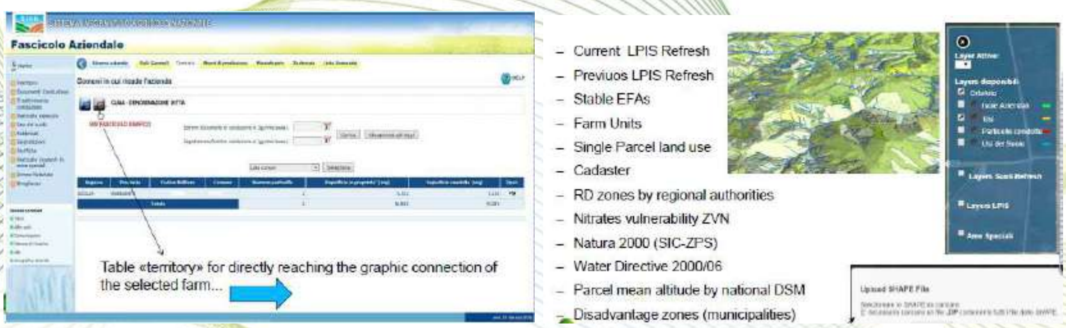

Figure 1. SIAN (Italy) Picture from Livio Rossi SIN RTI

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4.2 Remote Sensing

A few Member States already use remote sensing to the maximum extent as part of their control regime. For instance, the smallest countries use remote sensing because the size of data is more feasible to manage than other countries. The application of remote sensing could allow to reduce the number of on-the-spot controls and more targeted use of resources when inspectors need to be deployed on-farm. The use of the imagery together with other data sources of technologies could be optimised to add value to the overall control regime.

For instance, Light Detection and Ranging (LIDAR) which is an active remote sensing system that can be used to measure vegetation height across wide areas. LIDAR uses light in the form of a pulsed laser to measure ranges (variable distances) to the earth. Its use, with remote sensing, has enabled a better evaluation of the eligible areas of grassland under the pro-rata method for areas of permanent grassland. In addition, its use in conjunction with crop identification software has provided the potential support of a more cost-effective means of undertaking the greening crop diversification inspection requirements in a short period. However, reliance on this method is often tempered by the existence of cloud cover over these inaccessible areas.

4.3 Sentinel data

A number of Member States are either piloting or considering the use of Sentinel imagery. Recent regulatory changes and the new CAP reform proposals introduce the possibility for the greater use of monitoring techniques across IACS schemes where Sentinel is likely to play a significant role.

The document "Analysis of administrative burden arising from the CAP" provides an overview on the key benefits and issues identified:

Table 1: Key benefits and issues identified

Benefits	Issues
-Opportunity to replace 5% on-the-spot checks with a system for 100% monitoring; -Farmers may have the possibility to after claims and rural development agreements on an ongoing based on satellites data; -Simplifying the annual claims process and reduction of control unit size. Consequently, MS will reduce their costs; - If this technology is combined with geotagged pictures, satellites will allow the accuracy increase and results confirmation from farmers/technicians; -Elimination of bottlenecks; -Penalties and error rates reduction; -Identification of irregularities in advance; -Cost reductions in the cost of procurement of control imagery due to "open source" data;	- Move from a system of annual change to constantly change; - Sentinel data requires additional sources and methods to full replace of existing methods; -For instance, the geometric resolution of Sentinel-2 is insufficient for some elements and features such as hedges, ponds, ditches, trees in line or in groups, margins of field, traditional walls; -Monitoring parcels of < 0.5 ha (present in very high numbers in some Member States); -Potential increased total cost of ownership including: - Costs of software; - Algorithms; - Data storage.

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-Potential alternatives for greening controls thanks to the frequency and availability of data; -Determination of cultivated areas, grassland and other features for direct payments; -Support for compensation or derogations regard unnatural events such as flood or severe drought conditions; - Identifying potential anomalies in eligible areas with automated software for future follow up.	

4.4 Spatial Software tools

Several development areas are working in the use of tools to assist on ingestion data and change analysis. In this case, the specific areas are:

-software that determines specific land use;

-hyperspectral analysis that allows for identifying the type of land cover by interpretation of the colours on ground; and

-the identification of potential anomalies for further research through tools that automatically update the LPIS where the area is considered to be sufficiently accurate against a specified set of rules thereby eliminating the need for manual digitisation.

Imagery, whether regularly obtained via sentinel or more traditional means, is combined with other layers of developed, procured or open-source data that allow a suite of checks against different regulatory direct payment and rural development requirements to take place. Most of these tools use probability assessments where parcels, land uses, areas or features are flagged as potential anomalies often using “traffic light” coding.

4.5 Geo-tagging

Geo-tagging refers to adding the metadata for this geo-spatial information on images or other media. Inspectors or farmers provide evidence via time, date and location stamped images taken via smartphones or tablets. Identified uses include:

-Providing an effective means for any area that is not effectively monitored by imagery or where there is doubt that needs verification as the result of controlled use of that imagery;

-Validation of crop type or feature within a land parcel particularly in determining crop diversification obligations under greening but also for specified crops or areas under voluntary coupled schemes and features in rural development measures;

-A potential cost-effective alternative means of confirmation of small land parcels against a combination of sentinel and high-resolution imagery;

- Where the model provides the opportunity for the farmer or representative to submit the geo-tagged evidence, the ability to save travel and resource costs by eliminating or reducing the need for rapid field visits or even full on the-spot controls;

- A supplementary route to provide secondary information for certain crops or schemes such as details of seed labels;

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- Another tool for updating and maintaining the accuracy and currency of the LPIS.

Overall, there are positive views about the potential uses of geo-tagging within an overall framework of spatial and technical monitoring tools. The full costs of using this technology are however only currently being explored. Technical skills are needed to provide an authoritative set of images that can be used to assure the accuracy of control or declared areas. It should be reasonably easy to train control officers in its use but it may be more problematic where farmers would supply the evidence.

