LEAF DELIVERABLE 6.11

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

Acronym: ENVISION

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1 Introduction

This report consists of three key sections (Section 2, 3 and 4), which include the methodology, results and discussion of the research findings within each section. The first section presents the LEAF Marque trial audit, which tested the applicability of ENVISION services to monitor farm compliance with the requirements of the LEAF Marque Standard. The second section presents an in-depth review of the LEAF Marque Standard requirements in the newest version of the standard to identify additional opportunities to apply earth observation (EO) and ENVISION services within the LEAF Marque assurance system. The third section examines the feasibility of incorporating EO into environmental assurance systems via engagement with LEAF Marque stakeholders.

Background information about LEAF's role and objectives in the ENVISION project, as well as information about the structure and key characteristics of the LEAF Marque assurance system have been included at the beginning of the report to contextualise the research performed by LEAF over the course of the project.

1.1 Overview of Task 6.5: Contribution to Standards – LEAF Marque

To encourage the development of new markets for EO-enabled products and services, ENVISION aims to support the incorporation of EO-enabled services into environmental assurance systems, which would catalyse a new market demand by certification bodies for monitoring services. LEAF's role in the ENVISION project was to demonstrate a test case for the application of ENVISION services within an environmental assurance system.

LEAF consistently investigate how new approaches to assurance can increase the effectiveness and robustness of the LEAF Marque Standard requirements and assurance system, including innovative and technological approaches. Further, as a global environmental sustainability standard, LEAF Marque aims to continuously adapt and strengthen its requirements to enable all farms to practice sustainable agriculture and build more resilient businesses. EO and ENVISION services have the potential to help LEAF Marque achieve these assurance and sustainability objectives by improving the efficiency, reliability and transparency of the assurance process and enabling the monitoring of new outcome-based approaches to assess the environmental sustainability performance of farms.
The project aimed to test the applicability of the ENVISION services to (1) monitor a set of existing LEAF Marque Standard requirements, (2) identify how EO and ENVISION services can be used to strengthen the LEAF Marque Standard by enabling the monitoring of outcome-based requirements and (3) assess the feasibility of incorporating EO into environmental assurance systems like LEAF Marque. This research informs the second objective of Task 6.5, which is led by the project partner INOS: the development of a roadmap for engaging standard-setting organisations to promote the uptake of ENVISION services in environmental assurance systems.

The findings and knowledge generated from the ENVISION project will inform LEAF's approach to engaging with EO technology after the end of the project, including the potential to explore the incorporation of EO monitoring and ENVISION services into the LEAF Marque assurance system.

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1.2 LEAF Marque Assurance System

To provide context to LEAF's research activities in this report, an overview of the LEAF Marque assurance system is outlined here.

Whilst LEAF develops and manages the LEAF Marque Standard requirements and maintains oversight of the LEAF Marque assurance system, the LEAF Marque certification process occurs external to LEAF. Farm businesses obtain LEAF Marque certification through audits conducted by third-party, LEAF Marque-approved certification bodies. Certification bodies verify that farms are compliant with the requirements of the LEAF Marque Standard, observing performance on the day of the annual LEAF Marque audit, rather than monitoring compliance throughout the certification cycle.

The certification bodies are responsible for audit delivery, certification decisions, and audit data management. Whilst a certification body auditor is responsible for conducting LEAF Marque audits, certification decisions are made independently of the audit by a second qualified member of certification body staff to maintain the robustness and integrity of the assurance process.

All certification bodies are accredited and must comply with LEAF Marque procedures, including the completion of annual LEAF Marque training and oversight activities. Certification bodies are ISO 17065 accredited for relevant baseline farm assurance certification system(s) that are a prerequisite requirement for LEAF Marque certification, and certification bodies must obtain an extension of scope to be accredited for the LEAF Marque Standard. Accreditation must be obtained from an Accreditation Body that is part of the European Accreditation, Multilateral Agreement on Product Certification, or members of the International Accreditation Forum which have been subject to a peer evaluation in the product certification field and have a positive recommendation in its report.

