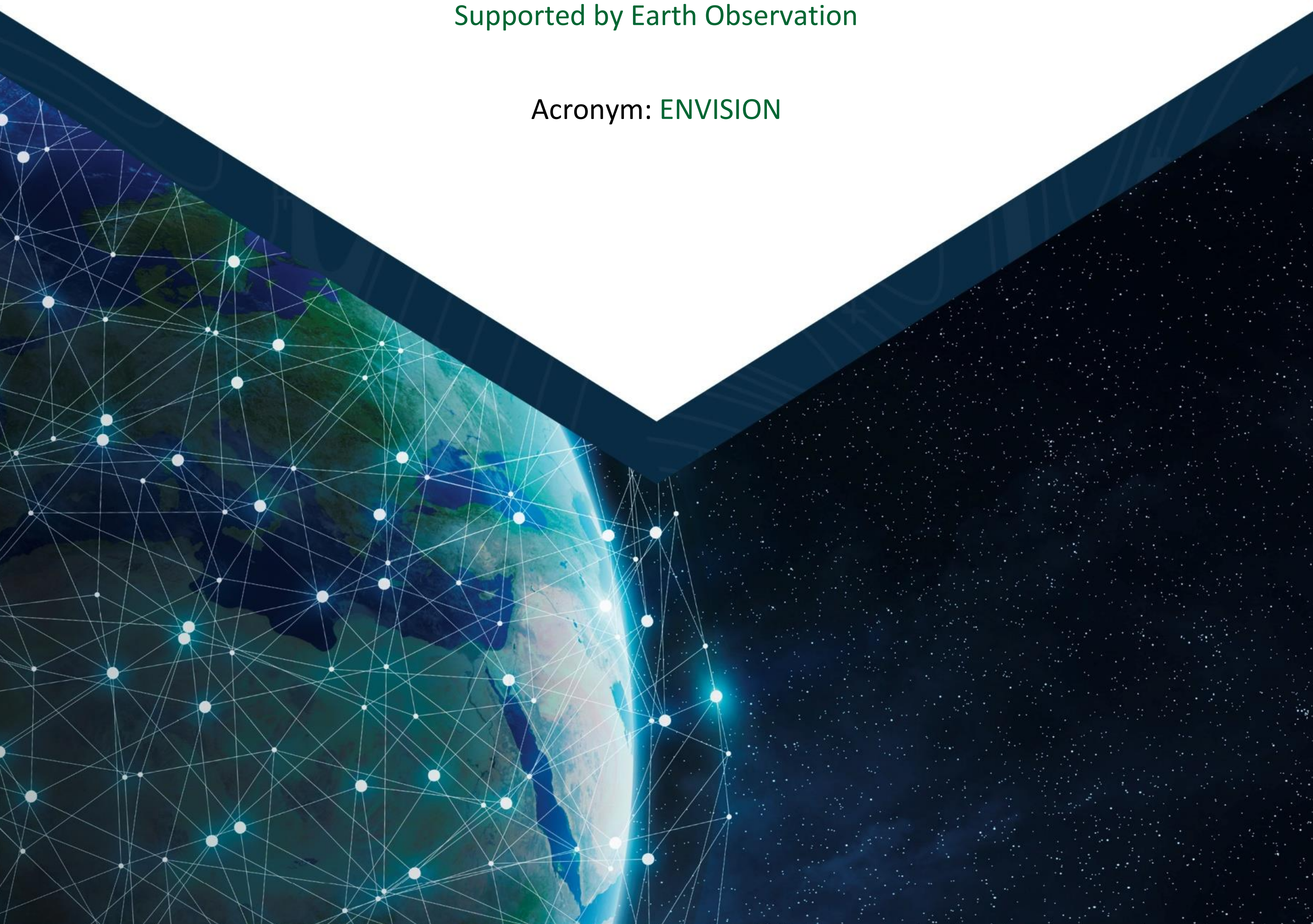
REVIEW OF CURRENT SERVICES PROVISION

Project: Monitoring of Environmental Practices for Sustainable Agriculture Supported by Earth Observation

Acronym: ENVISION



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LIST OF ABBREVIATIONS

BPS – Basic Payment Scheme

CAP – Common Agricultural Policy

CB – Certification Body

CwRS – Control with Remote Sensing

DIAS – Data and Information Access Services

EAFRD - European Agricultural Fund for Rural Development

EO – Earth Observation

ESA – European Satellite Agency

EU – European Union

EV ILVO – The Institute for Agricultural, Fisheries and Food Research, Belgium

GAEC – Good Agricultural and Environmental Condition

GEOSS – Global Earth Observation System of Systems

GHG – Greenhouse Gases

GIS – Geographical Information System

GNSS – Global Navigation Satellite System

IACS – Integrated Administration and Control System

IAF – International Accreditation Form

IDB – Index DataBase

JRC – Joint Research Centre

LPIS – Land Parcel Identification System

MS – Member State

NDVI – Normalised Difference Vegetation Index

NIR – Near Infra-Red

NOA – National Observatory of Athens

PA – Paying Agency

RECAP – peRsonalised public sErvices in support of the implementation of the CAP (project)

RFID – Radio Frequency Identification

SI – Sustainable Intensification

SMR – Statutory Management Requirements

SWIR – Short Wave Infra-Red

SWOT – Strengths, Weaknesses, Opportunities and Threats

UAV – Unmanned Aerial Vehicle

VHR – Very High Resolution

1 Executive Summary

Introduction

- This report explores the potential for Earth Observation data services to provide authenticating agencies, such as national Paying Agencies and Certification Bodies, opportunities to monitor agricultural practices remotely, along with the potential of these services to improve decision making that can facilitate the move towards more sustainable agriculture systems.

- As the global need for food increases, there a growing need to balance this production with environmental protection and for a move towards sustainable intensification of agricultural systems. Successive reforms of the Common Agricultural Policy have led towards more sustainable farming approaches; with subsidy payments to farmers being subject to meeting an increasing number of environmental measures. However, more demanding agri-environmental mechanisms can achieve higher environmental standards and voluntary market-based schemes allow farmers to achieve certification to demonstrate their compliance with higher environmental and animal welfare standards.

Remote assessment of compliance

- All such schemes require some form of inspection to ensure compliance with the policy measures and achievement of standards. Elements of these inspections can be conducted remotely, with the associated reduction in monitoring costs, through services and products based on Earth Observation data. These services are either commercial or are available for free to the end users and can continuously monitor indicators of vegetation health, soil quality/protection, water quality/availability, biodiversity and ecosystem health.

- Adoption of these services by Paying Agencies and Certification Bodies has been slow, but they provide such bodies an opportunity to switch from a single time-point inspection to a continuous, systematic monitoring process (‘checks by monitoring’) that is automated, across wider areas and covers all beneficiaries, thereby preparing for the post-2020 CAP changes.

- At the same time, farmers are choosing to adopt new technologies on-farm to assist with agronomic and management decision making. These new, data-driven, precision agricultural technologies generate large amounts of spatially explicit information that can improve the financial, social and environmental sustainability of their agricultural system. Earth Observation based services to arable farmers facilitate the precise and variable application of fertilisers, pesticides and irrigation and can provide yield mapping and predictions to improve production while minimising environmental impact. Livestock farmers can also benefit from animal welfare and tracking and pasture management while also recording indicators of greenhouse gas emissions and other metrics of climate impacts.

- These data can be used to provide the farmer with a picture of farm performance but can also provide automated evidence of compliance with regulations which can reduce their administrative burden. The control system for organic agriculture is due to be strengthened in 2021 and all certification schemes aim to continually drive up farming standards, therefore remote, continuous assessment is going to be needed to keep pace with change. COVID-19 has driven this by necessity, but changes to operating protocols are needed before longer term adoption.

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Services for Paying Agencies

- Our analysis of the current EO service provision to Paying Agencies (n=14) that could allow remote monitoring showed that they are considered by PAs to be cost-effective solutions that are available both as generic and customised solutions with great potential to reduce non-compliance with agri-environmental policies. They are currently working well to help monitor i) crop classification, ii) the identification of mowing, ploughing and harvesting events and iii) the marking of non-agricultural land to update their LPIS, predominantly for compliance checks, but also for systematic checks for financial aid. However, 43% do not have the organisational capacity to adopt them currently despite most of them receiving support from the EC.
- Weaknesses in these services were identified to be a lack of personnel training and knowledge on how to use them and the accuracy level of satellite images that limit the number of agricultural practices that can be monitored remotely.
- The additional services needed by PAs are i) monitoring of the Soil Organic Carbon, ii) identification and monitoring of organic crop cultivations, iii) monitoring crop fertilisation and plant protection, and iv) detection and monitoring of grazed grassland, areas under risk of soil erosion, burnt and abandoned land, and crop seeding.
- Important aspects that need to be addressed before widespread adoption by PAs include; the need for improved rural internet access, the use of a common platform and data format between agencies and farmers that can link up with other IT management systems, reduced costs for development and implementation of services, and the constant need for adaptation and change. The 2020 European Court of Auditors report showed that those PAs who are already using EO services for compliance checks identified that future changes and uncertainty over rules, small land parcels and inadequate IT systems present the biggest challenges in practical terms.

Services for Certifying Bodies

- Our analysis of the current EO service provision to Certification Bodies (n=8) showed that they have greater capacity than PAs to adopt novel IT services (88% were positive about adoption) despite receiving less training and support. They are currently using EO services to remotely monitor crop diversity, Soil Organic Carbon, vegetation status, crop growth, grassland management and soil erosion, plus a few other categories, predominantly for compliance checks. A third of Certification Bodies reported using geo-tagged photos for monitoring agricultural parcels.
- Weaknesses were identified around privacy, technical limitations such as inability to collect and analyse crop, soil and water samples, observe and assess biodiversity, evaluate crop health, and estimate the usage of fertilisers and pesticides.
- Opportunities for new service improvement included an increase of spatiotemporal resolution of relevant data products to facilitate observations of inaccessible plots and for several critical growing periods throughout the year.
- The additional services they would like include i) resource scarcity and degradation particularly of water and fossil fuel, ii) harmful emissions, iii) insect and fungus related issues (plant health) and crop protection practices, and iv) harvesting. Currently, on-farm inspections are still mandatory, so a greater acceptance of remote monitoring is required before full scale adoption is possible.

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Barriers to uptake

- For farmers, the uptake of EO-based services (predominantly as precision agricultural technologies including machine guidance and variable rate technologies) is low across Europe. The cost (both financial and personnel time) of adoption of precision/smart farming technologies is a barrier, data privacy concerns and ethical implications are also important, while there are still issues relating to access to computing technologies, IT skills and low trust in institutional frameworks. Peer-to-peer-sharing and learning is an important approach that can build trust and confidence amongst and between agencies and farmers. In addition, adoption could be improved with the provision of independent informational support and demonstration of the viability of economic return.

Conclusions

- In conclusion, there is huge potential to develop EO services to help PAs and CBs to monitor scheme compliance remotely and to incorporate on-farm data collected by precision technologies as an evidence source. While uptake of these technologies by authenticating bodies and farmers is currently low, the knowledge gained from bringing these together could well encourage and promote more sustainable farming systems by providing transparent information towards achieving a common goal.

- A trusted, robust infrastructure around the EO services is needed to ensure that all data collection/sharing systems can 'talk' to each other. In addition, there needs to be a campaign to increase awareness of the availability of these EO services alongside development of training and support systems. However, as noted in the response from the CBs, to maximise adoption of the ENVISION services, all stakeholders need to be involved from the start in co-creation to produce resilient, useful, adaptable, cost-effective services that help to achieve the goal of sustainable agriculture.

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2 Market need for monitoring of environmental practices for sustainable agriculture

2.1 Sustainable agriculture

The global population is growing and is expected to reach 9 billion by 2050. The goal of sustainable agricultural systems is to meet the population's current and increasing need for food without compromising the ability of future generations to meet their own needs. Within this, the stewardship of natural and human resources needs to be balanced with economic considerations. It is generally considered that the three pillars of sustainability, social (people), environmental (planet) and economic (resources), need to be held in a dynamic balance or the system becomes unsustainable. The sustainable intensification of agricultural systems aims to increase agricultural yields with the use of fewer inputs and without creating an adverse environmental impact or employing additional limited natural resources such as agricultural land.

2.2 Environmentally-friendly agricultural practices

Adopting and maintaining environmentally-friendly agricultural practices is core to achieving sustainable agricultural intensification. This is because agricultural malpractices can contribute to a range of environmentally damaging effects including greenhouse gas emissions, soil degradation, loss of soil organic carbon, water pollution and negative impacts on biodiversity.

There are various policy and market-based approaches that exist to encourage and support more environmentally-friendly farming practices in Europe. The main policy instrument is the Common Agricultural Policy (CAP) of the European Union which has been progressively reformed to improve the sustainability of European farming systems (European Commission, 2020a). The CAP reforms of 2018 further increased the importance of this policy in tackling climate change and environmental protection and aim to support farmers to contribute towards the commitments in the European Green Deal (European Commission, 2020b). In addition to these EU-wide policies, there are Pillar II rural development policies developed by Member States and several voluntary market-based initiatives that support more environmentally friendly farming practices. Farmers can apply for specific certification schemes that go beyond the requirements set out by regulation and the CAP and provide certification that agricultural products have been produced according to a series of specific standards.

2.2.1 Integrating Environmental Requirements into the CAP

'Cross compliance' is the term given to the mechanism within the CAP that links direct payments to compliance by farmers with basic standards concerning the environment, food safety, animal and plant health and animal welfare, as well as the requirement of maintaining land in good agricultural and environmental condition (European Commission, 2020c). In the frame of cross compliance, in order to get support payments through the Basic Payment Scheme, farmers must not only be compliant with 18 Statutory Management Requirements (SMRs), based on pre-existing EU directives and regulations, but also with 11 standards aimed at ensuring the "good agricultural and environmental condition" (GAEC) of agricultural land and landscape conservation. The Statutory Management Requirements (SMRs) are related to environment, animal and plant health, public health and animal welfare and identification and registration of animals. The Good Agricultural and Environmental Condition (GAEC)

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standards refer to a wide range of issues including soil protection, maintenance of soil organic matter and structure, avoiding the deterioration of habitats, water management and maintenance of permanent pastures.

In addition to the above, as a result of the 2013 CAP reforms, an element (30%) of the basic payment has been conditional on the adoption of additional 'greening' measures, providing support to farmers who adopt or maintain farming practices that help meet environmental and climate goals. Farmers need to establish an agricultural production system that considers the following three actions (European Commission, 2020d):

- crop diversification: a greater variety of crops makes soil and ecosystems more resilient;
- maintaining permanent grassland: grassland supports carbon sequestration and protects biodiversity (habitats);
- dedicate 5% of arable land to areas beneficial for biodiversity: Ecological Focus Areas (EFA), for example trees, hedges or land left fallow that improves biodiversity and habitats (EC website, 2020).

2.2.2 Agri-Environment Schemes

Across Europe, Agri-environment Schemes provide important sources of funding that enable farmers to meet environmental objectives on their farms. The schemes are funded under the second pillar of the CAP, supporting the EU's rural development policy. These schemes include measures that are targeting at the achievement of specific environmental objectives, such as the protection or enhancement of biodiversity, soil, water, landscape or air quality, or climate change adaptation and mitigation. The schemes and measures are in many cases designed to meet several environmental objectives, and also to contribute to economic and social benefits. Farmers who choose to adopt those specific environmental management practices and therefore go beyond the basic requirements (e.g. cross compliance measures and greening measures in the BPS) are then eligible to claim payments for agri-environmental measures. Agri-environmental Schemes have been are mandatory for Member States since 1992, but enrolment is voluntary for farmers.

There is a wide variety of management practices promoted through the AES mechanism, which reflects the complexity of both farming systems and ecosystems across the EU. Some examples of measures include organic farming; integrated production; reducing inputs of fertilisers and/or pesticides; crop rotation; enhancing habitats for wildlife; introducing buffer strips; managing livestock to provide the right grazing pressure on grassland species and avoiding the risk of soil erosion; and conserving genetic resources in agriculture and local species and in animal breeds threatened by genetic erosion. Approximately 25% of the EU's utilisable agricultural area is under AES contracts with farmers, including organic farming (Science for Environment Policy, 2017), and expenditure on area based agri-environmental measures was €2.4 billion in 2018, with a further €1.6 billion on area-based rural development measures including organic farming (European Court of Auditors 2020)

2.2.3 The future of the Common Agricultural Policy

On 1 June 2018, the European Commission presented a number of legislative proposals on the CAP for the period 2021-27. The proposals aim to ensure that the CAP can continue to provide strong support for European farming, enabling prosperous rural areas and the production of high-quality food. The future CAP will be built within a framework of a new and more ambitious green architecture which

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combines the social, economic and environmental approaches towards achieving a sustainable system of agriculture in the EU. The utilization of the latest advances in technology (both production and decision-making enabling technologies) will mean that the CAP aligns with the European Green Deal, which aims for the creation of a competitive, innovative, inclusive and environmentally friendly future for Europe.

The role of farmers, agri-food businesses, foresters, and rural communities is essential within the objectives of the Green Deal and is identified in a number of key policy areas, but most specifically to the following:

- The Farm to Fork strategy building a sustainable food system (Farm to Fork Strategy – for a fair, healthy and environmentally-friendly food system | Food Safety (europa.eu))
- Adding to the new biodiversity strategy by protecting and enhancing the variety of plants and animals in the rural ecosystem; (EU Biodiversity strategy for 2030 | European Commission (europa.eu))
- Contributing to the climate action of the Green Deal to achieve the goal of net-zero emissions in the EU by 2050; (EU climate action and the European Green Deal | Climate Action (europa.eu))
- Supporting the updated forestry strategy by maintaining healthy forests;
- Contributing to a zero pollution action plan by safeguarding natural resources such as water, air and soil.