4.6 Drones

The most realistic use of drones is for targeted campaigns in specific areas where physical access is difficult for traditional on-the-spot controls. The information provided has a good accuracy but there are legal limitations in each Member States. Some MS policies require permissions from the landowners and an operator registered for the flight of a drone. However, drones resolve issues where remote sensing images are impacted by clouds.

4.7 Robots

Robots are an option to reduce the time intensive tasks of staff in checking applications. They are particularly interesting when interacting with software applications. Regarding EC and Ecorys 2018, the robots check data from insurance pensions and transfer the data to the paying agency. The robots could process daily data as 6 employees. However, the involvement of robots in this process required an initial economical input.

5 Monitoring AECPGs through key variables

CONSOLE is focused on the identification of innovative contractual relationships that promote the AECPGs. There are several models and advances in this issue which could be feasible to combine with the compliance technologies. The combination may allow designing new contractual relationships based on results and facilitate their implementation and monitoring. Most of the advances shown are related with the F2F strategy, SDGS and the new CAP to minimize the impact on the environment or promote the sustainability of land farm management.

For instance, the following table summarizes impact indicators and results linked to the objectives of the new CAP (Hart and Bas-Defossez, 2018):

Result indicator	Impact indicator
Climate	
Adaptation to climate change	Improving farm resilience
Reducing emissions in the livestock sector	Contribute to climate mitigation (reducing GHG emissions from agriculture)
Carbon storage in soils and biomass	Enhancing carbon sequestration (increase soil organic carbon)
Green energy from agriculture and forestry	Increase sustainable energy in agriculture (production of renewable energy from agriculture and forestry)
Natural resources	
Improving soils	Reduce soil erosion (% land in moderate and severe soil erosion on agricultural land)
Improving air quality	Improving air quality (reduce ammonia emissions from agricultural land)
Protecting water quality	Improving water quality (gross nutrient balance on agricultural land)
Sustainable nutrient management	Reducing nutrient leakage (nitrate in ground water - % of ground water stations with N

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	concentration over 50 mg/l as per the N Directive)
Sustainable water management	Reducing pressure on water (water exploitation index plus: WEI+)
Habitats and Eco-systems	
Supporting sustainable forest management	Increasing farmland bird populations (Farmland Bird Index)
Protecting forest ecosystems	Enhanced provision of ecosystem services (share of UAA covered with landscape features)

Most of the solutions are working on several technologies and combinations. 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 instance, 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 combination of Sentinel satellite imagery, spatial software capable of analysis and assessing the eligibility of features and land uses based upon probability assessments and geotagged photography under controlled conditions together present the opportunity to minimise the need for traditional on-the-spot controls. 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.

Following several methodologies are described for analysis of environmental variables that could be monitored through Earth Observation linked with the indicators proposed in the below table. The combination of the following methodologies with advances in AI and Machine Learning can be useful for developing tools for farmers and payments agencies or public administration.

5.1 Modelling approach

In many cases, the needs of environmental researchers are different to the modelers due to the application of empirical models (such as black box) and mechanistic models for diverse environmental applications (Krapu and Borsuk, 2019). There are many statistical analyses and models in different areas for land evaluation (De la Rosa et al, 2009, Dedeoglu et al, 2018). There is an increasing need for developing an only one solution that integrates *in-situ* and *ex-situ* management processes but this integration needs collaboration at different levels as implementation, monitoring and assessment (Schwartz et al., 2017). *In-situ* data can be defined as any observation taken by instrument in direct contact with the medium it senses. On the other hand, *ex-situ* data is any observation taken by an instrument in an indirect way (as remote sensing). Regarding the land evaluation process, many approaches have been used for land evaluation and assessment of vegetation-environment relationships, such as Decision support systems (DSSs). (Blanco-Velázquez et al, 2020). DSSs are computational systems that combine data and knowledge from different sources. For instance, MicroLEIS-DSS was developed to assist decision makers with a wide range of agro-ecological problems related to land productivity and land degradation (De la Rosa, 2009). The DSS can be applied for developing different policy strategies according to the area or through new input data, evaluating the application of measures needed to receive any payment under the CAP framework or similar. Models such as CAPRI and AgriPoliS were used in Sweden (Höjgard and Rabinowicz, 2012) to analyse the results of

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environmental support, and the impact on water quality was analysed using SOILNDB and ICECREAMDB. CAPRI and AgriPoliS are complementary, but with different modelling approach and geographical coverage. SOILNDB and ICECREAMDB were applied in arable land in Sweden in order to calculate nutrient leakage (N and K respectively). Both models are purely biological and do not estimate behavioural changes.

Some problems identified in the application of models is the lack of available databases. ENVASSO project, INSPIRE, etc provides suggestions and recommendations in the development of harmonized and standardized databases that will allow up-scaling results of local models and interoperability of *in-situ* databases.

5.2 Soil Organic Carbon

Ghoziladeh et al (2018) propose a correlation analysis among soil samples and Sentinel 2. In their work, 200 soil samples were collected (Haplic Stagnosol, Haplic Stagnic Cambisol, Leptosol, Calcic Chemozem, Haplic Cambisol, Luvisol, Albic Luvisol, Luvic Chernozem) in the Czech Republic. The areas selected were primarily rural and devoted to winter and spring cereals, oilseed rape, maize and potatoes.