2 LEAF Marque Trial Audit

As part of Task 6.5 'Contribution to Standards', LEAF conducted a trial audit to assess the potential for ENVISION services to verify farm compliance with the requirements of the LEAF Marque Standard. The findings from this trial audit will inform ENVISION's strategy to engage with environmental assurance systems. It will also inform LEAF's approach to incorporating EO into the LEAF Marque assurance system.

2.1 Method

LEAF determined the following outcomes for the trial audit to create an assessment framework for the results: (1) identify the appropriate verification method of Control Points to assess farm compliance with the requirements and (2) determine the auditability of the Control Points using ENVISION services.

ENVISION project partners provided feedback from a technical perspective to help LEAF determine which Control Points and ENVISION services would be appropriate to utilise in the trial audit. Because many of the services require historical data to be provided as an input to the services for the training process, the number of Control Points eligible for monitoring was limited because neither LEAF

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Marque nor its third-party certification bodies currently collect and store the required data. It was initially determined that the Vegetation Status Mapping service was the most appropriate to monitor LEAF Marque requirements, as well as using the satellite images generated by the ENVISION platform to perform visual monitoring in a similar way auditors perform visual inspections during onsite audits. However it was later determined that Vegetation Status Mapping would not effectively monitor the selected control points because they primarily focused on monitoring land use change, and the management of environmental features and boundaries. Thus, the trial audit utilised remote visual monitoring through the imagery generated by the ENVISION platform.

LEAF identified the following Control Points from the LEAF Marque Standard version 15.0 to be relevant for the trial audit:

- CP 2.7: No evidence of soil damage such as soil compaction or erosion, verifies soil risk assessed and field operations managed appropriately.
- CP 5.1: Indication of success of measures taken to reduce soil erosion and run-off by livestock, or failure to comply.
- CP 5.6: Environmentally sensitive areas are protected and managed appropriately.
- CP 8.6: No bringing into agriculture of land that is of statutory landscape designations
- CP 8.10: No removal of trees, licence required for removal.
- CP 8.11: Retention of trees in boundaries and hedgerows.
- CP 8.14: Sympathetic management of field boundaries (margins at least two metres wide)
- CP 8.15: Native habitat banks are present in fields larger than 20 hectares.

In the end, however, Control Points 5.1 and 5.6 were not monitored because the participating farm did not have livestock, Control Point 8.10 was not monitored because it duplicates Control Point 8.11 and Control Point 8.15 was not monitored because the farm's fields were smaller than 20 hectares in size.

To facilitate remote visual inspections of the fields using the satellite imagery available on the ENVISION platform, LEAF developed indicator criteria to verify compliance with each control point requirement (see Table 1). Because LEAF were limited to visual monitoring during the trial audit, to identify new opportunities for using EO in LEAF Marque, LEAF completed an in-depth review of the LEAF Marque Standard version 16.0 to determine what additional types of requirements could be monitored using EO in the future, especially outcome-based requirements. A summary of this review, as well as the new outcomes, EO products and ENVISION services identified to monitor the outcomes, can be found in Section 3.

The trial audit was conducted with a LEAF Marque certified farm, RB Organic Ltd., located in the eastern region of the United Kingdom. The trial audit monitored five parcels growing organic carrots and one parcel growing organic potatoes. Whilst LEAF Marque audits are conventionally conducted by third party certification bodies, for research purposes of the trial audit, LEAF performed the monitoring role of a certification body.

The trial audit was originally scheduled to run for 12 months, however, there were limiting factors that reduced the trial audit monitoring to a two-month period. The farm was delayed in confirming their participation in the trial and providing the farm data that was required to begin the monitoring, due to a busy growing season and changes in the personnel allocated to collaborate with the

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ENVISION project partners. Further, technical challenges with uploading the farm data to the ENVISION platform due to the ShapeFile format of the data caused additional delays. DRAXIS were able to resolve the technical issues to upload the farm data. The trial audit monitoring then occurred in January and February of 2023. The trial audit could not run for a longer amount of time as the parcels being monitored were rented by the farm, and the farm had rented different parcels for the 2023 growing season that began in March 2023.