Monitoring and evaluation of current and future policy mechanisms included in the CAP is essential to ensure that they are having the desired impact on environmental and climate protection.

2.3 Paying Agency monitoring requirements

The CAP is financed by the EU budget, including the European Agricultural Fund for Rural Development (EAFRD). Each EU Member State (MS) has a Paying Agency which administers the EAFRD and provides support payments to farmers through the Basic Payment Scheme (BPS). As outlined in section 2.2.1, Cross Compliance is a set of rules (SMRs and GAEC codes) with which farmers need to comply in order to receive this form of payment (European Commission, 2020c). The Paying Agencies (PAs) and their delegated bodies must ensure the eligibility of the applications from farmers through a series of farm checks of compliance of the management practices to the CAP rules. These are currently performed as on-farm checks in person on a randomly selected and risk analysis-based sample of farms. Poorly performing farms may be subject to financial penalties and risk exclusion from future support schemes.

Each Member State is responsible for the implementation of cross compliance. At first, they have to enact the corresponding national legislation to address cross compliance at national level. Afterwards, they have to establish a control system under which a sample of farmers (at least 1%) is checked with a view to detecting non-compliance. In each Member State, Paying Agencies (PAs) have the responsibility to control cross compliance requirements and assess the severity, extent, permanence and repetition of the detected non-compliance. Farmers' non-compliance with standards may lead to

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reduction or, in extreme cases, cancelation of their agricultural support and rural development payments. Additionally, apart from cross compliance, they may also be sanctioned under the local legislation arising from the Directives concerned. The selection of farms to be checked is based on risk analysis according to the specific legislation or to the given requirements.

2.4 Certification Body monitoring requirements

In addition to the policy mechanisms within the CAP, there are many voluntary certification schemes for agricultural products providing assurance that certain characteristics or attributes of the product, or production system, have been met (Gawron & Theuvsen, 2009). These schemes are monitored by Certification Bodies (CBs). These are independent bodies that are accredited by a national accreditation body as appointed by Member States (EC Regulation No. 765/2008) or signed up to the multilateral recognition arrangement for product certification of the International Accreditation Form (IAF). Certification of compliance with the scheme requirements is awarded following inspections and scheme logos are used to denote this on food products. Inspections (certification audits) ensure that producers in their area of responsibility follow the standards and meet verifiable criteria (European Commission, 2010). For example, for organic certification, farms must be checked by a Certification Body before they can market their products as organic and can demonstrate that they meet the control measures of the EU (or equivalent for countries outside the EU) according to the EC Regulation 2092/1991. Once they have been checked and found compliant, they receive a certificate confirming that they meet the EU requirements and can label their produce with the EU organic logo.

In addition to organic certification, other assurance schemes exist with their own logos to certify to the consumer that the food product has met a particular set of standards (food safety, animal welfare, environment, traceability or a combination of these). A Europe-wide study of these (Ipsos & London Economic Consortium, 2013) found over 900 food labelling schemes, 78% of which were certification schemes (see Figure 1). Example schemes from the UK include the Red Tractor scheme, the LEAF Marque and RSPCA Assured.

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Figure 2. Number of food labelling schemes managed per country (Taken from Ipsos and London Economic Consortium, 2013)

LEAF have implemented a protocol for remote audits during the COVID-19 pandemic. As part of the activities in Task 2.2 we will explore the integration of Earth Observation data to support remote monitoring of these Control Points.

Exemplar Certification Scheme

The LEAF Marque aims to inspire and enable sustainable farming that is prosperous, enriches the environment and engages local communities. The Intended Impacts of LEAF Marque are to improve:

- *Soil management to enhance soil quality and soil health*
- *The resilience of cropping systems*
- *Management of water use and water quality*
- *Energy efficiency and energy use*
- *Waste management*
- *Management of livestock to enhance the environment*
- *And enhance the management of native habitats and biodiversity*

All LEAF Marque audits are carried out independently, on-farm on an annual basis, either at the same time as the baseline certification system(s), or as a stand-alone audit. The Control Points for the audit are:

- *Organisation and Planning*
- *Soil Management and Fertility*
- *Crop Health and Protection*
- *Pollution Control and By-Product Management*
- *Animal Husbandry*
- *Energy Efficiency*
- *Water Management*
- *Landscape and Nature Conservation*
- *Community Engagement*

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2.5 Existing EU knowledge support systems

The Joint Research Centre (JRC), the European Commission’s science and knowledge service, supports agricultural monitoring activities and has incorporated the use of Earth Observation (EO) data as a cost-effective way to gather data on crop areas and other aspects of land use. They have developed the digital Land Parcel Identification System (LPIS) which records all agricultural parcels (a continuous area of land, declared by one farmer, which includes no more than one crop group) considered eligible for CAP payments. This is based on parcel area measurement using Global Navigation Satellite System (GNSS) devices. The JRC also support initiatives such as Control with Remote Sensing (CwRS) and the Integrated Administration and Control System (IACS) to help the European Commission and MSs to move towards sustainable farming practices with reduced environmental impacts.

To support the integration of EO data into research activities, the European Commission has created 5 cloud-based platforms to facilitate and standardise access to Copernicus services (the European Union’s Earth Observation Programme). These platforms are known as the Data and Information Access Services (DIAS). These platforms provide data in suitable formats for enabling remote monitoring of land use, but there is a need for the development of new data products that can track and assess environmentally-friendly agricultural practices.

It is therefore necessary to understand the possible pathways of integration of remotely-sensed EO data and farm level generated data to develop services for the continuous monitoring of agricultural parcels. A detailed review of the existing scientific and peer reviewed literature follows in the next section, to better inform the development and the use of technologies for decision making, monitoring and strategic development at a farm level. The main objective is to explore how EO data at a farm level can be used for remote monitoring of environmentally-friendly agricultural practices.

3 The use of remote sensing technologies for decision making, monitoring and strategic development, at farm level

"Remote sensing is the acquisition of information about an object or phenomenon from distance. This involves an instrument or a sensor mounted on a platform, such as a satellite, an aircraft, an UAV/UGV [Unmanned Aerial Vehicle / Unmanned Ground Vehicle], or a probe" (Weiss, 2020).

3.1 Earth observation data acquisition

Here we focus on the acquisition of information, through satellite and drone technology, for use in decision making, monitoring and strategic development at farm level. Data collected by satellites and drones in agricultural settings has been used to monitor (for example) (Andrew *et al.*, 2014; Weiss, 2020):

- Land use – extent of annual and permanent crops, crop diversity
- Expansion or reduction of agricultural land area.
- Management practices e.g. grazing, mowing, burning, etc.
- Crops – growth, health, yields, etc.
- Water – quality and abstraction.
- Soil – cover, properties, erosion.
- Environmental targets – related to, for example, crop diversity and land use and condition.

The data collected may be images (VHR – Very High Resolution), or multispectral data. Multispectral data can provide detailed information on a range of crop and soil traits using comparisons between (for example) Short Wave Infra-Red (SWIR) and Near Infra-Red (NIR) to distinguish between plants and soil, calculate vegetation indices in order to measure variables such as crop growth, moisture and chlorophyll content (Henrich *et al.*, 2009; Ray and Neetu, 2017) and distinguish between different crop types (Sitokonstantinou *et al.*, 2018).

3.1.1 Continuous EO data collection

Monitoring of agricultural parcels with the use of remote sensing EO data may be continuous, or employ "snapshots" – a single image or set of data collected at one point in time. Continuous monitoring, such as that available from the Sentinel satellites can enable monitoring of a farm, region, country for the entire year. Sentinel-1 radar satellites can, for example, provide data on crop biomass and detect when a crop has been harvested. Sentinel-2 satellites use high-resolution cameras to generate images which can be used to distinguish between different crop types, assess crop health and monitor land-use. Both Sentinel-1 and 2 cover Europe every 3-4 days (European Space Agency, 2018).

3.1.2 Snapshot EO data collection

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, can offer a more of a "snapshot" approach over a smaller area. Drones produce VHR images, offering precision. However, these images have limited geographical coverage and do not cover the wider scope of satellites (Earth Observing

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System, 2019). UAVs are high end reliable instruments and are becoming widely used by farmers to inspect the condition of crops, permanent vegetation and soil with the use of 2D or 3D images. This soil and field analysis provide data that can be useful for decision making about, for example, irrigation and managing nitrogen level on fields for better crop growth. Furthermore, UAVs assist in precision farming approaches and hence monitor the application of pesticides, water and use of fertilisers and thus result in higher input use efficiencies. Drones may also offer a more immediate method of detecting and responding to, for example, threats to crop health (https://aphascience.blog.gov.uk/2019/09/20/drones/). The two methods of image and data acquisition can complement each other and therefore provide values of Normalised Difference Vegetation Index (NDVI) and values from multispectral sensors, thus helping farmers better track transpiration rates and sunlight absorption rates and hence contribute to the better management of the crop health. Also, the integration of GIS mapping with the use of drones provides the option efficient input cost management and better business management.

3.2 EO data uses in agricultural decision-making

EO data are key inputs for the analysis and decision-making processes that are critical to enhance the monitoring of the limited natural resources employed to produce food. Information derived from EO systems are used to enhance the resilience of the production systems to climate shocks, water scarcity and to allow improvements in productivity both in terms of economic efficiency and yield. EO data is therefore considered by policy makers and farmers as an essential tool to support the monitoring of the crop and livestock production cycle, from designing, implementing, evaluating and supporting the development of an adaptive decision-making system.

EO data has a range of applications and uses within agriculture. These include:

Vegetation Indices

At farm level – monitoring crop growth and development through, for example, vegetation indices and biomass monitoring. A detailed vegetation index database, the Index DataBase (IDB), lists a significant number of remote sensing indices and is available here - https://www.indexdatabase.de/ Indices can support yield forecasting / predictions, monitoring for diseases or pest outbreaks, providing data to support precision farming techniques such as variable rate fertiliser applications or variable irrigation.

Crop Classification

Remote sensing data can also be used to automatically distinguish between crops / classify crop types. (Schmedtmann and Campagnolo, 2015; RECAP, 2018a, 4.4, p29/30; Kussell *et al.*, 2016; Sitokonstantinou *et al.*, 2018). This can enable monitoring of crop diversity, land use and monitoring of buffer zones and field margins (Sitokonstantinou et. al., 2018) and potentially features such as hedgerows (Bégué et al, 2018). See also https://www.ceh.ac.uk/crops2015

Monitoring potential environmental violations and support policy implementation

The recent advances in the technologies of EO have increased the ability to inventory, monitor and evaluate the status of both natural and artificial ecosystems (Patias *et al.* 2020). Hence, EO data can be used for monitoring farmland in order to check compliance with the conditions required for subsidies and payments.

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EO monitoring for sustainability and environmental reasons

Tied in with various aspects, such as compliance monitoring or the sustainable intensification of agriculture, EO data can be used for yield predictions; land use analysis; monitoring of changes in farmland area; and monitoring aspects of climate change. It is therefore possible for EO to provide a readily accessible, long-term database with EU and global coverage that incorporates both spatial and temporal resolutions. Hence, EO could significantly contribute to SI assessments, providing opportunities to quantify agricultural intensity and environmental sustainability.

The list below summarises the potential EO-based indicators which could be used to assess environmental sustainability.

Indicators of Environmental Sustainability

Vegetation health
- Crop condition
- Biophysical traits inc. biomass, fraction of absorbed photosynthetically active radiation (fAPAR), photosynthetic activity
- Structural traits inc. crop/canopy height, leaf area index (LAI), biomass, canopy morphology
- Biochemical traits inc. chlorophyll (Ch), water content, nitrogen (N) and phosphorus (P)

Soil Quality
- Soil organic carbon (SOC)
- Soil organic matter (SOM)
- Soil moisture content
- Soil salinity
- Crop residue/conservation tillage density
- Nitrogen status/availability

Soil erosion/protection
- Vegetation cover
- Erosion feature detection
- Erosion modelling e.g. USLE

Water Quality
- Water Quality Indices derived from different spectral band combinations
- Physical water quality parameters incl. total suspended solids (TSS), turbidity, suspended sediment concentration (SSC), chlorophyll concentration, temperature and water clarity
- Chemical water quality parameters incl. concentration of total nitrogen, NO_3-N (nitrate as nitrogen) and total phosphorus
- Water quality proxy e.g. health of vegetation alongside water bodies

Water Availability
- Water body area and configuration
- Water use efficiency and crop water stress
- Water level and volume

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Biodiversity

- Direct mapping of individuals and associations
- Plant (and animal) species diversity
- Habitat suitability based on known habitat requirements of specific species
- Species Richness
- Landscape structure inc. composition, isolation and complexity
- Invasive Species

Ecosystem Health

- Vigour - Net Primary Productivity (NPP) & Gross Primary Productivity (GPP) - Fractional cover of green vegetation, non-photosynthetic vegetation (NPV) and bare soil - Biochemical properties inc. nitrogen, phosphorus and chlorophyll
- Organisation
- Resilience - Species richness and biodiversity
- Ecosystem Services as a Proxy for Ecosystem Health - Vegetation structural traits

List adapted from Hunt *et al.* (2019)

3.3 EO data service providers

Data from the Sentinel satellites is freely available through the Copernicus platform (https://land.copernicus.eu/). A wide range of commercial companies and organisations offer services in using and interpreting remote sensing data for monitoring crops and farmland and supporting agricultural decision making, for example;

- SatAgro - www.satagro.pl/
- Agricolus - www.agricolus.com/en/

A number of EU Horizon 2020 projects have investigated the use of EO / satellite data to support agricultural and environmental monitoring and decision making. Examples include:

- EOMORES (H2020 project), monitoring water quality https://eomores.eu/
- Demeter (H2020 project) digital farming https://h2020-demeter.eu/
- RECAP (H2020 project) monitoring cross compliance (https://www.recap-h2020.eu/)

In addition, a wide range of organisations and companies offer services and expertise in relation to EO data and agricultural monitoring. A list of current providers of EO services has been gathered and categorised (See Annex I). The list aims to summarise the available tools for providing services in relation to a number of areas, including: monitoring performance; assessing land derived inputs; policy evaluation and implementation; reducing farmer administration burden and improve decision making; promote synergies amongst stakeholder groups; provide an early warning system; enhance productivity and support the sustainable intensification of agricultural systems. These services are either commercial or are available for free to the end users (farmers, PAs, CBs, agribusiness consultants). The table in Annex I gives information about the different EU research projects, service provision companies and start-ups, as well as a short description of the objectives and the services provided. The information was used in the design of the questionnaire to PAs, CBs and lighthouse stakeholders of ENVISION to carry out a SWOT (Strengths, Weaknesses, Opportunities and Threats)

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analysis of the current technologies in terms of the technical and operational requirements. Furthermore, these will be used as reference points across the tasks of WP2 to continuously review and assess the current status of commercial and non-commercial services.

3.4 How is remote monitoring currently used at farm level?

Remote monitoring at farm level plays an important role in precision agriculture. Precision agriculture is defined as 'a whole-farm management approach using information technology, satellite positioning (GNSS) data, remote sensing and proximal data gathering. These technologies have the goal of optimising returns on inputs whilst potentially reducing environmental impacts' (European Parliament, 2014). The opportunities available to EU farmers for the adoption of precision agriculture and the potential support for the CAP in terms of monitoring and implementation are presented in report from the DG for internal policies[1]. The document highlights how precision agriculture has become possible thanks to the development of sensor technologies combined with procedures to link mapped variables to appropriate farming practices such as tillage, seeding, fertilization, herbicide and pesticide application, harvesting and animal husbandry. The report covers applications in the arable, livestock, fruits and vegetables and the viticulture sectors.

This gathering and analysis of remote monitoring data supports and enables a range of measures at farm-level such as:

- precision and variable rate applications of fertilisers (Basso *et al.*, 2015) and pesticides (Campos *et al.*, 2020),
- precision irrigation (de Lara *et al.*, 2019)
- yield monitoring and predictions (Toscano *et al.*, 2019; d'Andrimont *et al.*, 2020).

Precision agriculture and remote monitoring can also play a substantial role in livestock farming, often in animal welfare and tracking. There may also be remote monitoring of pasture and grassland (Estel *et al.*, 2018) and the variable rate application of manure (Baille *et al.*, 2018) can involve remote monitoring. However, there is less of a focus on the use of EO data from satellites or drones, with wider use of remote monitoring via Radio Frequency Identification (RFID) tags and sensor networks monitoring (for example) ambient temperature and feed intake (O'Grady and O'Hare, 2017).

Precision agriculture is seen as a potential route to sustainable intensification (SI) within agriculture, enabling monitoring of crops and livestock and adjusting farm management practices accordingly to improve sustainability (Dicks *et al.*, 2018). This collection and analysis of remote sensing data can also contribute towards various environmental measures, such as

- mitigating greenhouse gas emissions (Soto *et al.*, 2019),
- measuring variables in crops associated with climate change
- measuring crop growth / estimating yields in areas vulnerable to food insecurity (Becker-Reshef, 2020)

[1]https://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT%282014%29529049_EN.pdf

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Remote sensing data is also currently used to monitor agricultural land for compliance. Within the EU, Paying Agencies (PAs) and Certification Bodies (CBs) can use EO data to monitor farmland and check compliance.

Each EU Member State (MS) has a Paying Agency (or Paying Agencies)[2], entities responsible for monitoring farmers' performance in relation to the environmental rules stemming from EU policy. The current practice is that these entities mainly perform on-farm checks (on a randomly selected and risk analysis-based sample of farmers), and farmers with poor performances in relation to their subsidies' requirements are subject to penalties which may include exclusion from participation in funding schemes and/or monetary fines. This monitoring system partly relies on Control with Remote Sensing (CwRS) with the use of EO data: Very High Resolution – VHR and High Resolution – HR (10-20m) images.