The Sentinel-2 images (Level-1C processing) were downloaded and included in the work. The analysis included the 12 bands and the following indexes:

Index	Definition	Definition based on Sentinel-2	Details	Reference
NDVI	$\frac{\rho NIR - \rho Red}{\rho NIR + \rho Red}$	$\frac{B8 - B4}{B8 + B4}$	–	Rouse et al. (1974)
TVI	$\left(\frac{\rho NIR - \rho Red}{\rho NIR + \rho Red} + 0.5\right)^{1/2} \times 100$	$\left(\frac{B8 - B4}{B8 + B4} + 0.5\right)^{1/2} \times 100$	–	Nellis and Briggs (1992)
EVI	$G\frac{\rho NIR - \rho Red}{\rho NIR + C1 \times \rho Red - C2 \times \rho Blue + L}$	$G\frac{B8 - B4}{B8 + C1 \times B4 - C2 \times B2 + L}$	G = 2.5, C1 = 6, C2 = 7.5, L = 1	Huete et al. (2002)
SATVI	$\frac{\rho SWIR_1 - \rho Red}{\rho SWIR_1 + \rho Red + L} \times (1 + L) - \frac{\rho SWIR_2}{2}$	$\frac{B11 - B4}{B11 + B4 + L} \times (1 + L) - \frac{B12}{2}$	L = 1	Marsett et al. (2006)
SAVI	$\frac{(\rho NIR - \rho Red) \times (1 + L)}{\rho NIR - \rho Red + L}$	$\frac{(B8 - B4) \times (1 + L)}{B8 - B4 + L}$	L = 0.5	Huete (1988)
MSI	$\frac{\rho SWIR_1}{\rho NIR}$	$\frac{B11}{B8}$	–	Rock et al. (1985)
GNDVI	$\frac{\rho NIR - \rho Green}{\rho NIR + \rho Green}$	$\frac{B8 - B3}{B8 + B3}$	–	Gitelson et al. (1996)
GRVI	$\frac{\rho Green - \rho Red}{\rho Green + \rho Red}$	$\frac{B3 - B4}{B3 + B4}$	–	Tucker (1979)
LSWI	$\frac{\rho NIR - \rho SWIR_1}{\rho NIR - \rho SWIR_1}$	$\frac{B8 - B11}{B8 - B11}$	–	Xiao et al. (2004)
TSAVI	$\frac{s(\rho NIR - s \times \rho Red - a)}{(a \times \rho NIR + \rho Red - a \times s + X \times (1 + s \times s))}$	$\frac{s(B8 - s \times B4 - a)}{(a \times B8 + B4 - a \times s + X \times (1 + s \times s))}$	a = Soil line intercept s = Soil line slope X = Adjustment factor to minimize soil noise	Baret and Guyot (1991)
MSAVI	$\frac{(1 + L)(\rho NIR - \rho Red)}{(\rho NIR + \rho Red + L)}$	$\frac{(1 + L)(B8 - B4)}{(B8 + B4 + L)}$	L = 1–2 × s × NDVI × WDVI	Qi et al. (1994a)
MSAVI2	$\frac{2 \times \rho NIR + 1 - \sqrt{(2 \times \rho NIR + 1)^2 - 8 \times (\rho NIR - \rho Red)}}{2}$	$\frac{2 \times B8 + 1 - \sqrt{(2 \times B8 + 1)^2 - 8 \times (B8 - B4)}}{2}$		Qi et al. (1994b)
WDVI	$\rho NIR - C \times \rho Red$	$B8 - C \times B4$	$C = \frac{B8}{B4}$	Clevers (1988)
BI	$\frac{\sqrt{(\rho Red \times \rho Red) + (\rho Green \times \rho Green)}}{2}$	$\frac{\sqrt{(B4 \times B4) + (B3 \times B3)}}{2}$	–	Escadafal (1989)
BI2	$\frac{\sqrt{(\rho Red \times \rho Red) + (\rho Green \times \rho Green) + (\rho NIR \times \rho NIR)}}{3}$	$\frac{\sqrt{(B4 \times B4) + (B3 \times B3) + (B8 \times B8)}}{3}$	–	Escadafal (1989)
RI	$\frac{\rho Red \times \rho Red}{\rho Green \times \rho Green \times \rho Green}$	$\frac{B4 \times B4}{B3 \times B3 \times B3}$	–	Pouget et al. (1990)
CI	$\frac{\rho Red - \rho Green}{\rho Red + \rho Green}$	$\frac{B4 - B3}{B4 + B3}$	–	Pouget et al. (1990)
V	ρNIR	B8	–	Jordan (1969)

Source: Ghoziladeh et al., 2018.

The results showed the best SOC and Sentinel-2 spectral bands correlations (Random Forest) from B4 and B5, followed by B11 and B12. Among all spectral indices, BI, BI2, GNDVI and SATVI provided the strongest correlations with SOC.

Other research works with Landsat 8, Sentinel-2 and EnMap spectral bands to Soil Organic Matter modelling (Rosero-Vilasova et al, 2017) in Campos Amazonicos National Park savanna enclave, Brazil.

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5.3 Soil salinity

The soil salinity can be an indirect indicator of overexploitation of aquifers and a decrease of soil quality and water availability.

Taghadosi et al (2019) deals with soil salinity estimation using Sentinel-1 SAR imagery in an area which is highly affected by salinity hazard. They investigated a new method to relate radar intensity to measure in-situ salinity directly. In the first step, Sentinel-1 dual polarized VV (Vertical transmit Vertical receive) and VH (Vertical transmit Horizontal receive) data were acquired from the study site. A field study was also conducted, simultaneously, and the Electrical Conductivity (EC) of several soil samples was measured. The Support Vector Regression (SVR) technique, with different kernel functions, was used to relate explanatory variables to ground measured salinity. We also applied Feature Selection (FS) algorithms of the Genetic Algorithm (GA) and Sequential Feature Selection (SFS) for optimizing the model and selecting the best explanatory features. The results showed that ε-SVR with Radial Basis Function (RBF) kernel had the most accuracy with the Coefficient of Determination (R2) = 0.9783 and Root Mean Square Error (RMSE) = 0.3561 when the GA FS was applied. Also, GFO, VV and RVH had the best performance in salinity detection.

5.4 Soil moisture

The study from Thi et al, 2019 aims to develop a regional algorithm for estimating SMC by using Landsat 8 (L8) imagery, based on analyses of the response of soil reflectance, by corresponding L8 bands with the change of SMC from dry to saturated states, in all 103 soil samples taken in the central region of Vietnam. The L8 spectral band ratio of the near-infrared band (NIR: 850–880 nm, band 5) versus the short-wave infrared 2 band (SWIR2: 2110 to 2290 nm, band 7) shows the strongest correlation to SMC by a logarithm function (R2 = 0.73 and the root mean square error, RMSE ~ 12%) demonstrating the high applicability of this band ratio for estimating SMC.