LEAF planned to conduct a shadow audit, where LEAF would attend the farm's annual on-site LEAF Marque audit to observe the audit format and outcomes. This exercise would enable LEAF to compare the EO monitoring audit with the on-site LEAF Marque audit format, and its robustness in assessing compliance with the LEAF Marque Standard. Due to the delays in beginning the trial audit, LEAF was not able to attend the farm's annual LEAF Marque audit in June 2022. However, the farm did not receive non-conformances during the annual LEAF Marque audit against the control points selected for the trial audit.

Following the trial audit, LEAF collected feedback from the farm through a semi-structured interview. The farm was asked to provide feedback on the ENVISION platform and the benefits and challenges of using EO in environmental assurance systems like LEAF Marque.

2.2 Results

The results of the trial audit are summarised in Table 1. The table includes the control point requirement, method of verifying compliance, indicator criteria for verifying compliance and compliance outcomes. To note, during Week 1 two verification checks were performed to first establish a baseline observation for the first verification check to be performed. A summary of the interview results are also provided in this section.

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				Compliance monitoring			
Control Point	**Requirement**	**Verification Method**	**Verification indicators**	**Week 1**	**Week 3**	**Week 5**	**Week 7**
2.7	No evidence of soil damage such as soil compaction or erosion verifies soil risk assessed and field operations managed appropriately	Visual monitoring of satellite imagery	<u>Indicators of erosion:</u> - cracked, coarse, gravel like soil texture - exposed roots - pooling water - bare spots <u>Indicators of compaction:</u> - reduced plant growth / bare spots - water runoff - pooling water - dry / smooth surface of soil	Compliance not verified due to a lack of granularity in the satellite images of the fields.	See Week 1 results	See Week 1 results	See Week 1 results
8.6	No bringing into agriculture of land that is of statutory landscape designations	Visual monitoring of satellite imagery	Bringing land into agricultural use includes clearance of vegetation, cultivation, earth moving or building.	**Compliant** No new land brought into agricultural production	**Compliant** No new land brought into agricultural production	**Compliant** No new land brought into agricultural production	**Compliant** No new land brought into agricultural production

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				Verification Visual verification that field boundaries and original vegetation in the boundaries was maintained.	**Verification** Visual verification that field boundaries and original vegetation in the boundaries was maintained.	**Verification** Visual verification that field boundaries and original vegetation in the boundaries was maintained.	**Verification** Visual verification that field boundaries and original vegetation in the boundaries was maintained.
8.11	Retention of trees in boundaries and hedgerows	Visual monitoring of satellite imagery	No trees have been removed.	**Compliant** No removal of trees	**Compliant** No removal of trees	**Compliant** No removal of trees	**Compliant** No removal of trees
				Verification Visual inspection of tree retention in field boundaries.	**Verification** Visual inspection of tree retention in field boundaries.	**Verification** Visual inspection of tree retention in field boundaries.	**Verification** Visual inspection of tree retention in field boundaries.

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8.14	Sympathetic management of field boundaries: margins at least two metres wide	Visual monitoring of satellite imagery	Field margins remain 2 metres in width.	Compliance not verified due to lack of distance measurement feature on the platform. However, the margin widths did not appear to change.	Compliance not verified due to lack of distance measurement feature on the platform. However, the margin widths did not appear to change.	Compliance not verified due to lack of distance measurement feature on the platform. However, the margin widths did not appear to change.	Compliance not verified due to lack of distance measurement feature on the platform. However, the margin widths did not appear to change.
				Verification Visual inspection of field margin widths.	**Verification** Visual inspection of field margin widths.	**Verification** Visual inspection of field margin widths.	**Verification** Visual inspection of field margin widths.

Table 1: Results of the LEAF Marque Trial Audit.