With regard to agricultural certifications within Europe, inspection and certification for agricultural products is conducted by Certification Bodies (CBs)[3]. These entities have to inspect several requirements, and perform on-farm checks once per year, to ensure that farmers applying for a specific certification have met the required standards. From 2021, there will be an overhaul of the current regulations for organic farming, reflecting the changing nature of this rapidly growing sector (the global market accounted for 50.9 million ha of farmland in 2015 and is expected to expand at a growth rate of 8.4% by 2026[4] - overall valued at US$ 81.6 billion in 2015[4]). According to the EU regulation 2018/848 on Organic Production and Labelling of Organic Products, due to come into force in 2021, the control system will be strengthened thanks to tighter precautionary measures and robust checks along the entire supply chain.

With the changing CAP rules regarding remote monitoring, both PAs and CBs are able to use remote sensing data in order to monitor compliance. A survey undertaken by the European Court of Auditors of 66 PAs found 15 had used Copernicus Sentinel data in 2019 to check some aspects of compliance (European Court of Auditors, 2020). The report also highlights data from the JRC showing that "across the EU an average of 80 % of field inspections are now performed using remote sensing".

3.5 Farmer use of remote sensing technologies

3.5.1 What are remote sensing (EO) based data services?

Remote sensing data may involve very high resolution (VHR) images or large amounts of data requiring processing, analysis and interpretation before it can be utilised by farmers, PAs and CBs. Companies and organisations, commercial and non-for-profit, offer data services in collating and interpreting EO data, for example monitoring land cover and generating vegetation indices (See Annex I). Data and Information Access Services (DIAS) is one example. This was funded by the European Commission and comprises five cloud-based platforms providing centralised access to Copernicus data and information and processing tools (both open source and pay-per-use). DIAS offered its services in the form of online platforms to discover, manipulate, process and download Copernicus Sentinel data and information.

[2] A Paying Agency is responsible for the management and control of CAP expenditure. Currently, 78 PA for EAFRD are operating within the 28 MS.

[3] Certification Bodies are independent bodies appointed by the Commission to ensure that organic producers in their area of responsibility follow the standards and control measures of EU, or equivalent to the them for countries outside the EU.

[4]https://www.globenewswire.com/news-release/2019/01/25/1705536/0/en/Global-Organic-Farming-Market-is-Expected-to-Exhibit-a-Growth-Rate-of-8-4-by-2026.html

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3.5.2 How does this allow remote monitoring or replacement of on farm checks?

Remote sensing data can be gathered on a continuous basis, for example the Sentinel satellites generate images on a 3-4 day cycle and hence allow for the continuous monitoring of agricultural parcels. This means evidence, such as images and vegetation indices, can be gathered and developed for a whole farm over the whole year (if required). Hence, the use of EO data and related products can provide the opportunity to control with remote sensing the requirements of the Basic Payment Scheme. It can also be used for partial detection of compliance breaches, to provide back up evidence of the result of inspections, to support and provide multi-temporal crop signatures. Moreover, it can be used as a system to check and validate the changes to farmers submission where VHR data is available and hence contribute further the replacement of on-farm checks.

3.6 Existing Earth Observation services available for Paying Agencies and Certification Bodies

An internet and literature search was performed (November 2020) to identify the current range of commercial and non-commercial service providers of EO-based monitoring tools. These are characterised in Annex I. This search gathered information on a range of services that are available in utilising EO data in an agricultural context with services available relevant to PAs and CBs which include: data storage, processing and analysis; continuous monitoring services; facilitation / brokerage, bringing groups and organisations together; CAP compliance; and consultancy services. Also, more specialised services such as: crop-type identification and the monitoring of grassland mowing; water quality; water abstraction; vegetation indices; crop biomass and yield are also currently available.

3.7 Changes in PA and CB requirements for monitoring sustainable agricultural practices

3.7.1 Shift towards continuous monitoring

In 2018 new rules were adopted for the CAP which allowed automated checks, using earth observation (EO) data, such as that from the Sentinel satellites, geo-tagged photos and data and information from drones, to be used as evidence when checking requirements were being met for the Basic Payment Scheme (European Commission, 2018; European Space Agency, 2018). This was part of a move towards a “monitoring approach” which aimed to completely remove the need for on-farm checks and replace these with the use of automated checks based on EO data which enable the continuous monitoring of farmland (European Commission, 2018). There is now the option to carry out “checks by monitoring” on 100% of beneficiaries for all eligibility requirements, using the Copernicus Sentinel satellite data, instead of checking 5% through on-farm visits. This approach offers significant simplification and streamlining of administration and control systems and will reduce costly inspections in the field (DG AGRI, 2017).

The European Commission proposes to give Member States the support, flexibility, evidence-based tools, and responsibility to be ambitious in tailoring the design and funding of environmental and climate schemes. This opens up a new market for the provision of commercial services to PAs (78 in Europe) and CBs (247 in Europe) through the use of GEOSS and Copernicus data. A total of 14 Paying Agencies in five Member States informed the Commission of their intention to use the technology for their checks in 2019 (European Court of Auditors, 2019).

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3.7.2 COVID impacts (expediating the need for remote inspections)

While there is still high uncertainty regarding the long term socio-economic consequences of the global Covid-19 pandemic on production systems, it is undeniable that it has led to a big change in focus and priorities of agricultural activities (Food Standards Agency, 2020; European Commission, 2020e). Extensive measures calling for social distancing and labour force on-site to be reduced only to essential staff, have greatly hindered on-farm operations (Bochtis *et al.*, 2020; Luckstead, Nayga Jr & Snell, 2020) and among others the work of PAs and CBs in performing important inspections to ensure standards are met with regard to relevant agri-environmental policies and quality of produce (European Commission, 2020e; UKAS, 2020).

These circumstances have driven a shift towards the establishment of protocols for entirely remote inspections (LEAF, 2020; PEFC, 2020; Red Tractor, 2020). According to these protocols, remote audits rely on the farmer's ability to disseminate information and documentation effectively over the web, and guide the inspector around the farm under assessment, streaming live through generic communication platforms such as Zoom or Skype. Potential risks associated with such processes are identified in the farmer's technical capacity, their ability to manipulate and provide essential data, as well trust issues regarding the accuracy and reliability of the information they convey (Gallo, 2020; ISO, 2020; Pinto, 2020). The proposed protocols indicate that on-farm inspections are still considered to be the central part of the auditing process, and do not reveal any clear trends towards the use of innovations that could shift the weight from visits on farms. Therefore, current remote monitoring practices imply that there is a need for certifying organisations both in the private and the public sectors, to be updated and supported in the adoption of sophisticated solutions that allow for the automated remote monitoring of agricultural land and practices.

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4 Analysis of current service provision

In order to understand whether the technical and operational needs of PAs and CBs are being met with the current remote monitoring services, the ENVISION consortium undertook a data gathering exercise through expert consultation.

4.1 Methodology

A questionnaire was devised to characterise the capacities of European PAs and CBs in terms of IT infrastructure and their awareness with regard to existing commercial and non-commercial services for the remote monitoring of agricultural parcels and sustainable agricultural practices. The questionnaire was also used to identify the strengths, weaknesses, opportunities and threats associated with the current service provision (SWOT analysis).

Three distinct sections were identified in the questionnaire: Section A – Demographics, Section B – Current Status of Services, and Section C – SWOT analysis. Project partners NOA and EL ILVO contributed to the definition and assessment of the specific questions included. Close-ended questions in the form of 'Multiple choice' and 'Single line – short text' questions were preferred whenever possible to allow the participants to provide sufficient information with minimum effort. 'Forced response' and 'Character range' criteria were used, to ensure participants did not skip questions and to maximise the chance to obtain detailed responses throughout, particularly when longer essay type responses were required. The estimated completion time for the questionnaire was approximately 15 minutes. The questionnaire was then reviewed and granted approval according to the procedures specified by the University of Reading Research Ethics Committee.

In order to facilitate communication of the questions to participants, two surveys were formed to address the PAs and CBs separately by varying specific phrases of the questionnaire, and in this way adopting a more tailored approach (Annexes II and IV). The objectives of any individual question were the same between the two surveys, despite differences in wording. The surveys were hosted online via the Qualtrics XM Platform^{TM} (Qualtrics, Provo, UT), which generated individual open-access links for the distribution of each one.

Invitations to participate and complete the survey were sent via email to 289 contacts in total, including 42 PAs and 247 CBs across Europe, as shown in Tables S2 (Annex III) and S3 (Annex V). Personalised invitations were sent to key employees of an organisation, whenever relevant contact information was available. In each invitation, the participants found information regarding the main aim of ENVISION, instructions specific to the survey and contact information for the investigators (URDG). The email invitations further included a Participant Information Sheet that presented relevant information in more detail, and a pdf version of the questionnaire to facilitate exploration of the questions and redistribution within the organisation. Participants who were contacted were notified that upon following the link to the survey, they could pause and resume the questionnaire at their convenience. In addition, they were notified that redistribution of the survey to employees of the organisation that could contribute with information for specific sections of the survey, was highly encouraged. Invitations were emailed with a priority on the PAs, between the 16 October 2020 and 28 October 2020 including a reminder round. Furthermore, a personal reminder and request to redistribute the survey to their network of relevant organisations, was sent to PAs and CBs that participate in ENVISION. Consultations with DRAXIS, ETAM, EL ILVO and NOA were held to ensure that the proposed approach was suitable for the scope of ENVISION.

The online questionnaire closed on the 6th November for PAs and 10th November for CBs. The results were then analysed, grouped in the same two organisational categories, PAs and CBs. Quantitative methods including descriptive statistics and graphs were used for the analysis and report of responses to close-ended questions. Open-ended questions were evaluated following a thematic analysis approach, where the most prevalent categories of responses were identified, reviewed and reported. Text analysis was performed using Text iQ on Qualtrics XM Platform™ (Qualtrics, Provo, UT), whenever appropriate.

4.2 Results

4.2.1 Summary of results for PAs

Of the 42 PAs contacted for the purposes of this survey, only 14 have completed the survey thus far (33.3%). The number of applications processed by each PA on an annual basis greatly varied with the fewest applications being processed in Slovakia (21610 applications y^{-1}) and the most in Poland (1,36 million application y^{-1}). With regards to the organisation's capacity to support the adoption of novel IT systems for remote monitoring, 57.1% responded 'Yes, they do have the capacity' and 42.9% responded 'No'. For the percentage of farmers engaging the organisation electronically to submit financial aid applications and payment claims, 85.7% of the organisations responded '>75% of the farmers' while the remaining 14.3% responded '<15% of the farmers'. Table 1 below summarises the main data types provided electronically by farmers to monitor the 6 core services of ENVISION.

Table 1. Data types submitted to organisations by farmers for the monitoring of the 6 core services of ENVISION

Agricultural practice	Data types and representation in survey (%)
Crop Diversity	Crop type per parcel (57.1%) · Geotagged photos (7.1%) · Not Specified (35.8%)
Soil Organic Carbon	No Data (100%)
Vegetation Status	Sowing dates for catch crops (14.3%) · Geotagged photos (7.1%) · Not Specified (14.3%) · No Data (64.3%)
Crop Growth	Geotagged photos for catch crop (7.1%) · No Data (92.9%)
Grassland (Mowing/Ploughing)	Grassland type (7.1%) · Grassland resting and mowing periods (7.1%) · Geotagged photos (7.1%) · Not Specified (28.6%) · No Data (50.1%)

In addition to the services presented in Table 1, organisations identified 'Green winter coverage' and 'Geotagged photos of seeding' as other practices that they currently monitor.

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4.2.2 Current status of services

Table 2 summarises survey findings regarding the awareness of organisations about current commercial or non-commercial IT systems for remote monitoring of agricultural practices.

Table 2. Current Information Technology (IT) systems for remote monitoring that were identified by the organisations

IT system	Percentage of organisations that identified the system (%)
Area Monitoring System	64.3
Sen4CAP	92.9
DIONE services	50.0
NIVA4CAP services	64.3
EO4AGRI	50.0

Further to the above, other monitoring systems that the organisations identified were: 'Sinergise' (https://www.sinergise.com/), 'Geo-spatial Aid Application GSAA', 'NPA CbM system', 'Sen2Agri' (http://www.esa-sen2agri.org/), and 'Sat4Envi' (https://polsa.gov.pl/projekty/sat4envi).

The majority of participating organisations (92.9%) reported they have received support to adopt and use the IT monitoring systems identified above. The European Commission was reported to have supported 92.3% of those organisations, while the remaining 7.7% received support from Governmental Departments or Authorities. Private Organisations and Research Institutes appeared to have been involved in supporting 53.8% and 38.5% of the organisations respectively. This support came in the form of participation in workshop or conference focusing on new technologies and their use for monitoring agricultural practices for 92.9% of the cases. Additional support with funding was given to 28.6% of the organisations for research and development of remote monitoring IT services, while 7.1% of the organisations reported they have received support only in the form of funding for the roll out and evaluation of novel remote monitoring IT services.

Table 3 below provides information regarding the most recent experiences of organisations in using EO data for remote monitoring of agricultural land.

Table 3. Participation of organisations in recent remote monitoring actions using Earth Observation (EO) data

Remote monitoring actions using EO	Percentage of organisations that identified the system (%)
Implemented checks by remote monitoring in the most recent round of compliance checks.	71.4
Used the Copernicus Sentinel data systematically to check some of the requirements for financial Aid.	64.3
Used geo-tagged photos or drones for monitoring agricultural parcels.	21.4

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Aside from compliance checks, 21.4% of the organisations have identified additional uses of the remote monitoring technologies mainly to update / improve LPIS, and to help control and identify missing catch crops.

Most of the organisations that participated in the survey (85.7%) are currently participating in projects for the development of monitoring services for agricultural practices. Sen4CAP, NIVA and DIONE were reported to have the largest participation, while 28.6% of the organisations responded that they participate in projects developed and implemented on a national level.

The current global Covid-19 pandemic has helped 35.7% of the organisations highlight gaps in the services provided by current monitoring systems. The specific gaps they have identified were related to the need for improved virtual communication systems, increased provision of geotagged photos and better systems to process those, and the issues caused by within- and between-nation variability in agricultural practices that hinder remote monitoring using EO data.

The most prevalent solutions proposed to overcome such limitations were the development of new geotagged photo-apps to reduce contact between farmers and inspectors while maintaining supply of data, and the reduction of requirements (data inputs) for monitoring to enable checks even in cases where access to information is limited. The organisations that identified limitations and proposed the specific solutions above are already working on their development.

The results of a survey regarding potential limitations that may hinder adoption of IT systems for remote monitoring, are summarised in Table 4 below.

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Table 4. Organisation perception (% of total responses) of potential limitations that may hinder the adoption of Information Technology (IT) systems for remote monitoring of agricultural practices

Potential Limitation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Number of parcels to be followed-up is too high	5.6	11.1	38.9	22.2	22.2
There is uncertainty in legislation regarding the European Commission's conformity audits	0.0	5.6	22.2	44.4	27.8
There is a need to improve the IT infrastructure (hardware and software)	0.0	0.0	16.7	33.3	50.0
Development of the remote monitoring system is time consuming and costly compared to the benefits	5.6	16.7	55.6	16.7	5.6
There is a risk of farmers taking legal action because they don't agree with the assessment	5.6	16.7	27.8	50.0	0.0
Farmers might consider monitoring / warning alerts as intrusive	0.0	22.2	33.3	44.4	0.0
Implementing remote monitoring systems implies significant changes to the organisational structure of the paying agency	5.6	11.1	16.7	55.6	11.1
There is a need to introduce significant changes to the LPIS	11.1	16.7	27.8	38.9	5.6

An analysis of the organisations' adoption of remote inspection protocols showed that 28.6% of them perform less than 15% of their inspections remotely, 21.4% of PAs between 15-30%, 7.1% of PAs 30-45%, 14.3% of PAs 45-60%, 14.3% of PAs 60-75%, and 21.4% of PAs perform more than 75% of their inspections remotely.

With regards to the six core ENVISION services, 42.9% of PAs uses remote monitoring services to monitor Crop Diversity, 0.0% for Soil Organic Carbon, 7.1% for Vegetation Status, 0.0% for Crop Growth, 42.9% for Grassland Mowing / Ploughing, and 0.0% for Soil Erosion. Harvest marking was identified as an additional service that 7.1% of PAs currently monitor remotely.

When PAs were asked about what is performing well with current remote monitoring services for their organisation, the most prevalent responses were about: i) crop classification, ii) the identification of mowing, ploughing and harvesting events and iii) the marking of non-agricultural land to update their LPIS.

The main problem areas identified with the performance of current remote monitoring services were: i) insufficient spatial resolution of current systems to detect and classify small parcels, ii) need for more accurate detection of grassland and tree crops, iii) 'atmospheric noise' during periods that monitoring

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is critical, iv) concerns regarding the stability of the Copernicus data hub, v) concerns regarding additional resources required to update IT systems and accommodate the ever changing technological innovations, and vi) adjusting the capabilities of currently available data and services to the existing and future policies.

Most organisations proposed that the priority in resolving some of the issues mentioned above is to adjust CAP monitoring requirements according to the capabilities of current EO based services and improve their availability across countries. Many activities within the scope of CAP cannot be accurately detected and monitored via satellite, yet they may be important conditions for subsidy. At the same time, organisations acknowledge that they need to invest in improving their IT infrastructure, knowledge and training, to be able to better accommodate existing data and current or future services. Finally, on a research and development level, a need for enhanced accuracy and reduced uncertainty of classification and detection models was identified.

The organisations further identified additional services they would like to be able to monitor. The most common responses regarding these were: i) monitoring of the Soil Organic Carbon, ii) identification and monitoring of Organic crop cultivations, iii) monitoring crop fertilisation and plant protection, and iv) detection and monitoring of grazed grassland, areas under risk of soil erosion, burnt and abandoned land, and crop seeding.