5.5 Water quality

Water quality can be useful for biodiversity and remote sensing data can be used for monitoring and identification of water bodies over large-scale regions in a more effective and efficient manner. However, this technique must be integrated with traditions in situ sampling method and field surveying in order to provide precise results. Various empirical, semi-analytics and machine learning algorithms exist to derive relationships between multi spectral image surface reflectance and water quality indicators derived from in situ measurement. The capabilities of Landsat-8 satellite image were analysed by Jakovljeciv et al, 2018 for assessment of abundance of phytoplankton's (biological parameters) and Turbidity, Dissolved oxygen, Total Phosphorus and Total Nitrogen (physic chemical parameters) in region of Vojvodina, Republic of Serbia. The Neuron Networks are used to analyse correlation between in situ measurements and 7 Landsat 8 atmospherically corrected satellite images acquired in 2013. Satellite-based monitoring, in combination with in situ data, provides an improved basis for more effective monitoring of large numbers of water bodies over large geographical areas. Relationship between derived and WFD quality parameters is established in order to provide usage of remote sensing data for ecological status classification according to WFD.

5.6 Metabarcoding

Metabarcoding represents a revolutionary method of analyzing biodiversity that combines two technologies: a pre-selection of the genetic material of interest (one or a few DNA / gene regions that operate in a barcode or barcode mode) to through Polymerase Chain Reaction (PCR) and subsequent massive sequencing of these to identify the range of organisms present in the environmental sample. Selection and combining of target regions (primer delimited) in the PCR amplification process determines which group of organisms are to be analyzed.

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The bacteria and fungi present in the soil play a crucial role as mediators of biogeochemical processes and in the establishment of plant communities. To know which organisms are present in one or the other group, PCR primers must be selected that are sufficiently conserved to amplify the maximum number of organisms in the group, but with sufficient resolution to discern families that fulfil different functions in the ecosystem (Phytosudoe Project)

6 Current developments

Currently, different entities and countries are involved in the development of ITC tools applying some technologies below mentioned. In fact, several international projects focus on the improvement of the technologies available for monitoring AECPGs and facilitate the implementation of new contractual relationships. In addition, other developments are focused on the design of new contractual relationships based on their feasibility thanks to the current technologies. Following, an overview of some examples can be found as a portfolio of new advances in this topic.

6.1 MARS Project

The aim of the MARS project (https://ec.europa.eu/jrc/en/mars) is to use the remote sensor technology of satellites to monitor crops, predict yields, track the weather patterns that might affect farmers (and the broader impact of climate change as a whole) and to track agricultural biodiversity, among others. All of which are neatly summarised in regular MARS Bulletins providing a wealth of information for farmers, traders and analysts on what to expect in Europe and beyond.

6.2 Use of UAVs

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 exploitation 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.

6.3 Without physical inspections

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.

6.4 Automated area classification

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, as well as the whole area of Austria based on Sentinel 2 data.

6.5 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 integrating satellite remote sensing and user-generated data (admin data; geotagged

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and time stamped photos, etc.) into added value services for a cost-efficient, transparent and reliable remote 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 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. 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. 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.

6.6 APII

The Advanced Platform for Intelligent Inspections (APII) is a technological solution in development by a partnership between two companies (Seresco, Proyestegal) and a RTO (Gradiant), under the framework of the PRIMARE programme15, a Public Procurement of Innovative solutions (PPI) by the Galician Agency for Technology Modernisation (AMTEGA) 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 ingest and processes data from different sources, encompassing:

a.) high-resolution satellite imagery (such as Worldview or GeoEye) and UAV imagery acquired with different payloads: RGB, multispectral, LIDAR and different camera configurations (nadir, oblique).

b.) open data from the Copernicus program (Sentinel-2 imagery), PNOA (Aerial Orthophotography National Plan) and Cadastral Information.

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 advice for the most suitable irrigation and harvesting times, based on the observation of the crops.

6.7 Gaiasense

Gaiasense and the H2020 DataBio Big Data Lighthouse project. Gaiasense is a technological solution, developed and operated by NEUROPUBLIC S.A., offering a range of innovative smart farming services which, among others, are contributing to the realisation of the proposed CAP reform. The Gaiasense solution implements a holistic approach which combines data collected

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

a.) Crop type modelling using machine learning methodologies and EO historical data as training features (a priori procedure)

b.) Automatic EO product generation and assignment of generated EO-based indices (e.g. NDVI) for each agricultural parcel (continuous procedure)

c.) Collection of data related to the farmers' aid application for "Greening". Crop type declaration for each agricultural parcel.

d.) Classification of each parcel after the farmers' declaration period closes and comparison against its declared label.

6.8 NIVA

The NIVA project. The "New IACS Vision in Action (NIVA)" is a H2020 project that started 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.

6.9 FaST

FaST is the Farm Sustainability Tool for nutrients. It will be a digital tool to help individual farmers improve both the agronomic and environmental performance of their farms, by supporting them in the development of an accurate Nutrient Plant Management (NPM). NPM is the process of ensuring a farm utilizes its crop nutrients as efficiently as possible, in order to optimize crop yield and quality, whilst also protecting the environment by not having as excess of nutrients. According to GAEC 5 and article 12(3), Member States will establish a system to provide the FaST for nutrients to individual farmers, who in return will be obliged to activate the tool and input the information necessary for the tool to be operational. Minimum elements and functionalities of the tool have been defined. In addition, the tool allows adding other electronic on-farm and e-governance applications due to modularity of the tool. The Commission will support Member States with the design of the FaST, the data storage and processing services required. The tool is developed on the Cloud system and connected with Earth Observation

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Services from Copernicus. In addition, information about soil, environmental, farmer objectives, farm practices and products and procedures are included in the tool.