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Interview Results

RB Organic identified multiple benefits and opportunities to using the ENVISION services and EO on farm and in the LEAF Marque assurance system. Whilst the farm was not able to thoroughly test and evaluate the ENVISION platform during the research, they expressed that the platform would likely enable farms to report different types of data to customers, such as retailers, in the future who may require this information from farms to assess their sustainability impacts. It was also highlighted that EO and the ENVISION services provide a good tool to demonstrate and prove with data that the farm is doing best practice in sustainable agriculture in many areas of the business. It provides an opportunity to identify and track real-time problems in fields that are difficult to observe during crop walks. Using EO also has the potential to increase the efficiency and reduce the amount of time it takes to perform different monitoring and testing, such as soil testing.

RB Organic also identified challenges to adopting EO technology to use on farm, and incorporating EO into the LEAF Marque system. As a small operation, RB Organic would find it difficult to use EO services and the ENVISION platform to their fullest extent, mainly due to the limited time capacity of the management staff to learn and integrate the technology into the everyday operations and decision-making mechanisms of the business. The platform and data need to be very user-friendly to benefit farms and the operating system of the platform needs to be fast and reliable so that it does not hinder staff's ability to use the tool when required. There were also concerns raised about the potential for environmental assurance systems to carry out continuous monitoring of compliance as opposed to one annual audit. Farms may experience unease and discomfort knowing they are being constantly surveyed despite their efforts and intentions to implement sustainable farming to the best of their ability.

The farm also expressed that although it doesn't seem very accessible to farms now, the more developed EO technology becomes, the more it will be used on a large scale and the cheaper and more accessible it will become.

2.3 Discussion

The results of the LEAF trial audit demonstrate that several elements of the LEAF Marque assurance system require significant modifications in order to adequately integrate the ENVISION services for compliance monitoring. LEAF, and the certification bodies that conduct LEAF Marque audits, do not collect and store the necessary data to enable the use of ENVISION services through the platform. This not only limited LEAF's ability to conduct extensive testing and validation of the services but also the number of LEAF Marque requirements that could be monitored in the trial audit. This is likely a representative limitation that other environmental assurance systems would experience if they do not already collect the necessary data or utilise EO in their systems.

Using the findings from the trial audit and the results in Section 3 regarding the identification of new requirements to be monitored by ENVISION services and other EO products, it would be beneficial to design modifications to the LEAF Marque assurance system that could be tested, along with the LEAF Marque requirements and EO services and products, by conducting new case studies. Due to the amount of time required to design the cases and the limited amount of time remaining in the

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ENVISION project, these additional studies would fall outside of scope, and need to occur after the conclusion of the ENVISION project.

The results for the LEAF Marque requirements monitored during the trial audit under task 6.5 highlight the limitations of a remote visual monitoring approach to assessing compliance. Whilst this method could be less expensive to implement at scale, it is not a robust way to monitor compliance nor does it adequately measure environmental sustainability outcomes. It was most challenging to use the satellite imagery on the platform when monitoring for signs of soil degradation due to the lack of granularity and resolution of the image at the maximum magnification level, which reduces an auditor's ability to understand the effectiveness and suitability of the farm's soil management practices. It was also challenging to monitor the width of field margins for the parcels, as there was no distance measurement feature available on the platform. LEAF Marque requirements ensure that fields use margins of at least two metres as buffer zones and as potential areas to enhance biodiversity on farm, so it is important that auditors can accurately verify the size of the margins.

The farm was assessed as compliant with two requirements during the trial audit. The farm did not bring new areas of land into agricultural production, nor did it remove trees from the field margins and parcel boundaries. This was verifiable via visual monitoring due to the small size of the parcels; however it is not a reliable and robust method to measure compliance with these requirements alone. It is especially not feasible to conduct visual remote inspections to monitor for land conversion and treed margins for large parcel sizes.

The trial farm provided similar feedback and insights that farmers reported during the feasibility research outlined in Section 4 of this report. Whilst the ENVISION platform and services would be valuable for farms to use, there is a knowledge gap and resource related barriers that may impact the uptake of the technology in the short term. Future case studies to test the services within the LEAF Marque assurance system would enable more farms to participate and become familiar with using the technology, as well as provide more in-depth feedback on using EO data to evidence their compliance with LEAF Marque requirements.