High uncertainty characterised the adaptation plans of PAs in view of the monitoring requirements introduced with the new CAP, with the majority of organisations not having a structured action plan to accommodate potential change in current inspection and monitoring strategies. Participation in ESA, Horizon 2020 and other research and innovation projects to gain further knowledge and develop novel tools to address the new requirements was an action plan proposed by multiple organisations. In order to ensure that future use of such novel tools is sustainable within each organisation, the PAs responded that they should invest in enhancing their IT departments and bringing in external expert opinion whenever needed, while maintaining the status of the organisation as the core element in the monitoring and inspection process. In addition, they highlighted the importance of rolling out and evaluating newly developed systems as soon as possible, and also educating the applicants on them as soon as these are established.

4.2.3 SWOT analysis

EO based remote monitoring services were identified as cost-effective solutions by greatly reducing the need for frequent on-farm inspections and minimising computational time for the relevant assessments, particularly as more and more inspectors get familiar with these. Their capacity to store data for more than 10 years and flexibility, where organisations can either implemented 'ready-to-use' systems or adapt and develop 'in-house' solutions, were reported as the strongest features of current remote monitoring services. Another important strength identified was that remote and continuous monitoring leaves less room for the farmers to not comply with relevant agri-environmental policies.

The main weaknesses identified with the SWOT analysis largely reiterate important issues presented earlier in the 'Current status of services' section. More specifically, for a large share of PAs across Europe there is still a need for personnel to receive training and update knowledge regarding the newly developed IT systems. Furthermore, current services are unable to detect many of the practices included in the CAP cross compliance measures, and they are not accurate enough to address the

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specific needs of many countries that are defined by high diversity in crops, high topographic variability and a system of small parcels. Because of these weaknesses, PAs cannot see remote monitoring as a replacement for on-farm inspections, but as a supplement for only a few specific services.

Outside the organisation boundaries, one opportunity for improvement of current services was identified in relation to the provision of high quality, mobile internet connections to farms across the countries, to facilitate dissemination of information and exchange of essential data. PAs suggested that another avenue for research that could greatly increase adoption of remote monitoring systems is the improved accuracy of the services by updating the relevant algorithms and increasing spatiotemporal resolution of available data. The use of a common platform for all services and a common data format, could further support the implementation of new IT systems.

Certain external-to-the-organisation threats were also identified that could potential hinder adoption of services. A common concern regarding potential increases in the cost of development and implementation of services, as well as training of employees to use these, was identified. Another potential threat that PAs highlighted is the lack of consensus among developers about the uniformity of data and platforms between past, current and future system configurations. Finally, the most prevalent threat perceived by PAs is that complex IT services could not be adapted in time to accommodate changes in relevant legislation and policies, particularly when there is little available information and high uncertainty prior to these.

4.2.4 Summary of results for CBs

For the survey on current services for sustainable agricultural practices adopted by CBs, only 8 organisations have responded so far (3.24%). These varied greatly in terms of the number of assessments they performed on an annual basis, with half of them reporting tens of thousands of assessments annually (19,000 – 123,000), while others less than two thousand assessments per year. The crop production, whether conventional or organic, was the most widely represented sector with 75% of the organisations performing assessments in both, followed by organic livestock production with 37.5%, and conventional livestock production at 25%. Organisations were also active in organic processing of food products (12.5% of CBs that responded) and integrated production (12.5%). With regards to their capacity to support the adoption of novel IT systems for remote monitoring of sustainable agricultural practices, 87.5% responded positively and the rest 12.5% 'No'. For the percentage of farmers engaging the organisation electronically to submit applications for certification, 37.5% of the organisations responded '<15% of the farmers', 12.5% stated '45-60%'. 25% stated '60-75%' and the remaining 25% responded '>75%'. Table 5 below summarises the main data types provided electronically by farmers to monitor the 6 core services of ENVISION.

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Table 5. Data types submitted to Certification Bodies (CB) by claimants for the monitoring of the 6 core services of ENVISION

Agricultural practice	Data types and representation in survey (%)
Crop Diversity	Crop type per parcel (75%) · No Data (25%)
Soil Organic Carbon	No Data (100%)
Vegetation Status	Sowing and harvesting data (25%) · No Data (75%)
Crop Growth	Yield (37.5%) · No Data (62.5%)
Grassland (Mowing/Ploughing)	Grassland type (12.5%) · Soil practices in organic crop production (12.5%) · No Data (75%)
Soil Erosion	Estimates for risk of soil erosion (12.5%) · Information on existing systems for prevention of soil erosion (12.5%) · No Data (75%)

In addition to the services presented in Table 5, certification bodies reported that claimants provide data for the assessment of 'Water consumption', 'Irrigation practices', 'Usage of fertilisers and plant protection products', and 'Private data of the enterprise'.

4.2.5 Current status of services

Of the CBs that participated in the survey, only 16.7% were aware of current IT systems for remote continuous monitoring of agricultural practices, specifically identifying 'DIONE services'. Half of the organisations reported they have received support to adopt and use such IT monitoring systems. Government Departments and Authorities, Research Institutions and Organisations, and Private Organisations were reported to have equally (16.7% each) supported CBs. This support came in the form of participation in workshop or conference focusing on new technologies and their use for monitoring agricultural practices.

Table 6 below provides information regarding the most recent experiences of certification bodies in using EO data for remote monitoring of sustainable agricultural practices. None of the organisations that participated uses remote monitoring technologies for purposes other than to perform compliance checks.

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Table 6. Participation of certification bodies in recent remote monitoring actions using Earth Observation (EO) data

Remote monitoring actions using EO	Percentage of organisations that identified the system (%)
Implemented checks by remote monitoring in the most recent round of compliance checks.	50.0
Used the Copernicus Sentinel data systematically to check some of the requirements for financial Aid.	16.7
Used geo-tagged photos or drones for monitoring agricultural parcels.	33.3

Only 33.3% of the organisations that participated in the survey are currently involved in projects for the development of monitoring services for agricultural practices, naming the 'ENVISION Horizon 2020' and 'Internet of Farm & Food Horizon 2020' projects.

The current global Covid-19 pandemic has helped 33.3% of the organisations highlight gaps in the services provided by current monitoring systems. The gaps were related to the greater need for automated monitoring procedures that can minimise time spent on-farm and the more specific need for remote monitoring of livestock systems including infrastructure and their management (e.g. animal housing conditions), and animals.

The organisations suggested that acquiring information on acreage, crop health, grassland and soil management, water and energy consumption, and location and conditions of structures associated with livestock production, would help them overcome such limitations.

The results of a survey regarding potential limitations that may hinder adoption of IT systems for remote monitoring, are summarised in Table 7 below.

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Table 7. Certification bodies' (CB) perception (% of total responses) of potential limitations that may hinder the adoption of Information Technology (IT) systems for remote monitoring of agricultural practices

Potential Limitation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Number of parcels to be followed-up is too high	0.0	16.7	50.0	33.3	0.0
There is uncertainty in legislation regarding the European Commission's conformity audits	0.0	16.7	33.3	50.0	0.0
There is a need to improve the IT infrastructure (hardware and software)	0.0	0.0	0.0	66.7	33.3
Development of the remote monitoring system is time consuming and costly compared to the benefits	0.0	16.7	50.0	33.3	0.0
There is a risk of farmers taking legal action because they don't agree with the assessment	0.0	16.7	16.7	50.0	16.7
Farmers might consider monitoring / warning alerts as intrusive	0.0	0.0	0.0	66.7	33.3
Implementing remote monitoring systems implies significant changes to the organisational structure of the certification body	0.0	33.3	0.0	33.3	16.7

An analysis of the organisations' adoption of remote inspection protocols showed that 50.0% of them perform less than 15% of their inspections remotely, 25.0% between 15-30%, and 25.0% between 45-60%.

With regards to the six core ENVISION services, 75% of the CBs reported they use remote monitoring services for the assessment of Crop Diversity (e.g. using video conferences, geotagged images), 0.0% for Soil Organic Carbon, 50% for Vegetation Status, 25% for Crop Growth, 25% for Grassland Mowing / Ploughing, and 25% for Soil Erosion. The most prevalent method for remote monitoring is through the use of video conference systems (e.g. Skype, Zoom, WhatsApp video calls).

CBs responded that the video conference system works well for their organisation for the monitoring of the above practices, particularly when supplemented by geotagged images provided by the claimants and satellite images obtained through paying agencies and other repositories. The main problem area they identified with the operation of these systems, was their inability to monitor fertiliser usage, and soil and water management practices, which the CBs considered important requirements for the compliance checks. Another issue they highlighted was that of poor network connectivity and battery life of current technologies used by the farmer during the video conferences. Remote inspections of facilities' indoors conditions is also problematic due to poor signal strength.

While, as CBs responded, with current regulations for organic crop and livestock production it is mandatory to carry out on-site inspections, the organisations acknowledged that they need to enhance

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their infrastructure and enhance their capabilities to adopt novel IT systems for remote monitoring. Further funding may be required for this purpose, as well as an improvement of the accuracy of current remote monitoring services, particularly with regards to monitoring of fertiliser usage, soil and water quality, and soil erosion. The CBs proposed that direct collaborations with companies that develop such services may facilitate adoption. Regarding the sustainability of remote monitoring IT systems within the organisations, they responded that addressing the issue of acceptance by claimants (i.e. overcoming farmer privacy issues) and assessors should be prioritised. Other important conditions that should be met to ensure sustainable use are affordable costs and ease of use by both the CB and the claimant.

The organisations further identified additional services they would like to be able to monitor. The most common responses were: i) resource scarcity and degradation particularly of water and fossil fuel, ii) harmful emissions, iii) insect and fungus related issues (plant health) and crop protection practices, and iv) harvesting.

4.2.6 SWOT analysis

Similar to Paying Agencies, CBs also identified EO based remote monitoring services as cost-effective solutions for compliance checks, by minimising travel costs and time spent on-farm. Remote monitoring also helped organisations maintain safety of their employees during the Covid-19 pandemic.

One weakness that CBs identified regarding the adoption of remote monitoring services by their organisation, was that it is difficult to address issues of privacy and confidentiality expressed by their members – claimants, when using such systems. Limitations of the technical capabilities of current remote monitoring services were also identified as weaknesses, specifically the inability to collect and analyse crop, soil and water samples, observe and assess biodiversity, evaluate crop health, and estimate the usage of fertilisers and pesticides.

Outside the organisation boundaries, the main opportunity for improvement of current services was identified in relation to the increase of spatiotemporal resolution of relevant data products. This would facilitate observations of inaccessible plots and for several critical growing periods throughout the year. The enhancement of current internet-network provision would also greatly benefit adoption of remote monitoring methods.

Finally, the most widely acknowledged threat from the perspective of CBs, was that current regulations enforce on-farm inspections and therefore should be adapted to recognise and promote the use of remote auditing.

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4.3 Conclusions from analysis of current service provision

The online survey for current service provision revealed the potential for remote monitoring services to aid the inspection process and compliance checks performed by Paying Agencies and Certification Bodies across Europe. Soil Organic Carbon, vegetation status, grassland management and soil erosion are areas currently underrepresented, and there is a great need for both types of organisations to improve their monitoring. Most organisations have acknowledged the potential benefits of remote auditing and continuous monitoring, so much with regard to observing otherwise inaccessible agricultural land, as well as from an economic perspective with the reduction of resources used for on-farm inspections (i.e. travel costs and time spent). Furthermore, remote monitoring has enabled organisations to avoid jeopardizing the health of their assessors with on-farm inspections during the Covid-19 pandemic.

The survey also brought up several important issues and limiting factors that need to be addressed to facilitate the adoption and use of current or novel IT systems. First and foremost, the organisations have identified a fundamental need for improvement of their IT infrastructure and knowledge. Although support has been provided through additional funding and training on specific technologies, there is a lack of monitoring at the follow-up stages of application to ensure sustainable use of the technologies within the organisations. Several issues were also identified in relation to the technical aspects of remote monitoring IT systems. Specifically, the majority of organisations would like to receive data products of high spatiotemporal resolution and accuracy, to be able to address current problems of distinguishing and classifying narrow land parcels, mixed crops, livestock facilities and their conditions, soil and water quality, and crop protection management practices. Moreover, they suggested they would like to see IT systems that are flexible and customisable by the organisations, to accommodate specific needs / peculiarities at national and regional levels. The survey highlighted a lack of confidence of organisations towards the adaptability of remote monitoring services to the changing agri-environmental policies, and regarding the potential costs that may arise from the need to update the systems at frequent intervals. It is essential if organisations are to adopt the systems, that information regarding costs of implementation and recurring costs are clear and available from the beginning. Finally, it is important that when using remote monitoring systems, farmers' privacy and confidentiality are maintained throughout. To achieve this, the organisations propose that transparent protocols for data storage, handling and reporting should be made available to end-users.

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5 The extent to which ENVISION will be able to promote sustainable development and more effective governance of policies and environmental protection schemes

ENVISION will offer tools to enable continuous, large scale and uninterrupted monitoring of farm management activities in relation to sustainability. A monitoring service that will identify whether a declared agricultural parcel can be considered to comply with the sustainable agricultural practices stemming from EU policies or certification scheme standards by verifying conditions related to an agricultural activity or a crop type. As such ENVISION aims to reinforce the monitoring of cross-compliance measures, environmental greening and certification requirements, through the identification of unsustainable agricultural practices which can result in environmental degradation such as:

1. Water pollution: nitrates and phosphates from agricultural sources can lead to eutrophication and the development of harmful algal blooms in water bodies adjacent to agricultural lands.
2. Soil degradation: practices such as unsustainable crop harvesting, unbalanced fertilization, and overgrazing can lead to soil erosion and loss of soil fertility and structure.
3. Biodiversity loss: practices such as monoculture can lead to the loss of crop genetic diversity, reducing climate change resilience, and the destruction of critical habitats for the creation of arable land.
4. Landscape degradation: the conversion of forests, grasslands and other habitats to agricultural land can result in landscape degradation. This can augment the impacts of climate change, lead to the annihilation of important habitats, and affect the water cycle.
5. GHG emissions (ENVISION will not directly monitor GHG emissions but it will provide an estimation of their reduction in relation to the amelioration of farming practice) Large quantities of agriculture-sourced GHGs are emitted mainly due to deforestation, unsustainable management of croplands & grasslands, extensive soil disturbance, and conversion of grassland to arable land.

ENVISION promotes sustainable development and effective governance of environmental and sustainability policy through highlighting how farming can align with sustainable development and sustainable intensification goals, focusing attention on the environmental aspects of the CAP and how monitoring via EO data can support environmental schemes and compliance with these schemes.

CAP 2021-27 will have an increased focus on environmental measures, with increased funding opportunities for “green farming”. Potential measures within the new CAP include:

- “the preservation of soils through requirements to protect carbon-rich wetlands and practice crop rotation;
- an obligatory nutrient management tool, designed to help farmers improve water quality and reduce ammonia and nitrous oxide levels on their farms;
- a new stream of funding from the CAP's direct payments budget for "eco-schemes", which will support and incentivise farmers to undertake agricultural practices beneficial for the climate, biodiversity, and the environment.” (https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en)

All of the above areas are covered by the proposed scope of ENVISION. Specifically, ENVISION builds on the work of RECAP project, which developed a platform for the delivery of services to improve implementation of the CAP. The platform was aimed at PAs, CBs, agricultural consultants and farmers and collated data from both satellites and through farmers' mobile devices in order to monitor agricultural land and activities.

In the development of the RECAP platform, pilot data were used to evaluate compliance in the UK, Spain, Serbia, Greece and Lithuania and focussed on crop type identification and stubble and residue burning. RECAP also demonstrated accurate automatic identification a variety of crop types using remote sensing data and provided evidence of how improved monitoring using EO data could benefit both those monitoring and those being monitored (RECAP Project, 2018a).

Using a communication platform such as RECAP could encourage compliance as it was found that 61% of farmers participating in the RECAP pilot somewhat agreed or strongly agreed that the RECAP platform increases their understanding of CAP Cross-Compliance (CC) rules, and 55% somewhat or strongly agreed that the platform decreases the likelihood of their breaking CC rules. (RECAP Project, 2018a, p. section 4.2[5])

RECAP also demonstrated accurate automatic identification a variety of crop types using remote sensing data (Sitokonstantinou *et al.*, 2018). Dicks *et al.* (2018) highlight agricultural practices most likely to deliver sustainable intensification in UK farming; these include "providing training for farm staff on how to improve sustainability/environmental performance" and "benchmarking of environmental, in addition to financial, performance". Certification bodies such as Red Tractor (https://redtractor.org.uk/) and organic certification can offer benchmarking based in part on the use of remote sensing data.

Uptake of remote monitoring, using EO data, has been noted to be lower than uptake of other technology focussed agricultural practices, such as in-field yield monitoring (Finger *et al.*, 2019). The change to the CAP allowing satellite data to be used in checks and monitoring of compliance could change this.

Farmers across Europe are starting to use precision farming technologies and techniques that collect large amounts of farm level data. Therefore, they may already collect and use some of the data required for cross compliance checks. As the pilots in RECAP and the s-SHAPE projects (e-SHAPE Agro-Industry pilot) demonstrated to farmers, they can benefit from combining data collected by Sentinel and ground-truthed data, collected from networked on-farm sensors, to give a wider overall picture of farm performance and compliance with regulations.

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6 The factors that influence adoption of agricultural technologies at farm and governance level

6.1 Adoption of remote sensing technologies and techniques

Figures on the use and adoption of remote sensing technologies by farmers are varied. While there is exploration of the use of precision farming and smart farming technologies, for example variable rate application of fertilisers and the use of tractor guidance systems, there is less focus on remote sensing as a stand-alone technology. Uptake of remote sensing among farmers has been variable, depending on crop-type, size of farm and location, with up to 80 % of farmers in Argentina reporting using some form of remote sensing imagery compared with 10 % or less in some US states (Lowenberg-DeBoer and Erickson, 2019). Within the EU uptake appears low, although again data does not appear to be consistently collected, with 10 % of farmers in France (INRAE, 2020) and 11 % of farmers in Germany (Lowenberg-DeBoer and Erickson, 2019) reporting using some form of remote sensing.