6.10 Sga@PP and SgaFot

Sga@PP and SgaFot are two applications for mobile phones with which to facilitate Andalusian farmers and ranchers the processing of the application for CAP aid. Both apps, which work in a complementary way, allow the beneficiaries of the CAP to consult their files and send geo-referenced photographs, in order to correct erroneous data or present allegations. Specifically, the SgaFot app allows the farmer or rancher to take images or delimit traces that will later be incorporated into his file to correct errors, with the guarantee of providing reliable information since the date and location of the images cannot be manipulated.

6.11 LIAISON

LIAISON is an EU-funded' research and innovation' project that aims to help unlock the potential of "working in a partnership for innovation" in agriculture, forestry and rural business. They identified several types of innovations but they are focused on social or economic dimensions. In fact, one of their expected outputs will be a policy brief on improving the institutional environment for partnerships, projects and networks for innovation as the digitalization of the sector.

6.12 Contract 2.0

Contracts 2.0 is a European Union (H2020) funded project that works on contractual solutions that provide the right incentives to farmers and land managers to produce more environmental public goods, but will also allow them to reconcile the profitability of their farms with the objectives of sustainability. One of the expected outputs is the innovative design of new contractual relationships and their economic viability.

6.13 Effect

Effect is a European H2020 funded research project with the overarching goal to develop and test innovative agri-environmental contract mechanisms to improve the provision of environmental goods. There are several case studies that focus on payments based on results. One of the aspects analyzed is the economic viability of these contracts taking into account the application of technologies.

6.14 Ecological modeling (LifeWatch-ERIC)

LifeWatch-ERIC is a European Infrastructure Consortium providing e-Science research facilities to scientists seeking to increase our knowledge and deepen our understanding of Biodiversity organisation and Ecosystem functions and services in order to support civil society in addressing key planetary challenges. LifeWatch includes several virtual labs available and free. Ecological modeling vLab comprises two online coupled models, which are parameterised and initialised for the specific conditions at a few specifically identified areas for which the required datasets exist. In an attempt to make the tool user friendly a graphic user interface to view model results dynamically through any internet browser. Model results will be stored at the HCMR servers and the user will be able to select the area, scenario, and parameter required, which will then be returned as results in the form of plots. All model parameters and options will be available to the user online. The ultimate operation, therefore, of this vLab will be to allow the user to submit a request for the model to run under a different scenario than those already available. (https://www.lifewatchgreece.eu/sites/default/files/videos/lwgrdemo.m4v)

6.15 iSQAPER

iSQPAPER is a European Union (H2020) funded project that evaluates the effect of innovative soil management on ecosystem services, including climate regulation and carbon neutrality. A

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main output of iSQPAPER is the SQAPP, soil quality app that runs in many platforms including mobile phones in Chinese, English, Estonian, French, German, Greek, Hungarian, Italian, Nederlands, Polish, Portuguese, Romanian, Slovenian, Spanish. (https://www.isqaper-project.eu/)

6.16 Soilmentor

Soilmentor is a software developed by Vidacyle to provide knowledge and information about healthy soils and biodiversity. Soilmentor provides and facilitates monitoring soil health and understanding what to focus on. Soilmentor has been designed with a friendly interface taking into account the needs and demands of farmers. (https://soils.vidacycle.com)

6.17 Maiagrazing

Maiagrazing is a decision-making solution to make graze planning more accurate. Taking into account seasonal changes, the software provides suggestions and recommendations to match stocking rate to carrying capacity. Maiagrazing is an online tool that helps farmers maximise their pastures and profits in the good times and reduce risks when it's tough. In a map, the users can see where herds are located. (https://maiagrazing.com)

7 CONSOLE and technology

CONSOLE is not focused on new advances on technologies. Most Case Studies have to go beyond compliance requirements. However, the pandemic situation has promoted and accelerated the digitalisation of the sector. For instance, farmers have to submit their CAP applications for direct payments and also provide data and information (Germany). A template document was shared to the CONSOLE consortium to identify the main technologies involved.

Based on the information provided by the partners and the different contract types identified in the CONSOLE project, a depth analysis of the cases studies was carried out in order to identify the technologies involved and their link with the four contract types.

Following, the technologies applied in the CONSOLE Case Studies are cited.

7.1 LPIS

Land parcel information system is usual in all of the CS. However, most of data included focus on identification of plots or parcels. Nevertheless, some partners include environmental data in order to facilitate the identification of impacts from contractual types (ES3-Spain). This data management supports the biodiversity monitoring and scoring approach (DE2-Germany) and allows estimating the impact on soil organic carbon from contractual type application (ES3). The Austrian case study AT2 "Biodiversity monitoring with farmers" includes a portal webpage where the farmers are reporting their monitoring results.

7.2 GSAA and spatial data software

In the AT4 Case Study a specific software for the operational data of the farmers (management measures, soil sampling, etc) is included. The software allows downloading several documents regarding user' queries (e.g. information about the amount of stored CO_2 on a specific field, the soil sample results, and the reported management measures from the farmers). In this case study AT4, the monitoring of CO_2 is the key AECPG in order to obtain a certificate of the tons sequestered. The soil samples for each field in the program are paid by the farmers (390€ for each soil sample). In the program three soil samples are required: initial soil sample at the beginning of the contract; second soil sampling (success sampling) after 3 to 7 seven years, according to the farmer's needs; and a third sample (control sample) after additional 5 years. On the other hand, FI4 Case Study allows landowners and domestic animal herders a close collaboration through an

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online platform. The platform provides an example of a contract model for leasing pastures with several benefits: improve biodiversity, landscape and animal welfare.

7.3 Remote sensing

Remote sensing is currently applied in the monitoring and control of machinery (remote control) in shrub clearance. This technology is combined with Internet of Things and Artificial Intelligence and allows the monitoring and checking of the management measures applied (For instance, remote caterpillar control in CS1-Germany).