3 Using EO to enable outcome-based standards

3.1 Introduction

Whilst the pilot study trialled the monitoring of selected requirements in version 15.0 of the LEAF Marque Standard using ENVISION services, there are other potential opportunities to use EO monitoring in future versions of the LEAF Marque Standard. LEAF Marque are investigating ways to better incorporate outcome-based requirements into the Standard, and it's been recognised that EO could enable this by allowing certification bodies and farmers to measure outcomes in a consistent way. Thus, LEAF have investigated what new outcome-based requirements can be added to the LEAF Marque Standard, and how EO services can be used to measure the outcomes and monitor farm compliance with the requirements.

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3.2 Background

Food and agriculture supply chains are facing increasing pressure from governments, international institutions and the public to evidence they are working to achieve national and international sustainability targets. There has historically been little consensus on what the best methods are to measure the impacts of sustainable agriculture, however, there is now an increasing demand to adopt outcome-based approaches to quantify and measure impacts (Zhang et al., 2021). Sustainability standards, such as LEAF Marque, contain primarily practice or process-based requirements, such that farms are required to successfully implement sustainable practices and processes to become certified through the standards' assurance systems. Whilst the implementation of sustainable management practices has been widely used as a proxy for sustainability impacts, outcome-based approaches measure impacts directly (Gorter & Wojtynia, 2017). Thus, sustainability standards are investigating new ways to design and measure outcomes across a range of key sustainability issues, including greenhouse gas (GHG) emissions, biodiversity, water, and deforestation (Jennings, McCormack & Sheane, 2020).

In moving toward more outcome-based approaches it is important to define what the term 'outcome' means in the context of standards. In 2017, the International Social and Environmental Accreditation and Labelling Alliance (ISEAL Alliance) commissioned research to identify the strategic and operational implications of designing and implementing outcome-based sustainability standards, including what systems should consider when transitioning from practice-based to outcome-based requirements. A number of opportunities and key benefits of transitioning to outcome-based standards were identified. Outcome-based requirements can clarify what stakeholders should expect to achieve by implementing the standard and can also drive innovation. Where outcomes are required and practices are not specified, this allows room for users to develop their expertise, technical knowledge and adopt more efficient and effective technologies to achieve the required outcomes. Similarly, outcome-based requirements can also facilitate and enable the monitoring of continuous improvement by standards users.

Outcomes are the results (i.e., reduced pesticide use) of practices and activities (i.e., training, IPM practices) that have been implemented (Gorter & Wojtynia, 2017). Outcomes can then be used to assess the wider impact (i.e., decreased negative effects of farming on the environment) of such practices and interventions. There are four main approaches that can be used to measure compliance with standard requirements (Gorter & Wojtynia, 2017):

1. Binary measures – Assess whether or not a practice has been implemented (yes/no)
2. Threshold metrics – Require that a certain level must be met
3. Progress metrics – Must demonstrate improvement since the previous audit
4. Reporting metrics – Specific data must be recorded and reported for compliance but is not required to meet a certain threshold or show positive change

Threshold, progress and reporting metrics can be used by standards to develop outcome-based requirements, such that farms are required to measure and report on the results of practices and monitoring activities they've implemented.

In recent years, a proliferation of tools and mechanisms available for outcome-based monitoring has provided more opportunities for farms to measure these types of outcomes, however the variability, reliability and required user know-how appear to be barriers to widespread uptake. LEAF have

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received informal feedback that the skills and capacity (time and resources) of farm staff as well as confusion on how to select appropriate tools and measurement approaches leave LEAF Marque certified farms feeling ill-prepared to monitor outcome-based requirements. Thus, it is important for standard-setting organisations to account for these factors when designing requirements and defining appropriate mechanisms for monitoring compliance.

3.3 Method

As part of the feasibility study in Task 6.5, LEAF explored how EO can enable the inclusion of more outcome-based requirements in the LEAF Marque Standard. LEAF conducted an in-depth review of version 16.0 of the LEAF Marque Standard to evaluate which requirements could incorporate outcome-based measures and identify what those measures would be. Then LEAF assessed which outcomes could be measured and monitored using EO, and identified which EO services, including but not limited to ENVISION services, could be utilised for the monitoring.