Use at governance level (such as by Paying Agencies and Certification Bodies) also appears to be variable. A survey by the European Court of Auditors (2019) found 15 out of 66 PAs surveyed had used the Copernicus Sentinel data in 2019 to check aid applications for some schemes. They also note that across the EU an average of 80% of field inspections are performed using some form of remote sensing.

What may influence uptake and use of remote monitoring by farmers?

Figure 2 (from Soto *et al.*, 2019) highlights the factors affecting farmer uptake of precision agriculture technologies (PAT). However, many of the technologies this study focussed on involved satellite and EO data, and the barriers faced by many farmers would be similar in terms of using satellite data to evaluate for e.g. cross compliance.

Economic*	Institutional/ regulatory**	Organisational***
High initial investments	Low institutional support for farmers	Lack required competencies/ skills
Poor access to capital	Use of overly scientific language (jargon)	Poor information
Competing financial priorities	Farmer's knowledge not considered in R&D	Inability to assess technologies
Long pay-back periods (ROI)	Lack of regulatory frameworks	
High implementation costs (actual and perceived)	Overly complex technologies	
Uncertain returns and results	Results/ effects of technology difficult to observe	
Temporal asymmetry between costs and benefits	Farmer's beliefs and opinions	
	Low trust	

* Cullen et al., 2013; Faber and Hoppe, 2013; Guerin and Guerin, 1994; Montalvo, 2008
** Bogdanski, 2012; Eidt et al., 2012; Montalvo, 2008
*** Montalvo, 2008

Figure 3. Overview of the socio-economic barriers for farmers in introducing PAT (Soto et al., 2019)

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6.2 Economic considerations

There is a cost to farmers in implementing remote monitoring and using remote monitoring technologies. The costs involved could include purchasing both hardware and software, data storage and the cost of interpreting and analysing data. Although technologies such as remote sensing have been shown to reduce costs in research and trial settings (e.g. using precision application and tractor guidance systems), there is less evidence for cost savings "in the field".

Soto *et al.* (2019) and Vecchio *et al.* (2020) note the barrier to farmers utilising precision farming technologies, such as remote observation data for variable rate applications and tractor guidance systems, was cost and the potential for low rates of return or the long time period between investment in technology and seeing reductions in costs. In addition to economic costs, there are also associated time costs in implementing new techniques and technologies. The time taken to learn how to use new systems and time to educate farm workers in effectively using new technologies (Soto *et al.,* 2019)

There is also a time cost to farmers when submitting evidence for CAP payments. Could technologies such as ENVISION help to reduce this time cost? Farmers using precision farming techniques may already collect some of the data required for compliance checking. RECAP was shown to reduce the time farmers spent on cross-compliance administration (RECAP Project, 2018b). Pesce *et al.* (2019) note the potential for continuous monitoring systems and the use of a range of data (such as EO data) by organisations such as PAs to reduce, or even potentially remove the administrative burden on farmers.

In relation to the economic costs associated with acquiring and interpreting EO data, resources (such as processing software and data storage facilities) and EO data of the detail and quality needed for agricultural monitoring are freely available (Lemoine, 2017). For example, EO data from the Sentinel satellites is freely available and used by many of the organisations listed in Annex I who offer agricultural monitoring and compliance checking services. The DIAS (Data and Information Access Service) platform was set up to facilitate access to Sentinel data and information and also access to processing tools. It consists of five cloud-based platforms which "allow users to discover, manipulate, process and download Copernicus data and information" (Copernicus 2020).

6.3 Institutional / regulatory considerations

In relation to remote monitoring and use of EO data, many institutional and regulatory considerations focus on the acquisition, ownership, use and storage of data. There may also be considerations around how data is collected, for example, legal constraints around the use of UAVs (unmanned aerial vehicles) for collecting data (Barnes *et al.*, 2019; Soto *et al.*, 2019).

Data use, ownership and privacy are areas in which legal and regulatory frameworks have a role to play, ensuring data privacy and ethical use of data (Finger *et al.*, 2019). Regulatory frameworks can also impact on data availability for use 'off farm', "… *fragmented and unclear data governance arrangements may weaken farmers' willingness to adopt digital solutions. This, in turn, may reduce the availability and accessibility of agricultural data for policymaking, for the agricultural innovation system, and for developing services for farmers*" Jouanjean *et al.* (2020).

Kritikos *et al.*, (2017) consider that with data collection in relation to precision farming "*the main challenge is to develop a framework that can cope with the potential threats to the privacy and autonomy of individual farmers in a pragmatic, inclusive and dynamic manner*". With the rapid pace of technology development, regulatory considerations may lag behind. This rapid pace of development and change can also impact on data sharing. Regulations need to consider the movement of data on an international level to ensure knowledge flow and services work across borders. There can be regulatory differences between countries with respect to data use and ownership and data sharing arrangements may not be everyday practice for farmers (Jakku *et al.*, 2019).

The purpose of data collection can also shape regulatory frameworks. Farmer's concerns around data gathered by commercial companies for use with a specific technology (e.g. variable rate fertiliser application) (Jakku *et al.*, 2019) may be different to concerns around data gathered for use by PAs and CBs in compliance checks. Enabling the submission of EO data and geo-tagged data could lead to changes in regulations around data collection and governance. For example, the European Court of Auditors (2020) consider how some aspects of Greening measures cannot currently be checked using EO data from the Sentinel satellites. The requirements, measurements and regulations concerning Greening payments could conceivably be altered to take into account changes in the monitoring process.

6.4 Organisational considerations

In order for data generated from remote monitoring services to be of use both on-farm and for e.g. cross-compliance monitoring, farmers, certification bodies and paying agencies all require access to IT equipment and broadband internet connections capable of dealing with the data, as well having the digital literacy skills to be able to operate the systems. Detailed, comprehensive and recent data on the availability and use of IT by farmers across the EU is not readily available. Figure 3 below (Holster *et al.*, 2012) highlights ICT use by farmers across the EU for a variety of on-farm activities, farm PC ownership and internet access varied between countries.

Country	Farm PC	Internet access	FMIS Farm Mgt Info System	Phones/ Handheld	LPIS relevance	Geo Fertilizing	Animal Registration
Belgium	High	High	Average	High	High	Average	High
Bulgaria	Low	Low	Low	-	Average	-	-
Czech Rep.	High	High	High	Low	Average	Average	Average
Denmark	High	High	Average	High	High	Average	High
Estonia	High	High	Average	-	Average	Low	Average
Finland	High	High	High	High	High	Average	High
France	High	Average	Average	High	High	Average	High
Germany	High	High	Average	High	High	Average	High
Greece	Low	Low	Low	Average	Average	Low	Average
Hungary	Average	Average	Low	Low	Average	Low	Average
Ireland	Average	Average	Average	Average	Average	Average	High
Italy	Average	Average	Average	High	Average	Average	High
Latvia	Low	High	Low	-	Average	Low	High
Netherlands	High	High	High	High	High	Average	High
Poland	Average	Average	Average	-	Average	Low	Average
Portugal	Low	Average	Low	Average	Average	Low	Low
Romania	Low	Low	Low	Low	Average	-	Average
Slovakia	High	Average	Low	Low	Average	Low	Average
Slovenia	Low	Low	Low	Low	Average	-	Average
Spain	High	Average	Average	High	High	Average	High
Sweden	High	High	Average	High	High	Low	High
United K.	High	Average	Average	Low	Average	Low	High
Switzerland	High	Average	Average	Low	Average	Average	High

Figure 4. Level of ICT and technology adaptation in the EU countries and Switzerland (Holster et al., 2012)

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More recent studies into use of smartphone use for agricultural monitoring and management show high levels of smartphone use by farmers. For example, Dehnen-Schmutz *et al.* (2016) looked at use of smartphones by British and French farmers within agricultural citizen-science projects. They found 89 % of respondents owned a smartphone, 84 % used it for farm management and 72 % used it on a daily basis. Bonke *et al.* (2018) surveyed smartphone use by German farmers, 93 % of the respondents use smartphones for agricultural purposes, for example using apps and tools to identify pests, diseases and weeds. However, both studies note the small sample sizes of respondents.

6.5 Accessibility and infrastructure

Is the infrastructure available to support the use of remote sensing? EO data can comprise VHR (very high resolution) images and large amounts of data. Is there the broadband availability to support access to images and data, the capacity for storage and retrieval of data? The potential incompatibility of systems, for example getting software and hardware from one company or developer to "talk" to another organisations' products also needs to be considered (Soto *et al.*, 2019).

In order to be able to use and access the data, images etc generated by remote monitoring, there needs to be access to software, hardware and infrastructure (i.e. broadband, wifi, 4G / 5G etc.) that can deal with the data. Remote sensing can generate high volumes of data on a regular basis.

Internet access and availability across the EU varies. Data from 2016 indicates that, on average, 80 % of rural households in the EU 28 had internet access in 2016. However, this varied from over 95 % coverage in Luxembourg to less than 50 % in Bulgaria (Eurostat, 2017). A study by Rose *et al.*, 2016, highlighted the issues some farmers had using agricultural decision support tools "in the field", including slow download speed, lack of mobile phone signals and incompatibility of software with the device they were using.

Cloud computing and organisations dealing with Big Data can support this access to data. For example, the DIAS (Data and Information Access Service) platform which was set up to facilitate access to Copernicus Sentinel data, information and a range of data processing tools. Five cloud-based platforms which "allow users to discover, manipulate, process and download Copernicus data and information" (Copernicus 2020).

6.6 What may influence uptake by farmers?

The uptake of remote sensing technologies and use of EO data by farmers could be influenced by a wide range of factors. Technical ability and interest in using the technology could play a role in uptake. Effectively interpreting and using EO data can require a wide range of technical knowledge and skills, developments and the pace of change can be rapid.

Social concerns may also be factor in the uptake of technologies such as remote sensing and monitoring. Farmers may feel that their knowledge of the land and contact with the land they farm is being undermined, leading to a loss of skills or knowledge and resistance to using technology to support agricultural decision making (Kritikos, 2017)

Concerns about data privacy and monitoring may also influence uptake. Farmers may have concerns around the continuous monitoring aspects of remote monitoring via satellite (European Court of

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Auditors, 2019) and the ownership and use of the data remote monitoring generates (Kritikos et al, 2017; Finger *et al.*, 2019).

The usability of technologies will play a role in their uptake. Systems to support agricultural monitoring and decision making need to be designed with end-users in mind or uptake is likely to be low (Rose *et al.*, 2018). The benefits of the systems also need to be highlighted to end-users. For example, the administrative burden of CAP compliance varies between farms; the median amount of time for farmers (across the EU) for completing administrative tasks associated with CAP compliance is 15 hours pa (DG-AGRI & ECORYS, 2018), although this ranges from 0.5 – 5 hours up to maximum range of 320 – 350 hours. The RECAP project demonstrated a time reduction on administration tasks when using the platform (RECAP Project, 2018b). Highlighting the benefits of these technologies, such as time saving, could support uptake at farm-level.

The benefits of peer-to-peer sharing and learning in relation to the adoption and use of precision farming technologies, including remote sensing, have been highlighted in a number of studies (see for example Soto *et al.*, 2019 and Barnes *et al.*, 2019). Peer-to-peer sharing can also offer a way of highlighting the benefits of utilising remote sensing data and being involved with the process of compliance checks.

The size of a farm also has an impact on uptake and use of new technologies. Smaller farms and older farmers are less likely to implement and use precision farming technologies, such as remote monitoring and sensing, and farms with higher income more likely to use them (Barnes et al, 2019; Kritikos *et al.*, 2017).

6.7 What may influence uptake by governing bodies?

Compliance checking and monitoring by Paying Agencies (PAs) and Certification Bodies (CBs) is currently carried out using a combination of on-farm visits and remote sensing data, such as that from the Sentinel satellites.

On-farm checks can have a number of drawbacks:

- checks are not continuous, they provide a "snapshot" taken at a specific moment in time;
- they are conducted on a small sample of farmers;
- they check a specific part of a farm, not the entirety (in the case of farmers applying for e.g. organic certification);
- checks are time-consuming and their cost is high, particularly if there is a need for follow-up inspections (DG AGRI & ECOSYS, 2018, pp. 95, 153, 155);
- when undertaken with the support of remote sensing images at fixed time points, they do not capture most of the temporal agronomic practices, farming activities and greening measures.

Continuous monitoring with remote sensing data could mitigate a number of these drawbacks, however uptake by PAs and CBs has not been uniform or universal. Why might this be?

A survey of 66 PAs in 2019 undertaken by the European Court of Auditors found 15 out of 66 paying agencies surveyed had used Copernicus Sentinel data in 2019 to check applications for some schemes

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and some groups of beneficiaries. Concerns from the PAs in using Sentinel data to monitor and check compliance included:

- Future changes to European Commission rules in using remote sensing data in checks
- Uncertainty regarding current rules on how to carry out checks using remote vs. on-the-spot data
- Inability to reach conclusions based on remote sensing data for reasons such as small land parcels and activities such as extensive grazing
- Being unable to make the changes needed to IT systems to work with the data, not having the resources or expertise (European Court of Auditors, 2019).

Figure 4 summarises the responses from this study.

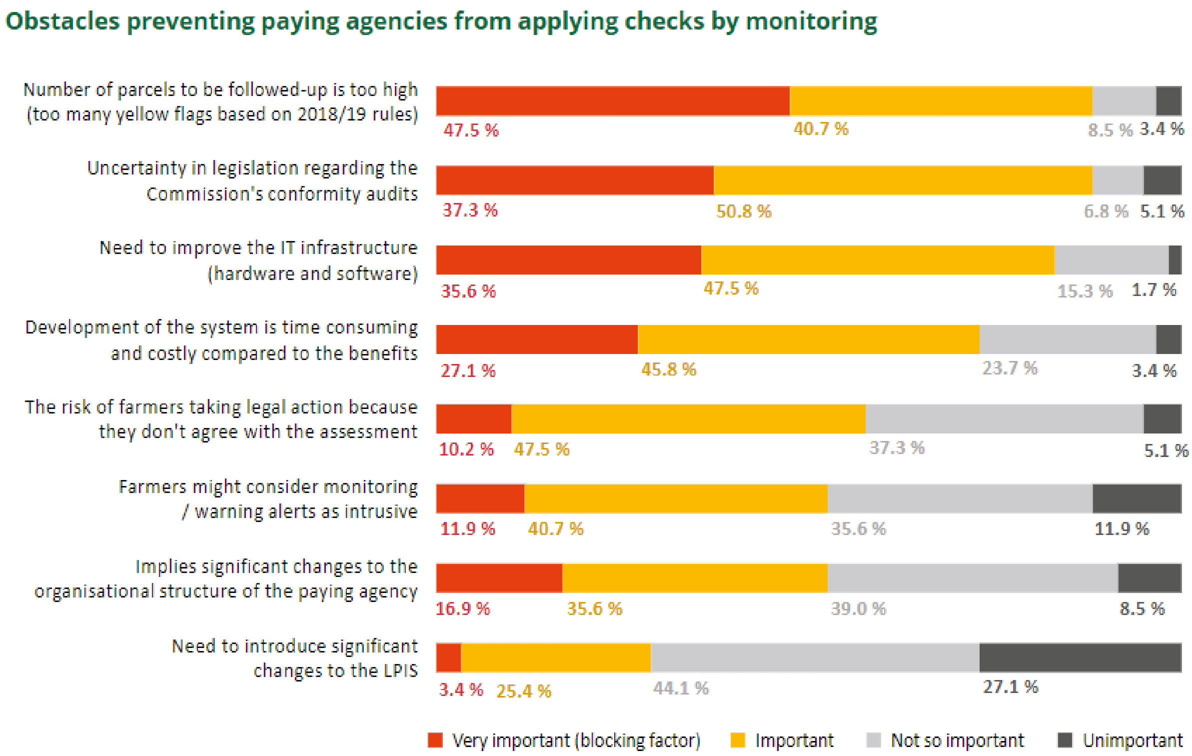

Figure 5. highlights the obstacles PA's highlighted in using remote sensing / monitoring data for checks (From: European Court of Auditors, 2020, Fig 12, p36)

Some of the issues relating to lack of uptake are similar to those at farm-level, for example:

- Technology costs, accessibility and lack of expertise
- Infrastructure concerns

The accuracy and spatial resolution of EO data was also of concern. Can the data be used to distinguish, for example, between crop types with sufficient accuracy? Is the data accurate enough to give a low number of false positives or false negatives when identifying crop types for compliance checking, so as to reduce the number of incorrect payments or payment refusal?

There were also concerns related to analysing remote sensing data for small land parcels of (Vasjova *et al.,* 2020) and technical issues such as problems with cloud cover affecting data collection when

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using Sentinel-2 data Toscano *et al.,* (2019). Various studies have, however, demonstrated the effectiveness of using EO data to distinguish accurately and consistently between crop-types (see, for example, d'Andrimont *et al.*, 2020; RECAP Project, 2018b; Sitokonstantinou *et al.*, 2018)

The potential to reduce costs and administrative burdens was seen as a positive way of promoting the use of remote monitoring in compliance checks (European Court of Auditors, 2019). As noted previously, the cost of in-field checks is high (DG AGRI & ECOSYS, 2018, pp. 95, 153, 155). Remote monitoring can reduce economic costs and administrative burdens for both farmers, PAs and CBs (European Court of Auditors, 2019; RECAP Project, 2018b). The continuous nature of remote monitoring can also provide a whole season or annual monitoring of crops and land, as opposed to the "snapshot" view from single on-farm visits, which, due to time and cost constraints may only take place once during the year or growing season.