7.4 Drones

Drones provide several benefits in small areas thanks to their accuracy and frequency data. However, national rules could limit the application of drones. For instance, in Germany, the use of drones in (steep slope) vineyards (https://www.praxis-agrar.de/pflanze/weinbau/spruehdrohnen-im-weinbau/ or, either to replace the use of helicopter spraying (authorized under exception rules) or also for biological control, e.g., enabling the application of pheromones has been tested. This requires – besides technological developments - adaptations in aviation law, but also protection law.

7.5 Geotagging

The huge use of smartphones allows the implementation of geotagging technology in the agricultural sector. In fact, Thunen Institute developed the project NatAPP (https://www.thuenen.de/en/lr/projects/natapp-smartphone-based-documentation-of-nature-conservation-measures/) combining a smartphone-based approach with an online information desk to facilitate implementation of nature protection measures by farmers.

7.6 Sentinel and SOC

The use of satellites in the CS can provide details about the surface, land use, etc. However, there are several advantages in the field of monitoring several variables. SP3 is focused on the monitoring of SOC in olive groves in order to facilitate new contractual relationships based on results. For instance, the impact on SOC from the olive integrated production in SP3 has been tested through the harmonization and standardization of data available prior to the implementation of this contract solution. Regarding preliminary results. Sentinel 2 data allows several indexes which could be related with changes on SOC. In fact, TVI, MSI and GNDVI could be related with SOC in some case studies.

8 Workshop: Practicability under the lens of technical issues

In the framework of CONSOLE Project, a workshop was developed in order to scan with the stakeholders the technologies available that can support the implementation of results based, collective and value chain-based solutions, to know their perception about current technologies, identifying which can help our contract solutions. This event was held in 1st December 2021 (online) led by UNIBO and EVENOR staff (see Table).

10:00-10:15
Welcome and roundtable presentation. – *Stefano Targetti (University of Bologna)*
10:15-10:30
Workshop introduction. Agri-Environmental Climate Public Goods and contract solution types identified in the CONSOLE Project. – *Stefano Targetti (University of Bologna)*
10:30-10:45
Current compliance and monitoring technologies identified in the CONSOLE Project. – *Francisco José Blanco-Velázquez (Evenor-Tech)*
10:45-11:05

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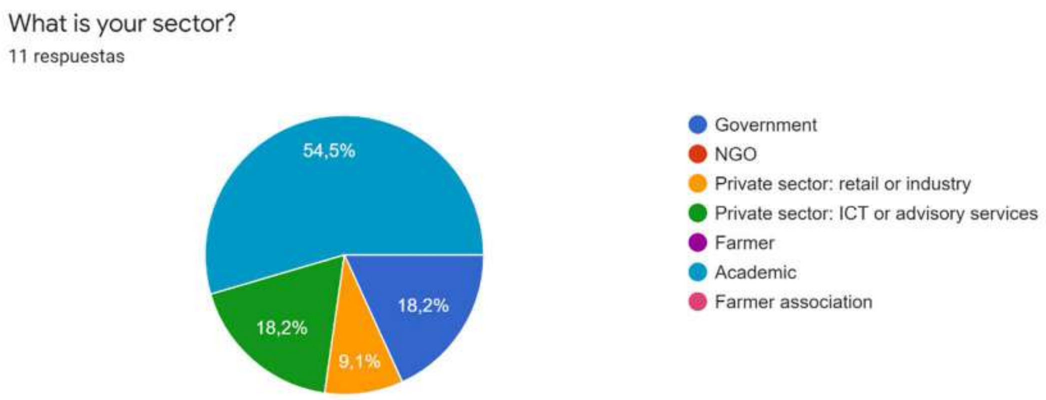
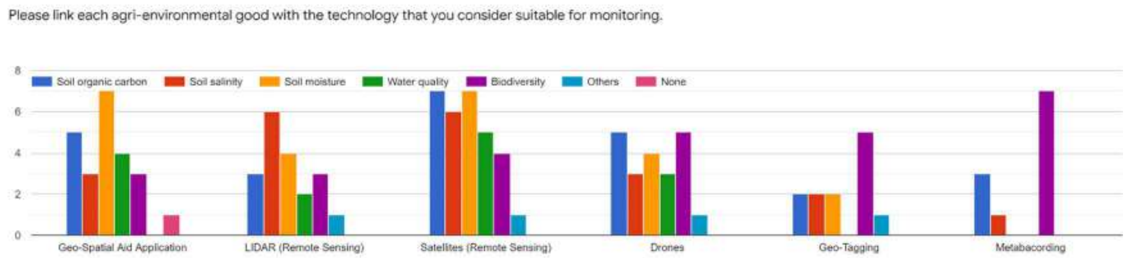
Evaluation of the technologies by the stakeholders. – ***Francisco José Blanco-Velázquez (Evenor-Tech)***	
	11:05-11:35
Discussion of the results. – ***Stefano Targetti (University of Bologna)***	
	11:35-11:55
New technologies development. Trends and discussion. – ***Francisco José Blanco-Velázquez (Evenor-Tech)***	
	11:55-12:00
Closure of the workshop. – ***Stefano Targetti (University of Bologna)***	

A total of 11 participants from public administration, research centers and private sector attended this workshop and provided their experience on this topic.



The participants were asked regarding what technologies they consider suitable for monitoring.



Satellites were selected as the technology most suitable for monitoring soil organic carbon, soil salinity, and soil moisture. However, soil biodiversity is most suitable to be monitored by Metabacording, Geotagging and Drones.

The second question looks for the classification of the technologies according to their importance of new contractual relationships and public goods.