It is interesting to note PAs concerns around "Future changes to European Commission rules in using remote sensing data in checks" (European Court of Auditors, 2019). The CAP is changing, what will this mean for the use of remote and EO data in cross compliance checks? Will the rules change significantly after time and money has been invested in using new technologies? This was raised as a concern in the RECAP Project (RECAP Project 2018b). A SWOT analysis highlighted potential threats for CBs that the RECAP platform would not be suitable for their needs with changing CAP rules and requirements (RECAP Project, 2018b)

As part of this we need to consider that any platform or software used to analyse or interpret EO data for CAP compliance needs to be adaptable to changing circumstances and as such it is not only the farmers, PAs and CBs who are the end users, but also the developers.

6.8 System usability

If farmers and PA's and CB's are to use a system for acquisition, input and analysis of data, it needs to be accessible and user-friendly, designed with users in mind.

With technological advances in agriculture it has been noted that although technology is developing rapidly and there is uptake of these new technologies this is by no means uniform or universal (Finger *et al.*, 2019). Some reasons for this "lack of uptake" among farmers, CBs and PAs are highlighted above, such as the cost of implementing new systems, insufficient infrastructure and seeing a lack of return on investments in technology. However, the usability and accessibility of systems also needs to be considered.

Rose *et al.*, (2018), highlighted the need for end-users to be involved in the development of agricultural decision support systems, otherwise use of the systems developed is likely to remain low. Co-design could mitigate some of the issues around lack of expertise in using EO data and remote sensing technologies, supporting the development of a platform accessible to all users which can lead them through areas requiring technical expertise they do not yet have. Rose *et al.* (2016) propose a checklist for the production of agricultural decision support tools, where farmer uptake is low, which includes: Ease of use; Trust (is the tool evidence based and do we have user's trust); Habit (does the tool fit with the existing habits of the farmer) and; Relevance to user. All of these can be part of a co-design process.

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Identifying the end-users is also important. Rose *et al.* (2018) highlight the need for continuous development of agricultural decision support systems, updating software and technology after the end of a project, to ensure the content and focus remains relevant. This could be supported through developers being considered as an end user, developing a system or platform that is simple to update (for example in the case of changing CAP rules) which remains relevant and usable. The role of those promoting the use of such platforms and systems also needs to be considered. Ayre *et al.,* (2019) highlight the role of agricultural advisers in promoting the use of smart and precision farming technologies, a peer-to peer learning role. They propose that advisers need to be involved in the design process in order to support this dissemination role. In the case of ENVISION the adviser role could be taken by PAs and CBs. Laudien *et al.* (2019) note the importance (during the co-design process) of enabling exchange of information between different groups of users, enabling all those involved in using and developing the system see how the other users would be using it.

Co-production of resources and products was an important aspect of the RECAP Project (2018a), with the aim of developing a user-friendly, efficient platform, therefore ENVISION will build on this to co-create the next set of services.

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7 Conclusions

This report has explored the potential for Earth Observation data services to provide authenticating agencies, such as Member State's Paying Agencies and Certification Bodies, opportunities to monitor agricultural practices remotely as part of the monitoring of compliance to rules and standards, and explores the potential of these services also to improve decision making that can drive towards more sustainable agriculture systems.

As the global need for food increases, there a growing need to balance this production with environmental protection and for a move towards sustainable intensification of arable systems. There is certainly evidence that successive reforms of the Common Agricultural Policy have led towards more sustainable farming approaches, with subsidy payments to farmers being subject to meeting an increasing number of environmental measures. However, more demanding agri-environmental mechanisms can achieve higher environmental standards and voluntary market-based schemes allow farmers to achieve certification to demonstrate their compliance with higher environmental and animal welfare standards.

All such schemes require some form of inspection to ensure compliance with the policy measures and achievement of standards. Elements of these inspections can be conducted remotely, with the associated reduction in monitoring costs, through services and products based on Earth Observation data. These services are either commercial or are available for free to the end users and can continuously monitor indicators of vegetation health, soil quality/protection, water quality/availability, biodiversity and ecosystem health. Adoption of these services by PAs and CBs has been slow, but they provide authentication bodies an opportunity to switch from a single time-point inspection or audit, to a continuous, systematic monitoring process ('checks by monitoring') that is automated, across wider areas and covers all beneficiaries, thereby preparing for the post-2020 CAP changes.

At the same time, farmers are choosing to adopt new technologies on-farm to assist with agronomic and management decision making. These new, data-driven, precision agricultural technologies generate large amounts of spatially explicit information that can improve the financial, social and environmental sustainability of their agricultural system. Earth Observation based services to arable farmers facilitate the precise and variable application of fertilisers, pesticides and irrigation and can provide yield mapping and predictions to improve production while minimising environmental impact. Livestock farmers can also benefit from animal welfare and tracking and pasture management while also recording indicators of greenhouse gas emissions and other metrics of climate impacts. These data can be used to provide the farmer with a picture of farm performance but can also provide automated evidence of compliance with regulations which can reduce their administrative burden. The control system for organic agriculture is due to be strengthened in 2021 and all certification schemes aim to continually drive up farming standards, therefore remote, continuous assessment is going to be needed to keep pace with change. COVID-19 has driven this by necessity, but changes to operating protocols are needed before longer term adoption.

Our analysis of the current EO service provision to Paying Agencies (n=14) that could allow remote monitoring showed that they are considered by PAs to be cost-effective solutions that are available both as generic and customised solutions with great potential to reduce non-compliance with agri-environmental policies. They are currently working well to help monitor i) crop classification, ii) the identification of mowing, ploughing and harvesting events and iii) the marking of non-agricultural land to update their LPIS, predominantly for compliance checks, but also for systematic checks for financial aid. However, 43% do not have the organisational capacity to adopt them at the moment despite most of them receiving support from the EC. Weaknesses in these services were identified to be a lack of personnel training and knowledge on how to use them and the accuracy level of satellite images that limit the number of agricultural practices that can be monitored remotely. The additional services needed by PAs are i) monitoring of the Soil Organic Carbon, ii) identification and monitoring of Organic crop cultivations, iii) monitoring crop fertilisation and plant protection, and iv) detection and monitoring of grazed grassland, areas under risk of soil erosion, burnt and abandoned land, and crop seeding.

Important aspects that need to be addressed before widespread adoption by PAs include; the need for improved rural internet access, the use of a common platform and data format between agencies and farmers that can link up with other IT management systems, reduced costs for development and implementation of services, and the constant need for adaptation and change. The 2020 European Court of Auditors report showed that those PAs who are already using EO services for compliance checks identified that future changes and uncertainty over rules, small land parcels and IT systems present the biggest challenges in practical terms.

Our analysis of the current EO service provision to Certification Bodies (n=8) showed that they have greater capacity than PAs to adopt novel IT services (88% were positive about adoption) despite receiving less training and support. They are currently using EO services to remotely monitor Crop Diversity, Soil Organic Carbon, Vegetation Status, Crop Growth, Grassland (Mowing/Ploughing) and Soil Erosion plus a few other categories, predominantly for compliance checks. A third of Certification Bodies are reported using geo-tagged photos for monitoring agricultural parcels. Weaknesses were identified around privacy, technical limitations such as inability to collect and analyse crop, soil and water samples, observe and assess biodiversity, evaluate crop health, and estimate the usage of fertilisers and pesticides. Opportunities for new service improvement included an increase of spatiotemporal resolution of relevant data products to facilitate observations of inaccessible plots and for several critical growing periods throughout the year. The additional services they would like include i) resource scarcity and degradation particularly of water and fossil fuel, ii) harmful emissions, iii) insect and fungus related issues (plant health) and crop protection practices, and iv) harvesting. Currently, on-farm inspections are still mandatory, so a greater acceptance of remote monitoring is required before full scale adoption is possible.

For farmers, the uptake of EO based services (predominantly as precision agricultural technologies including machine guidance and variable rate technologies) is fairly low across Europe. The cost (both financial and personnel time) of adoption of precision/smart farming technologies is a barrier, data privacy concerns and ethical implications are also important, while there are still issues relating to access to computing technologies, IT skills and low trust in institutional frameworks. Peer-to-peer sharing and learning is an important approach that can build trust and confidence amongst and between agencies and farmers. In addition, adoption could be improved with the provision of independent informational support and demonstration of the viability of economic return.

In conclusion, there is huge potential to develop EO services to help PAs and CBs to monitor scheme compliance remotely and to incorporate on-farm data collected by precision technologies as an evidence source. While uptake of these technologies by authenticating bodies and farmers is currently low, the knowledge gained from bringing these together could well encourage and promote more sustainable farming systems by providing transparent information towards achieving a common goal. A trusted, robust infrastructure around the EO services is needed to ensure that all data collection/sharing systems can 'talk' to each other. In addition, there needs to be a campaign to

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increase awareness of the availability of these EO services alongside development of training and support systems. However, as noted in the response from the CBs, to maximise adoption of the ENVISION services, all stakeholders need to be involved from the start in co-creation to produce resilient, useful, adaptable, cost-effective services that help to achieve the goal of sustainable agriculture.

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9 Annexes

ANNEX I: Existing remote monitoring services for PAs and CBs

Name	Description	Services		
EU research projects				
EOMORES	Monitoring the quality of inland and coastal water	Monitoring of algal blooms and blue-green algae	Sediment plume identification or changes in suspended matter	Monitoring of land-derived inputs of dissolved organic matter in lakes
ReCAP	Platform to support the implementation of cross-compliance standards, co-designed and co-created by public authorities, farmers and agricultural consultants	Remote monitoring of CAP compliance / obligations	Correlates EO, user-generated and geo-referenced data	Supplements in-field visits; Reduce farmer administration.
SEN4CAP	Aims to provide algorithms, products, workflows and best practices for agriculture monitoring relevant for the management of the CAP. Paying particular attention to how Sentinel derived information can support the modernisation and simplification of the CAP post 2020.	Cultivated crop type map	Grassland mowing product; Vegetation status indicator;	Agricultural practices monitoring
EO4AGRI	Improving operational Agriculture monitoring from local to global levels based on information derived from Copernicus satellite observation data and through exploitation of associated geospatial and socio-economic information services.	Information and best-practice sharing (in relation to EO data, services and tools), for farmers and PAs		
NIVA	New IACS Vision in Action - Digital solutions, e-tools and good practices for e-governance and development of IACS to facilitate data and information flows, while reducing administrative burden for farmers, paying agencies and other stakeholders. IACS - Integrated Administration and Control System)	Tools for monitoring via EO data	Practice sharing in relation to EO data use by PAs	
DIONE	Development of a direct payment controlling toolbox for paying agencies to abide by the modernised CAP, involving novel techniques that will improve the capabilities of satellite technology while integrating various data sources (drones, soil sensors and mobile applications).	Green accountability toolbox (automated checking for Greening compliance);	EO component (e.g. enhanced crop-type maps)	Land cover / Land use datasets (drone-based image capture); Geo-tagged photos framework (capturing geo-tagged photos from farmers); Low cost sensors for evaluating land degredation (smart sensors for PAs)
Open IACS	Support the generation, aggregation and cross-border reuse of open datasets, increase the capabilities of HPC (High Performance Computing) and the data capabilities of the European data infrastructure, and promote the use of HPC and data across borders in the public interest.	Open network / platform to combine and harmonise data required for the CAP for PA's, farmers and other agencies		
DIAS	Funded by the European Commission, five cloud-based platforms providing centralised access to Copernicus data and information and processing tools (both open source and pay-per-use). DIAS - Data and Information Access Services.	Online platforms to discover, manipulate, process and download Copernicus Sentinel data and information.		
SATIKAS	Satelite-based (Sentinel 1 and 2) mowing detection in Estonia for CAP compliance	Mowing detection via EO		

IoF	Internet of Food and Farm 2020 (IoF2020) explores the potential of IoT-technologies for the European food and farming industry. Mainly farmer-focussed. IoT - Internet of Things	IoT resources for agriculture	Case studies on IoT use in agriculture	
EARSC	European Association of Remote Sensing Companies - Umbrella organisation for remote sensing companies across Europe	Links to companies using / supplying earth observation data for a range of industries - including agricultural and environmental		
EOMall	Compare earth observation services from across Europe - part of EARSC	Searchable database of companies, case studies and services involved with earth observation		
Eurisy	Non-profit association bringing together space agencies, international organisations, research institutions, and private businesses involved or interested in space-related activities across Europe. Facilitating dialogue and collaboration between public institutions SMEs, industry and academia from the space and non-space sectors.	Facilitating links between groups involved in / interested in EO		
PROAKIS	Inventory of the AKIS organisations, institutions and their linkages in the 27 EU countries. (AKIS - Agricultural Knowledge and Information Systems)	Interactive, searchable directory of agricultural advisory organisations		
SAGRIS	Automated production of aggregated temporal (weekly or monthly) statistics for parcel-based automated crop monitoring, integrates Sentinel 1 and 2 data	Monitoring of farmland parcels	Monitoring crops and conditions	Providing end-users with personalised situational reports and early warning notifications
VEGA-GEOGLAM	Tools for analysis of EO data, results of data processing and other related information. Mainly aimed at partners of the SIGMA project and uses the framework of the GEOGLAM crop monitor, however also access to the data for a wider community.	Agricultural land and crops state analysis with vegetation indices time-series	Analysis of satellite data for global monitoring of agricultural production and yield forecasting	
LPIS	The LPIS is the main tool allowing farmers to annually declare areas of cultivated fields and eventually the ecological focus areas via Geo Spatial Aid Application – (GSAA).	IT system based on photographs of agricultural parcels		
DataBio	Using Big Data to support the production of raw materials from agriculture, forestry, and fishery/aquaculture for the bioeconomy industry in order to produce food, energy and biomaterials, while taking into account responsibility and sustainability issues.	Aggregate, process and analyse Big Data from agriculture, forestry, and fishery	Enabling sectors to selectively utilize numerous software components, pipelines and datasets.	
TerraSigna	Earth Observation data processing. Data selection, analysis and processing, using in-house created and developed algorithms and techniques.	Monitoring via EO data (e.g. environmental and coastal)	Big data (e.g. satellite imagery) analysis	
DIANA	Using EO and other data sources for the identification and inspection of non authorised water abstractions for irrigation and improving water management policies and practices.	Detecting, monitoring and assessing non-authorised water abstractions using EO		
NEUROPUBLIC	Information systems / platforms utilising EO data and remote sensing systems for variety of activities, including smart farming system (Gaiasense) and CAP compliance	Combining remote sensing and EO data for farm management and CAP compliance	Processing of data (for compliance checks)	

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BELCAM	Using EO data to monitor agriculture at parcel levels, down to 10m resolution.	Satellite imagery	Vegetation indices	
SENSAGRI	Using Sentinel 1 and 2 data to develop an "innovative portfolio of prototype agricultural monitoring services". SENSAGRI - Sentinels Synergy for Agriculture	Measuring Surface Soil Moisture (SSM)	Measuring green and brown leaf area index (LAI)	Crop type mapping
CropSAT	Using satellite imagery to visualise the crop variation within fields.	Monitoring crop biomass in fields / parcels		
UKCEH Land Cover Plus: Crops	Detailed, interactive, digital maps of cropping in Great Britain. Two million land parcels are categorised within the Land Cover Map spatial framework, providing information on annual crop types for every field in Great Britain.	Crop maps of: winter wheat (including oats), spring wheat, winter barley, spring barley, oilseed rape, field beans, potatoes, sugar beet, maize, and improved grass.		
FaST	Digital service platform for agriculture, environment and sustainability aimed at EU farmers, Member State Paying Agencies, farm advisors and developers of digital solutions. Generation and re-use of solutions for sustainable and competitive agriculture based on space data (Copernicus and Galileo) and other data public and private datasets.	Satellite-based monitoring service for agriculture aimed at PAs		
HAZI	Services for the agri-food sector, supporting the sustainable evolution of the rural and coastal environment, professionalisation of workers and the quality of products in the Basque region.	Projects using EO data to support environmental initiatives		
Service provision companies and start-ups				
Zebris	Solutions and services utilising geoinformatics and remote sensing as well as scientific consulting services on questions of forest science, water management, environmental monitoring, soil protection, agriculture and the management of georisks.	EO data acquisition, processing, analysis and storage		
Assimila	Using EO data and environmental modelling in understanding, monitoring and predicting the environment. Agriculture, land and climate risks are particular focus areas	Crop modelling and monitoring		
Sustainable Environmental Consultants	Sustainability verification and validation platform to provide solutions to help you meet your sustainability goals. Our offerings include sustainability risk management, agricultural compliance and engineering, and erosion control solutions	Agricultural monitoring schemes	Regulatory monitoring (US focus)	
SINERGISE	Solutions for managing spatial data, particularly in land administration and agriculture processes. Agriculture related systems covering Integrated Administration and Control System (IACS) legislation.	Land parcel identification system	Controls with remote sensing - Sentinel data.	
GISAT	Aims to provide a wide range of value added, complete, high quality, affordable and 'state-of-the-art' geoinformation services based on the Earth Observation technology.	Remote sensing data and services to support CAP		
Cloudeo	Services focussing aroung geospatial and EO data for a range of industries, including agricultural	Data and software services in relation EO data.	Consultancy services	

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Cloudferro	Cloud computing and Big Data services with a focus on providing access to EO data	Cloud computing and data storage for EO data		
Draxis Environmental	Focus on developing real life environmental ICT solutions and providing specialized environmental consultation services.	Environmental software and databases	Consultancy services	
SIRS	Supports international and local groups / organisations in the management of territories through data from satellite, aircraft and drones and on-site visits	Following up on CAP; Crop inventories; Hedgerow geo-referencing; Mapping soils.	Crop inventories	Hedgerow geo-referencing; Mapping soils.
TerraNIS	Geoinformation services based on Earth Observation. Agronomic, viticultural and oenological advice and decision support tools for land management	EO data acquisition and processing for e.g. crop and biodiversity monitoring		
Ariespace	Satellite solutions for agriculture, developing operational solutions for the management of irrigation, agro-forestry resources and plants.	Remote sensing for: Irrigation; Fertilisation monitoring; Vegetation indices		
Brockman Consult	Tailor-made software solutions, information products and expert advice in Earth Observation.	EO data processing		
Earthi	Geo-spatial Information provider fusing multi-operator / multi-resolution / multi-sensor Earth Observation (EO) data including satellite video coupled with advanced analytics and geo-spatial experts to provide near-real time actionable insights.	Mapping agricultural land and crop classification	Vegetation and crop health monitoring	

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ANNEX II: Questionnaire to survey and assess current service provision – PAs

ENVISION Assessing Technical and Operational Requirements - PAs version

Start of Block: Section A - Demographics

Your participation in the survey is entirely voluntary and all of your responses will be kept confidential.No personally identifiable information will be associated with your responses to any reports of these data.This research has been reviewed and approved by the School of Agriculture, Policy and Development Research Ethics Committee.

Name of organisation

____

Country

____

Number of applications processed by your organisation annually (approximately)

____

Area of coverage (i.e. nation-wide or specific regions)

____

Does your organisation have the capacity (IT technology and personnel knowledge) to support the adoption of novel IT systems for monitoring of agricultural practices?

- o Yes (1)
- o No (2)

Approximately what is the percentage of farmers that engage your organisation electronically to submit financial aid applications and payment claims?

- o < 15% (1)
- o 15 - 30% (2)
- o 30 - 45% (3)
- o 45 - 60% (4)

- 60 -75% (5)
- > 75% (6)

What kind of data do claimants currently provide through the online system in relation to the monitoring of the following practices? Please type your response for all that apply.

- Crop Diversity (1) ____
- Soil Organic Carbon (2) ____
- Vegetation Status (3) ____
- Crop Growth (4) ____
- Grassland (Mowing / Ploughing) (5) ____
- Soil Erosion (6) ____
- Other. Please specify: (7) ____

End of Block: Section A - Demographics

Start of Block: Section B - Current Status of Services

Can you identify any commercial or non-commercial IT system (current or under development) for the remote continuous monitoring of agricultural parcels? Please tick all that apply.

1. Area Monitoring System (AMS) (1)
2. Sen4Cap (2)
3. DIONE services (3)
4. EO4AGRI (4)
5. e-Shape services (5)
6. NIVA4CAP services (6)
7. Other. Please specify: (7) ____

Have you ever received support or training to unlock the potential benefits of the systems identified above (previous question)? Please tick all that apply.

8. Yes, from the European Commission (1)
9. Yes, from Governmental Departments or Authorities (2)
10. Yes, from Research Institutions or Organisations (3)
11. Yes, from Private Organisations (4)
12. Yes, from other sources. Please specify: (5) ____
13. No, we have not received any support or training (6)

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If yes, which of the following is true? Please tick all that apply.

14. We have participated in a workshop or conference focusing on new technologies and their use for monitoring of agricultural parcels (1)
15. We have been funded to research and develop services (i.e. ESA research projects) to support remote monitoring of agricultural parcels (2)
16. We have been funded to roll out and evaluate the implementation of commercial and non-commercial services to support remote monitoring of agricultural parcels (3)
17. Other, please define: (4) ____

Have you participated in any of the following actions with the use of Earth Observation data? Please tick all that apply.

18. Implemented checks by remote monitoring in the most recent round of compliance checks. Please briefly describe the process (methodology): (1) ____
19. Used the Copernicus Sentinel data systematically to check some of the requirements for financial aid (2)
20. Used geo-tagged photos or drones for monitoring agricultural parcels (3)

Are you currently participating in a project for the development of monitoring services for agricultural parcels?

- o Yes. Please specify: (1) ____
- o No (2)

Have Covid-19 related impacts and restrictions helped your organisation to identify gaps in services provided by current monitoring systems?

- o Yes. Please specify: (1) ____
- o No (2)

How could novel, remote monitoring services help you to overcome those gaps during the Covid-19 pandemic?

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Are you using the monitoring processes (technologies) for other purposes beyond compliance check, for example to adhere to certain agri-environmental policies?

- o Yes. Please specify: (1) ____
- o No (2)

Please state the level of agreement or disagreement with the following statements.

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
Number of parcels to be followed-up is too high (1)	o	o	o	o	o
There is uncertainty in legislation regarding the European Commission's conformity audits (2)	o	o	o	o	o
There is a need to improve the IT infrastructure (hardware and software) (3)	o	o	o	o	o
Development of the remote monitoring system is time consuming and costly compare to the benefits (4)	o	o	o	o	o
There is a risk of farmers	o	o	o	o	o

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taking legal action because they don't agree with the assessment (5)					
Farmers might consider monitoring / warning alerts as intrusive (6)	o	o	o	o	o
Implementing remote monitoring systems implies significant changes to the organisational structure of the paying agency (7)	o	o	o	o	o
There is a need to introduce significant changes to the LPIS (8)	o	o	o	o	o

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Please answer the following questions regarding your current use of services for remote, continuous monitoring of agricultural practices.

Approximately what percentage (%) of your inspection process is done remotely?

- o < 15% (1)
- o 15 - 30% (2)
- o 30 - 45% (3)
- o 45 - 60% (4)
- o 60 - 75% (5)
- o > 75% (6)

Are you currently using any remote monitoring services for any of the following agricultural practices? Please type your response for all that apply.

- o Crop Diversity (1) ____
- o Soil Organic Carbon (2) ____
- o Vegetation Status (3) ____
- o Crop Growth (4) ____
- o Grassland (Mowing / Ploughing) (5) ____
- o Soil Erosion (6) ____
- o Other. Please specify: (7) ____

What is currently performing well for your organisation in respect to the use of remote monitoring services?

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What problems / problem areas have you identified in respect to the use of the current remote monitoring services?

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What do you need to be able to conduct all farm checks by remote monitoring?

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Which additional agricultural practices would you like to monitor remotely?

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How is your organisation going to meet the new CAP requirement of "checks by monitoring"?

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Looking to the future, how can you ensure that the use of remote monitoring is sustainable within your organisation?

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Page Break

End of Block: Section B - Current Status of Services

Start of Block: Section C - SWOT analysis

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Please complete this SWOT analysis for the remote monitoring services your organisation currently uses.
For the Strengths and Weaknesses, please refer exclusively to the internal operations of the organisation (e.g. technical capacity, quality of hardware / software).
The Opportunities and Threats are examined in respect to the external environment of the organisation.

Strengths of the current services (e.g. cost-effective system)

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Weaknesses of the current services (e.g. data intensive process)

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Opportunities - how can the current services be improved (e.g. by increasing the temporal and spatial resolution of data)

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Threats - what is changing (e.g. remote monitoring systems need to adapt to changing relevant policies)

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End of Block: Section C - SWOT analysis

The ENVISION project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869366

ANNEX III: Paying Agencies contacted for feedback on current service provision

Country	Paying Agency	Number of people contacted	Status of response	ENVISION partner
ALBANIA	Ministry of Agriculture and Rural Development of Albania		Pending	No
AUSTRIA	Agramarkt Austria		Responded	No
BELARUS	Ministry of Agriculture and Food of the Republic of Belarus		Pending	No
BELGIUM	Vlaanderen Paying Agency for Flanders		Responded	Yes
BELGIUM	Paying Agency for Wallonia		Pending	No
BOSNIA AND HERZEGOVINA	Ministry of Agriculture, Water Management and Forestry of the Federation of Bosnia and Herzegovina		Pending	No
BULGARIA	PRSR Bulgarian Paying Agency		Pending	No
CROATIA	APPRRR Croatian Paying Agency		Pending	No
CYPRUS	CAPO Cyprus Paying Agency		Responded	Yes
CZECH REPUBLIC	SZIF Czech Republic Paying Agency		Responded	No
DENMARK	Nature Hverv Danish Paying Agency		Responded	No
ESTONIA	PRIA Estonian Paying Agency		Pending	No
FINLAND	MAVI Finnish Paying Agency		Pending	No
FRANCE	ASP Public French Paying Agency		Responded	No
GERMANY	Federal Ministry of Food and Agriculture - German Paying Agency		Pending	No
GREECE	OPEKEPE Greek Paying Agency		Responded	No
HUNGARY	MVH Hungarian Paying Agency		Pending	No
IRELAND	Irish Paying Agency		Pending	No
ITALY	AGEA Italian Paying Agency		Pending	No
LATVIA	LAD Latvian Paying Agency		Responded	No
LITHUANIA	NMA Lithuanian Paying Agency		Responded	Yes
LUXEMBURG	Luxemburg Paying Agency		Pending	No
MALTA	Malta Paying Agency		Pending	No
MONTENEGRO	Ministry of Agriculture and Rural Development of Montenegro		Pending	No
NETHERLANDS	RVO Netherlands Paying Agency		Responded	No
NORTH MACEDONIA	IPARDPA North Macedonia		Pending	No
NORWAY	Landbruksdirektoratet		Pending	No
	Ministry of Agriculture and Food of Norway		Pending	No
POLAND	AGRIMR Polish Paying Agency		Responded	No
PORTUGAL	IFAP Portugish Paying Agency		Pending	No
ROMANIA	APIA Romanian Paying Agency		Pending	No
RUSSIA	Ministry of Agriculture of the Russian Federation		Pending	No
SERBIA	Directorate for Agrarian Payments		Pending	No
SCOTLAND	Rural Payments and Inspection Division Scottish Governement		Pending	No
SLOVAKIA	APA Slovakian Paying Agency		Responded	No
SLOVENIA	AKTRP Slovenian Paying Agency		Responded	No
SPAIN	FEGA Spanish Paying Agency		Pending	No

SWEDEN	Jordbruksverket Swedish Paying Agency		Responded	No
SWITZERLAND	FOAG Federal Office for Agriculture Switzerland		Pending	No
TURKEY	IPARD		Pending	No
UKRAINE	Ministry of Agrarian Policy of Ukraine		Pending	No
UNITED KINGDOM	Rural Payments Agency		Pending	No

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ANNEX IV: Questionnaire to survey and assess current service provision – CBs

ENVISION Assessing Technical and Operational Requirements - CBs version

Start of Block: Section A - Demographics

Your participation in the survey is entirely voluntary and all of your responses will be kept confidential. No personally identifiable information will be associated with your responses to any reports of these data. This research has been reviewed and approved by the School of Agriculture, Policy and Development Research Ethics Committee.

Name of organisation

____

Country

____

Number of assessments conducted by your organisation annually (approximately)

____

Area of coverage (i.e. nation-wide or specific regions)

____

In which agricultural production sectors is your organisation active as an assurance scheme? Please tick all that apply.

1. Organic livestock production (i.e. dairy, beef, pork, poultry) (1)
2. Conventional livestock production (4)
3. Organic crop farming (2)
4. Conventional crop farming (3)
5. Other. Please specify: (5) ____

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Does your organisation have the capacity (IT technology and personnel knowledge) to support the adoption of novel IT systems for monitoring of agricultural practices?

- Yes (1)
- No (2)

Approximately what is the percentage of farmers that engage your organisation electronically to submit applications for certification?

- < 15% (1)
- 15 - 30% (2)
- 30 - 45% (3)
- 45 - 60% (4)
- 60 -75% (5)
- > 75% (6)

What kind of data do claimants currently provide through the online system in relation to the monitoring of the following practices? Please type your response for all that apply.

- Crop Diversity (1) ____
- Soil Organic Carbon (2) ____
- Vegetation Status (3) ____
- Crop Growth (4) ____
- Grassland (Mowing / Ploughing) (5) ____
- Soil Erosion (6) ____
- Other. Please specify: (7) ____

End of Block: Section A - Demographics

Start of Block: Section B - Current Status of Services

Q1 Can you identify any commercial or non-commercial IT system (current or under development) for the remote continuous monitoring of sustainable agricultural practices? Please tick all that apply.

6. Sen4Cap (2)
7. DIONE services (3)
8. EO4AGRI (4)
9. e-Shape services (5)
10. NIVA4CAP services (6)
11. Other. Please specify: (7) ____

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Q2 Have you ever received support or training to unlock the potential benefits of the systems identified above (previous question)? Please tick all that apply.

12. Yes, from the European Commission (1)
13. Yes, from Governmental Departments or Authorities (2)
14. Yes, from Research Institutions or Organisations (3)
15. Yes, from Private Organisations (4)
16. Yes, from other sources. Please specify: (5) ____
17. No, we have not received any support or training (6)

Q3 If yes, which of the following is true? Please tick all that apply.

18. We have participated in a workshop or conference focusing on new technologies and their use for monitoring of sustainable agricultural practices (1)
19. We have been funded to research and develop services (i.e. ESA research projects) to support remote monitoring of sustainable agricultural practices (2)
20. We have been funded to roll out and evaluate the implementation of commercial and non-commercial services to support remote monitoring of sustainable agricultural practices (3)
21. Other, please define: (4) ____

Q4 Have you participated in any of the following actions with the use of Earth Observation data? Please tick all that apply.

22. Implemented checks by remote monitoring in the most recent round of compliance checks. Please briefly describe the process (methodology): (1) ____
23. Used the Copernicus Sentinel data systematically to check some of the requirements for accreditation / certification (2)
24. Used geo-tagged photos or drones for monitoring sustainable agricultural practices (3)

Q5 Are you currently participating in a project for the development of monitoring services for sustainable agricultural practices?

- Yes. Please specify: (1) ____
- No (2)

Q6 Have Covid-19 related impacts and restrictions helped your organisation to identify gaps in services provided by current monitoring systems?

- Yes. Please specify: (1) ____
- No (2)

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Q7 How could novel, remote monitoring services help you to overcome those gaps during the Covid-19 pandemic?

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Q8 Are you using the monitoring processes (technologies) for other purposes beyond compliance check, for example to adhere to certain agri-environmental policies?

- o Yes. Please specify: (1) ____
- o No (2)

Q9 Please state the level of agreement or disagreement with the following statements.

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
Number of practices to be monitored is too high (1)	o	o	o	o	o
There is uncertainty in legislation regarding relevant agri-environmental policies (2)	o	o	o	o	o
There is a need to improve the IT infrastructure (hardware and software) (3)	o	o	o	o	o
Development of the remote monitoring system is time consuming and costly compare to	o	o	o	o	o

the benefits (4)					
There is a risk of farmers taking legal action because they don't agree with the assessment (5)	o	o	o	o	o
Farmers might consider monitoring / warning alerts as intrusive (6)	o	o	o	o	o
Implementing remote monitoring systems implies significant changes to the organisational structure of the certification body (7)	o	o	o	o	o

Please answer the following questions regarding your current use of services for remote, continuous monitoring of sustainable agricultural practices.

Approximately what percentage (%) of your inspection process (assessments) is done remotely?

- o < 15% (1)
- o 15 - 30% (2)
- o 30 - 45% (3)
- o 45 - 60% (4)
- o 60 - 75% (5)
- o > 75% (6)

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Are you currently using any remote monitoring services for any of the following agricultural practices? Please type your response for all that apply.

- Crop Diversity (1) ____
- Soil Organic Carbon (2) ____
- Vegetation Status (3) ____
- Crop Growth (4) ____
- Grassland (Mowing / Ploughing) (5) ____
- Soil Erosion (6) ____
- Other. Please specify: (7) ____

What is currently performing well for your organisation in respect to the use of remote monitoring services?

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What problems / problem areas have you identified in respect to the use of the current remote monitoring services?

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What do you need to be able to conduct all farm checks by remote monitoring?

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Which additional agricultural practices would you like to monitor remotely?

How is your organisation going to achieve effective monitoring according to the requirements of future agri-environmental policies?

Looking to the future, how can you ensure that the use of remote monitoring is sustainable within your organisation?

Start of Block: Section C - SWOT analysis

Please complete this SWOT analysis for the remote monitoring services your organisation currently uses.
For the Strengths and Weaknesses, please refer exclusively to the internal operations of the organisation (e.g. technical capacity, quality of hardware / software).
The Opportunities and Threats are examined in respect to the external environment of the organisation.