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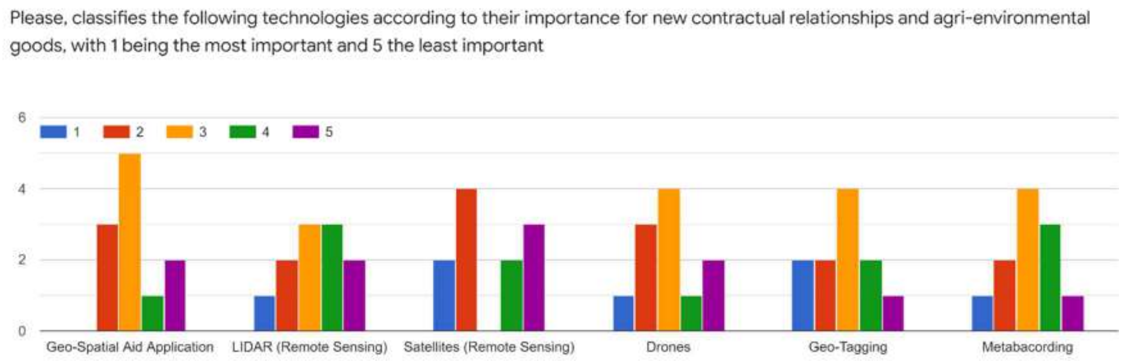
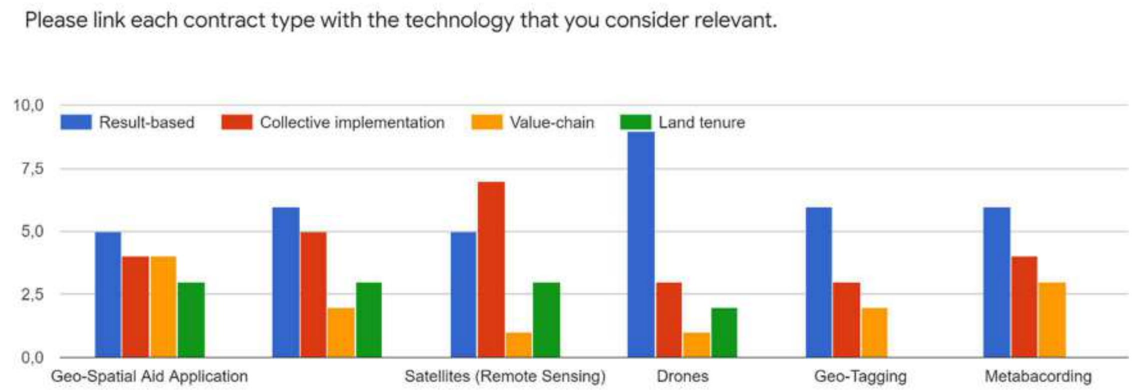


Geo-Tagging and satellites were selected as the most important technologies for new contractual relationships. This makes sense due to the previous results regarding public goods suitable to be monitored by technologies. However, the participants consider that other technologies can be more interesting due to their own characteristics. As the Figure highlight, LIDAR and Metabacording were selected in the medium and least important. As well as, some participants voted that satellite could be least important. This may be due to the restrictions of the use of satellites for some public goods and the requirements identified in previous sections.

Finally, participants provided their perception about what technologies are more relevant for the four types of contract solutions.



The participants considered that Drones, Metabacording, LIDAR and Geo-Tagging are more relevant for Result-Based contracts. Each one provides accuracy data and facilitates the monitoring of target variables. On the other hand, Satellites were selected as the most relevant technologies for Collective Implementation due to their coverage data. For the value chain, Geo-Spatial Aid application was selected because it allows integrating data from different sources (i.e. market prices). Finally, Land tenure does not require a complicated monitoring system so the technologies selected were Geo-Spatial Aid application, LIDAR, Satellites and Drones at the same level.

9 Conclusion

In the light of the information compiled and analysed, several items could be highlighted:

Firstly, the technology may support the design and apply new contractual relationships which promote agri-environmental public goods thanks to the reduction of costs and time. The

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continuous advances in terms of compliance and AECPGs monitoring will allow a better understanding of the measures applied, better monitoring of impacts and reduce errors quickly. However, there are issues pending on solving them. For instance, the lack of interoperability among data sources is a first barrier to compare and analyse results from agricultural and environmental sectors.

Secondly, technology advances at giant steps but not in the same way and in the same place. IoT and AI are the most advanced technologies with several benefits from multiple perspectives. Nevertheless, these technologies required important inputs to facilitate their implementation such as good internet connection, investments, knowledge, etc. Similar situations can be found with remote sensing technologies and/or satellites. The huge data produced required good platform data management in order to analyse the information included.

Thirdly, several methodologies monitor several AECPGs. There is a battery of methodologies available for monitoring several environmental indicators which could be feasible for different regulations and policy measures. A consensus among methodologies, environmental/agricultural indicators targets and policies could facilitate the implementation of real solutions with positive impacts for farmers, environmental and policy sectors.

Fourthly, the technologies analysed for monitoring AECPGs were categorised by stakeholders taking into account their relevance for the four contract types and the main AECPGs. Drones, satellites and Geo-tagging were the technologies more interesting for the stakeholders in terms of facilitating contract types that promote AECPGs provision and their monitoring. However, soil biodiversity monitoring is more limited by these technologies. Metabacording provides a useful tool for monitoring this public good and supporting the result-based contracts.

Finally, the pandemic situation has accelerated the digitalization of the sector. Several software tools and *apps* are in the agricultural sector, especially in the compliance area to reduce physical contact and facilitate the correct fill out of the documents. For instance, several apps are based on geotagging data providing key data required to check the information.

Now, new investment opportunities are on the table to promote the digitalization and, of course, the implementation of technologies/methodologies in the sector. For instance, Next Generation funding measures are focused on this topic for this purpose. In addition, new policies and strategies look for the achievements of the SDGS targeted.

The combination of both strategies could be the starting point of new digital and environmental agriculture.

As well as, current technologies for final consumers are available such as use of QR codes to trace-back the value chain information and use of APPs to promote the direct consumption of local and seasonal products direct from the producer to ethically demanding consumers.