Strengths of the current services (e.g. cost-effective system)

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Weaknesses of the current services (e.g. data intensive process)

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Opportunities - how can the current services be improved (e.g. by increasing the temporal and spatial resolution of data)

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Threats - what is changing (e.g. remote monitoring systems need to adapt to changing relevant policies)

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End of Block: Section C - SWOT analysis

The ENVISION project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869366

ANNEX V: Certifying Bodies contacted for feedback on current service provision

Country	Certification Body	Number of people contacted	Status of response	ENVISION partner
AUSTRIA	GfRS Gesellschaft für Ressourcenschutz mbH		Pending	No
AUSTRIA	Austria Bio Garantie GmbH		Pending	No
AUSTRIA	Austria Bio Garantie - Landwirtschaft GmbH		Pending	No
AUSTRIA	BIOS - Biokontrollservice Österreich		Pending	No
AUSTRIA	LACON GmbH		Pending	No
AUSTRIA	SLK GesmbH		Pending	No
AUSTRIA	LVA GmbH		Pending	No
AUSTRIA	SGS Austria Controll - Co. Ges.m.b.H.		Pending	No
AUSTRIA	LKV Austria Gemeinnützige GmbH		Pending	No
BELGIUM	CERTISYS		Pending	No
BELGIUM	TÜV NORD INTEGRA bvba		Pending	No
BELGIUM	Inscert Partner		Pending	No
BELGIUM	Comité du Lait		Pending	No
BULGARIA	BALKAN BIOCERT Ltd.		Pending	No
BULGARIA	Q CERTIFICATION S.P. A.		Pending	No
BULGARIA	CERES – CERtification of Environmental Standards Ltd.		Pending	No
BULGARIA	LACON - Private Institute for Quality Assurance and Certification of organically produced food products LTD.		Pending	No
BULGARIA	Control Union Certifications B.V.		Pending	No
BULGARIA	Inspection Institute for Organic products S.A. (BIO HELLAS)		Pending	No
BULGARIA	ECOGRUPPO ITALIA S.R.L. with branch office in Bulgaria – "ECOGRUPPO ITALIA –BULGARIA BRANCH UNIT		Pending	No
BULGARIA	SGS BULGARIA Ltd		Pending	No
BULGARIA	BULGARKONTROLA S. A.		Pending	No
BULGARIA	Agency for organic certification Ltd.		Pending	No
BULGARIA	COSMOCERT		Pending	No
BULGARIA	MAKOM CERTIFICATION		Pending	No
BULGARIA	Agro Organic Control Ltd.		Pending	No
BULGARIA	Bio Certification		Pending	No
BULGARIA	Nutramed		Pending	No
CROATIA	BIOINSPEKT d.o.o.		Pending	No
CROATIA	PRVA EKOLOŠKA STANICA d.o.o.		Pending	No
CROATIA	ZADRUGA AGRIBIOCERT		Pending	No
CROATIA	BIOTECHNICON d.o.o.		Pending	No
CROATIA	HRVATSKE ŠUME d.o.o.		Pending	No
CROATIA	TRGO-INVEST d.o.o.		Pending	No
CROATIA	AUSTRIA BIO GARANTIE d.o.o.		Pending	No
CROATIA	BUREAU VERITAS d.o.o.		Pending	No

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CROATIA	Eurotalus j.d.o.o.		Pending	No
CROATIA	EKO RAZVOJ d.o.o.		Pending	No
CROATIA	Nastavni Zavod za javno zdravstvo Dr. Andrija Štampar		Pending	No
CROATIA	BIOTER d.o.o.		Pending	No
CROATIA	MAREKO d.o.o.		Pending	No
CYPRUS	LACON LTD		Pending	No
CYPRUS	Eurocert Ευρωπαϊκη Εταιρεία Ελέγχων και Πιστοποιήσεων ΑΕ		Pending	No
CYPRUS	TUV AUSTRIA HELLAS MOV Ε.Π.Ε.		Pending	No
CYPRUS	CertifyBio Ltd		Pending	No
CZECH REPUBLIC	KEZ o.p.s.		Pending	No
CZECH REPUBLIC	ABCERT AG		Pending	No
CZECH REPUBLIC	BIOKONT CZ, s r.o.		Pending	No
CZECH REPUBLIC	BUREAU VERITAS CZECH REPUBLIC, spol. s r.o.		Pending	No
CZECH REPUBLIC	State Veterinary Administration		Pending	No
CZECH REPUBLIC	Czech Agriculture and Food Inspection Authority		Pending	No
CZECH REPUBLIC	Central Institute for Supervising and Testing in Agriculture		Pending	No
DENMARK	Landbrugsstyrelsen (The Danish Agricultural Agency)		Pending	No
DENMARK	Fødevarestyrelsen (The Danish Veterinary and Food Administration)		Pending	No
ESTONIA	Agricultural Board		Pending	No
ESTONIA	Veterinary and Food Board		Pending	No
FINLAND	Uudenmaan elinkeino-, liikenne- ja ympäristökeskus		Pending	No
FINLAND	Ruokavirasto		Pending	No
FINLAND	Sosiaali- ja terveysalan lupa- ja valvontavirasto Valvira (National Supervisory Authority for Welfare and Health)		Pending	No
FINLAND	Ålands landskapsregering		Pending	No
FRANCE	ECOCERT FRANCE		Pending	No
FRANCE	CERTIPAQ BIO		Pending	No
FRANCE	BUREAU VERITAS CERTIFICATION FRANCE		Pending	No
FRANCE	Certisud		Pending	No
FRANCE	CERTIS		Pending	No
FRANCE	BUREAU ALPES CONTROLES		Pending	No
FRANCE	QUALISUD		Pending	No
FRANCE	BIOTEK AGRICULTURE		Pending	No
FRANCE	EUROFINS CERTIFICATION		Pending	No
FRANCE	Control Union Inspection France		Pending	No
FRANCE	OCACIA		Pending	No
FRANCE	AFNOR Certification		Pending	No
FINLAND	Ruokavirasto		Pending	No
FINLAND	Sosiaali- ja terveysalan lupa- ja valvontavirasto Valvira (National		Pending	No

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	Supervisory Authority for Welfare and Health)			
FINLAND	Ålands landskapsregering		Pending	No
FRANCE	ECOCERT FRANCE		Pending	No
FRANCE	CERTIPAQ BIO		Pending	No
FRANCE	BUREAU VERITAS CERTIFICATION FRANCE		Pending	No
FRANCE	Certisud		Pending	No
FRANCE	CERTIS		Pending	No
FRANCE	BUREAU ALPES CONTROLES		Pending	No
FRANCE	QUALISUD		Pending	No
FRANCE	BIOTEK AGRICULTURE		Pending	No
FRANCE	EUROFINS CERTIFICATION		Pending	No
FRANCE	Control Union Inspection France		Pending	No
FRANCE	OCACIA		Pending	No
FRANCE	AFNOR Certification		Pending	No
GERMANY	Kiwa BCS Öko-Garantie GmbH		Pending	No
GERMANY	LACON Privatinstitut für Qualitätssicherung und Zertifizierung ökologisch erzeugter Lebensmittel GmbH		Pending	No
GERMANY	Ecocert IMO GmbH		Pending	No
GERMANY	ABCERT AG		Pending	No
GERMANY	Prüfgesellschaft ökologischer Landbau mbH		Pending	No
GERMANY	LC Landwirtschafts-Consulting GmbH		Pending	No
GERMANY	AGRECO R. F. GÖDERZ GmbH		Pending	No
GERMANY	QC & I Gesellschaft für Kontrolle und Zertifizierung von Qualitätssicherungssystemen GmbH		Pending	No
GERMANY	Grünstempel® - Ökoprüfstelle e.V.		Pending	No
GERMANY	Kontrollverein ökologischer Landbau e.V.		Pending	No
GERMANY	Fachgesellschaft ÖKO-Kontrolle mbH		Pending	No
GERMANY	ÖkoP Zertifizierungs GmbH		Pending	No
GERMANY	GfRS - Gesellschaft für Ressourcenschutz mbH		Pending	No
GERMANY	ARS PROBATA GmbH		Pending	No
GERMANY	QAL GmbH Gesellschaft für Qualitätssicherung in der Agrar- und Lebensmittelwirtschaft		Pending	No
GERMANY	ABCG Agrar- Beratungs- und Controll GmbH		Pending	No
GERMANY	Control Union Certifications Germany GmbH		Pending	No
GREECE	DIO -Inspection and Certification Organisation of Organic Products		Pending	No
GREECE	PHYSIOLOGIKE INSPECTIONS CERTIFICATIONS OF ORGANIC PRODUCTSPROMOTION		Pending	No
GREECE	BIO HELLAS		Responded	No
GREECE	A CERT SA		Pending	No

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GREECE	IRIS		Pending	No
GREECE	GREEN CONTROL		Pending	No
GREECE	GEOTECHNICAL LABORATORY S.A		Pending	No
GREECE	GMCert		Pending	No
GREECE	Q-CERT		Pending	No
GREECE	TUV HELLAS S.A.		Pending	No
GREECE	OXYGONO-HELLENIC CERTIFICATION BODY		Pending	No
GREECE	TÜV AUSTRIA-HELLAS-LTD		Pending	No
GREECE	Q-check P.C. or Q-check PRIVATE COMPANY		Pending	No
GREECE	EUROCERT SA		Pending	No
GREECE	COSMOCERT		Pending	No
HUNGARY	Biokontroll Hungária Nonprofit Kft.		Pending	No
HUNGARY	Hungária Öko Garancia Kft.		Pending	No
IRELAND	Irish Organic Association		Pending	No
IRELAND	Organic Trust Ltd		Pending	No
IRELAND	Global Trust Certification Ltd (SAI Global)		Pending	No
ITALY	BIKO - Tirol		Pending	No
ITALY	CODEX Srl		Pending	No
ITALY	QC&I Gmbh		Pending	No
ITALY	SUOLO & SALUTE Srl		Pending	No
ITALY	BIOS Srl		Pending	No
ITALY	ICEA Srl		Pending	No
ITALY	Bioagricert Srl		Pending	No
ITALY	ECOGRUPPO ITALIA Srl		Pending	No
ITALY	CCPB Srl		Pending	No
ITALY	Sidel Spa		Pending	No
ITALY	ABCERT Srl		Pending	No
ITALY	QCertificazioni Srl		Pending	No
ITALY	Valoritalia Srl		Responded	No
ITALY	Siquria		Pending	No
ITALY	CEVIQ srl		Pending	No
ITALY	Agroqualità S.p.a.		Pending	No
ITALY	Istituto Nord Ovest Qualità Soc. Coop.		Pending	No
ITALY	Dipartimento di Qualità Agroalimentare Srl		Pending	No
ITALY	CSQA		Pending	No
LATVIA	Biedrība 'Vides kvalitāte'		Pending	No
LATVIA	SIA 'Sertifikācijas un testēšanas centrs'		Pending	No
LITHUANIA	Ekoagros		Pending	No
LUXEMBURG	Administration des Services techniques de l'Agriculture (autorité compétente) Service de la protection des végétaux		Pending	No
LUXEMBURG	Prüfgesellschaft Ökologischer Landbau mbH (DE-ÖKO-007)		Pending	No
LUXEMBURG	Kontrollverein Ökologischer Landbau e.V. (DEÖKO-022)		Pending	No
LUXEMBURG	CERTISYS (BE-BIO-01)		Pending	No

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LUXEMBURG	GfRS Gesellschaft für Ressourcenschutz mbH (DE-ÖKO-039)		Pending	No
LUXEMBURG	Inscert Partner S.A. (BE-BIO-03)		Pending	No
LUXEMBURG	Bioagricert Srl (IT-BIO-007)		Pending	No
LUXEMBURG	TÜV Nord Integra bvba (BE-BIO-02)		Pending	No
MALTA	Malta Competition and Consumer Affairs Authority		Pending	No
NETHERLANDS	Stichting Skal Biocontrole		Pending	No
POLAND	EKOGWARANCJA PTRE Sp. z o.o.		Pending	No
POLAND	PNG Sp. z o.o.		Pending	No
POLAND	COBICO Sp. z o.o.		Pending	No
POLAND	Bioekspert Sp. z o.o.		Pending	No
POLAND	BIOCERT MAŁOPOLSKA Sp. z o.o.		Pending	No
POLAND	POLSKIE CENTRUM BADAŃ I CERTYFIKACJI S.A.		Pending	No
POLAND	AGRO BIO TEST Sp. z o.o.		Pending	No
POLAND	TÜV RHEINLAND POLSKA Sp. z o.o.		Pending	No
POLAND	CENTRUM JAKOŚCI AGROEKO Sp. z o.o.		Pending	No
POLAND	SGS POLSKA Sp. z o.o.		Pending	No
POLAND	DQS Polska Sp. z o.o.		Pending	No
POLAND	Bureau Veritas Polska Sp. z o. o.		Pending	No
POLAND	KCBiC Gwarantowana Jakość		Pending	No
PORTUGAL	Naturalfa - controlo e certificação , Lda		Pending	No
PORTUGAL	IVDP- Instituto dos vinhos do Douro e do Porto		Pending	No
PORTUGAL	ECOCERT PORTUGAL, Unipessoal Lda		Pending	No
PORTUGAL	SATIVA, Desenvolvimento Rural, Lda		Pending	No
PORTUGAL	CERTIPLANET – Certificação da Agricultura, Florestas e Pescas, Unipessoal, Lda.		Pending	No
PORTUGAL	CERTIS, Controlo e Certificação, Lda		Pending	No
PORTUGAL	AGRICERT – Certificação de Produtos Alimentares, Lda		Pending	No
PORTUGAL	TRADIÇÃO E QUALIDADE		Pending	No
PORTUGAL	CODIMACO - Certificação e Qualidade, Lda		Pending	No
PORTUGAL	SGS Portugal – Sociedade Geral de Superintendência, S. A.		Pending	No
ROMANIA	S.C ECOCERT S.R.L		Pending	No
ROMANIA	S.C. ECOINSPECT S.R.L.		Pending	No
ROMANIA	BIOS S.R.L ITALIA - SUCURSALA ROMÂNIA		Pending	No
ROMANIA	AGRECO R .F. GÖDERZ GMBH GERMANIA - SUCURSALA ROMÂNIA		Pending	No
ROMANIA	BIOAGRICERT ITALIA SRL – SUCURSALA ROMÂNIA		Pending	No
ROMANIA	AUSTRIA BIO GARANTIE GmbH ENZERSFELD SUCURSALA BUCURESTI		Pending	No
ROMANIA	CERTROM SRL		Pending	No
ROMANIA	S.C. ECOROISCERT SRL		Pending	No
ROMANIA	MICAREA ROMÂNĂ PENTRU CALITATE		Pending	No

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ROMANIA	CERES ORGANIC CERT SRL		Pending	No
ROMANIA	BIO CERT TRADIIONAL SRL		Pending	No
ROMANIA	SC SRAC CERT SRL		Pending	No
ROMANIA	MICAREA ROMÂNĂ PENTRU CALITATE		Pending	No
ROMANIA	CERES ORGANIC CERT SRL		Pending	No
ROMANIA	BIO CERT TRADIIONAL SRL		Pending	No
ROMANIA	SC SRAC CERT SRL		Pending	No
ROMANIA	SC TUV AUSTRIA ROMÂNIA SRL		Pending	No
SERBIA	Ecocert		Responded	No
SERBIA	Organic Control System OCS		Responded	Yes
SLOVAKIA	Naturalis SK, s.r.o.		Pending	No
SLOVAKIA	Biokont CZ, s.r.o.		Pending	No
SLOVAKIA	EKO-CONTROL SK s.r.o.		Pending	No
SLOVENIA	Institute for Inspection and Certification in Agriculture and in Silviculture Maribor (Institute KON – CERT Maribor)		Pending	No
SLOVENIA	Institute for Inspection and Certification of University of Maribor (IKC UM)		Pending	No
SLOVENIA	Bureau Veritas d.o.o.		Pending	No
SLOVENIA	TUV SUD Sava d.o.o.		Pending	No
SPAIN	SERVICIO DE CERTIFICACIÓN CAAE, S.L.U.		Pending	No
SPAIN	SOHISCERT S.A.		Pending	No
SPAIN	AGROCOLOR, S.L.		Responded	No
SPAIN	LGAI TECHNOLOGICAL CENTER, S.A		Pending	No
SPAIN	COMITÉ ARAGONÉS DE AGRICULTURA ECOLÓGICA		Pending	No
SPAIN	ECOCERT S.A.		Pending	No
SPAIN	KIWA ESPAÑA S.L.U.		Pending	No
SPAIN	CONSEJO DE LA PRODUCCIÓN AGRARIA ECOLÓGICA DEL PRINCIPADO DE ASTURIAS		Pending	No
SPAIN	Consell Balear de la Producció Agrària Ecològica (CBPAE)		Pending	No
SPAIN	INSTITUTO CANARIO DE CALIDADAGRO ALIMENTARIA (ICCA)		Pending	No
SPAIN	OFICINA DE CALIDAD ALIMENTARIA		Pending	No
SPAIN	CAECYL – CONSEJO DE AGRICULTURA ECOLÓGICA DE CASTILLA Y LEÓN		Pending	No
SPAIN	CCPAE		Pending	No
SPAIN	CAECV		Pending	No
SPAIN	DIRECCIÓN GENERAL DE AGRICULTURA Y GANADERÍA		Pending	No
SPAIN	CRAEGA		Pending	No
SPAIN	CAEM		Pending	No
SPAIN	CAERM		Pending	No
SPAIN	CPAEN/NNPEK		Pending	No
SPAIN	ENEEK		Pending	No
SPAIN	CERTIFOOD S.L.		Pending	No
SPAIN	BUREAU VERITAS IBERIA SL.		Pending	No
SPAIN	CCL CERTIFICACIÓN, S.L.		Pending	No

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SPAIN	SAI GLOBAL ASSURANCE SERVICES-OFICINA DE REPRESENTACIÓN EN ESPAÑA, LTD		Pending	No
SPAIN	QUALITAS NATURA CERTIFICACIÓN S.L.		Pending	No
SPAIN	OCE GLOBAL SLU		Pending	No
SPAIN	CPAER		Pending	No
SPAIN	ACCM		Pending	No
SWEDEN	KIWA Sverige AB		Pending	No
SWEDEN	SMAK Certifiering AB		Pending	No
SWEDEN	HS Certifiering AB		Pending	No
SWEDEN	Valiguard AB		Pending	No
SWEDEN	ControlCert Scandinavia AB		Pending	No
SWEDEN	Intertek Certification AB		Pending	No
UNITED KINGDOM	Organic Farmers & Growers CIC		Pending	No
UNITED KINGDOM	Organic Food Federation		Pending	No
UNITED KINGDOM	Soil Association Certification Ltd		Pending	No
UNITED KINGDOM	Bio-Dynamic Association Certification		Pending	No
UNITED KINGDOM	Irish Organic Association		Pending	No
UNITED KINGDOM	Organic Trust CLG		Pending	No
UNITED KINGDOM	Quality Welsh Food Certification Ltd		Pending	No
UNITED KINGDOM	O F & G (Scotland) Ltd		Pending	No
ICELAND	Vottunarstofa Tun		Pending	No
NORWAY	Debio		Pending	No
SWITZERLAND & LIECHTENSTEIN	Institut für Marktökologie IMO		Pending	No
SWITZERLAND & LIECHTENSTEIN	bio.inspecta AG		Pending	No
SWITZERLAND & LIECHTENSTEIN	ProCert Safety AG		Pending	No
SWITZERLAND & LIECHTENSTEIN	Bio Test Agro AG (BTA)		Pending	No

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