10 Acknowledgment

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11 References

AIOTI WGo6. 2019. IoT and digital technologies for monitoring of the new CAP. https://aioti.eu/wp-content/uploads/2019/05/AIOTI-CAP-controls-and-ICT-technologies-May-2019.pdf

Blanco-Velázquez FJ, Pino-Mejías R, Anaya-Romero M. 2020. Evaluating the provision of ecosystem services of phytoremediation measures for soil contamination. The case study of Guadiamar Green Corridor (SW, Spain). Land Degradation & Development. https://doi.org/10.1002/ldr.3608

De la Rosa D, Anaya-Romero M, Diaz-Pereira, E, Heredia R & Shahbazi F. (2009). Soil-specific agro-ecological strategies for sustainable land use – A case study by using MicroLEIS-DSS in Sevilla Province (Spain), Land Use Policy, 26, 1055–1065. DOI: 10.1016/j.landusepol.2009.01.004

Dedeoglu BB, Bilgihan A, Haobin Ye B, Buonicontri P, Okumus F. 2018. The impact of servicescape on hedonic value and behavioral intentions: The importance of previous experience. International Journal of Hospitality Management. Vol 72, 10-20. https://doi.org/10.1016/j.ijhm.2017.12.007

EC, 2018 Modernisig the CAP: satellite data authorized to replace on-farm checks. NEWS, Brussels, Belgium (https://ec.europa.eu/info/news/modernising-cap-satellite-data-authorised-replace-farm-checks-2018-may-25_en)

EC and ECORYS. 2019. Analysis of administrative burden arising from the CAP. Final Study. 10.2762/521652

Ghoziladeh A, Zizala D, Saberioon M, Borukva L. 2018. Soil organic carbon and texture retrieving and mapping using proximal, airborne and Sentinel-2 spectral imaging. Remote Sensing of Environment 218, 89-103. https://doi.org/10.1016/j.rse.2018.09.015

Hart K and Bas-Defossez F (2018) CAP 2021-27: Proposals for increasing its environmental and climate ambition, report for NABU by IEEP.

Höjgard S and Rabinowicz E. 2012. Evidence-based agri-environmental policies: The Swedish experience. Evaluation of Agri-environmental Policies: Selected Methodological Issues and Case Studies. OECD Publishing, Paris. https://doi.org/10.1787/9789264179332-en

Jakovljević G, Govedarica M, Álvarez-Taboada F. 2018. Assessment of biological and physic chemical water quality parameters using Landsat 8 time series, Proc. SPIE 10783, Remote Sensing for Agriculture, Ecosystems, and Hydrology XX, 107831F (10 October 2018); https://doi.org/10.1117/12.2513277

Krapu C and Borsuk M. 2019. Probabilistic programming: A review for environmental modellers. Environmental Modelling & Software. Vol 114, 40-48. https://doi.org/10.1016/j.envsoft.2019.01.014

PhytoSUDOE (SOE1/P5/E0189): "Demonstration of the improvement in soil biodiversity, functionality and ecosystem services through phytomanagement in contaminated and degraded soils within the Interreg Sudoe area." APPLICATION OF METABARCODING FOR BACTERIAL AND FUNGAL DIVERSITY MONITORING IN PHYTOSUDOE SITES. http://www.phytosudoe.eu/en/application-of-metabarcoding-for-bacterial-and-fungal-diversity-monitoring-in-phytosudoe-sites/

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Ramcharan A, McCloskey P, Baranowski K, Mbilinyi N, Mrisho L, Ndalahwa M, Legg J, Hughes D. 2018. Assessing a mobile-based deep learning model for plant disease surveillance. Computer Vision and Pattern Recognition. https://arxiv.org/abs/1805.08692

Rosero-Vilova O, Borini Alves D, Viassova L, Perez-Cabello F, Montorio Lloveria R. 2017. Modeling soil organic matter (SOM) from satellite data using VISNIR-SWIR spectroscopy and PLS regression with step-down variable selection algorithm: case study of Campos Amazonicos National Park savanna enclave, Brazil. Proceedings Volume 10421, Remote Sensing for Agriculture, Ecosystems, and Hydrology XIX. https://doi.org/10.1117/12.2278701

Ryan SF, Adamson NL, Aktipis A, Andersen LK, Austin R, Barnes L, Beasley MR, Bedell KD, Briggs S, Chapman B, Cooper CB, Corn JO, Creamer NG, Delborne JA, Domenico P, Driscoll E, Goodwin J, Hjarding A, Hulbert JM, Isard S, Just MG, Kar Gupta K, López´-Uribe MM, O'Sullivan J, Landis EA, Madden AA, McKenney EA, Nichols LM, Reading BJ, Russel S, Sengupta N, Shapiro LR, Shell LK, Sheard JK, Shoemaker DD, Sorger DM, Starling C, Thakur S, Vatsavai RR, Weinstein M, Winfrey P, Dunn RR. 2018. The role of citizen science in addressing grand challenges in food and agriculture research. Proc. R. Soc. B 285: 20181977. http://dx.doi.org/10.1098/rspb.2018.1977

Schwartz KR, Parsons ECM, Rockwood L, Wood TC. 2017. Integrating In-Situ and Ex-Situ Data Management Processes for Biodiversity Conservation. Ecol.Vol. https://doi.org/10.3389/fevo.2017.001k20

Taghadosi MM, Hasanlou M, Eftekhari (2019) Soil salinity mapping using dual-polarized SAR Sentinel-1 imagery, International Journal of Remote Sensing, 40:1, 237-252, DOI: 10.1080/01431161.2018.1512767

Thi DN, Ha NTT, Dang QT, Koike K, Trong NM. 2019. Effective Band Ratio of Landstat 8 Images based on VNIR-SWIR Reflectance of Topsoil for Soil Moisture Mapping in a Tropical Region. Remote Sensing, 11(6), 716. https://doi.org/10.3390/rs11060716

Wiggins, S. 2004. Agriculture, hunger and food security" DFID, United Kingdom.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement GA 817949