New outcomes were identified within multiple sections of the LEAF Marque Standard, including Organisation and Planning, Soil Management and Fertility, Pollution Control and By-Product Management, Animal Husbandry, Energy Efficiency, Water Management and Landscape and Nature Conservation. The outcomes aim to monitor farm performance against key sustainability issues addressed within these sections:

Climate resilience: New outcome-based requirements would measure the impact of extreme weather events and the amount of time required for farming systems to recover from the events. Low or reduced recovery times, relative to the severity of the weather event, can indicate a farm has implemented effective climate resilience strategies to mitigate the risks and negative impacts of such events. New outcomes also include monitoring crop diversity. Cropping diversity, which can be practiced through intercropping and crop rotations, support crop resilience to different environmental pressures like weather, pests and disease.

GHG emissions: New outcomes would measure GHG emissions on-farm (Scope 1 Direct emissions). EO based GHG emission measurements could inform farm management strategies to reduce and sequester carbon emissions, and be used to track emissions over time to monitor performance.

Water pollution: New outcomes would monitor for indicators of water pollution, including signs of excess nutrients and eutrophication, and synthetic chemical pollution from agrochemicals contaminating waterways and negatively impacting surrounding habitats.

Soil health: New outcomes would measure Soil Organic Carbon content, which could act as an indicator for improved soil organic matter, soil health and carbon sequestration on-farm. Outcomes would also monitor for signs of soil degradation to determine the effectiveness of applied soil management techniques.

Biodiversity and Nature conservation: New outcomes would monitor tree and habitat vegetation coverage, to assess for signs of deforestation and conversion of natural ecosystems to agricultural

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production. These outcomes would also monitor the health of vegetation in habitat areas, which could act as an indicator for habitat health. Additional outcomes would measure farm field margins to ensure adequate buffer area is provided between crop fields, and habitat areas and features.

Due to the potential of these sustainability approaches to mitigate the effects of climate change and environmental degradation, it is becoming increasingly important that activities and outcomes related to these issues can be monitored consistently and robustly. EO could significantly increase the capacity of stakeholders in the agriculture sector, including LEAF Marque certified farms, to monitor the impacts and outcomes of the activities they are implementing to mitigate and reverse these issues.

To note: LEAF have evaluated potential opportunities to monitor outcome-based requirements using EO, including potential requirements, outcomes, user requirements and EO services. It is recognised that many EO services require historical data. LEAF have not accounted for this factor during the evaluation in order to understand the different possibilities for using EO within the context of standards. Because LEAF do not currently collect data related to these services, this would need to be addressed before EO monitoring could be incorporated into the LEAF Marque Standard requirements and the assurance system.

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3.4 Results

Status	Control Point Number	Requirement	Outcome	EO User	User requirement	EO product (non-ENVISION)	ENVISION service
1. Organisation and Planning							
Use EO to monitor existing requirement - v16	1.3	The 'Farm Details' and 'Production Information' section of the 'My Profile' of 'myLEAF' has been completed and is accurate. • 'Production Information' includes all the business' products	N/A	CB	CBs can verify which crops are produced throughout the year.		Cultivated crop type map
NEW	-	The business measures the number of extreme climatic events (draught, flood) annually.	• Number of extreme precipitation events • Number of draught events	Farm & CB	Farms can monitor the frequency and length of extreme climatic events, and can use this information to evaluate their climate resilience. The CB can use this information for context.	Surface Soil Moisture Normalized Difference Water Index (NDWI) Weather forecasting	
Use EO to monitor existing requirement - v16	1.24	Measures are taken to enhance climate resilience • Risk assessment identifies the potential occurrence and impact from locally relevant extreme weather events (e.g., flooding, drought, resource availability) • Strategies for responding to high-risk impacts are defined • Risks and strategies are used to inform development of targets to enhance climate resilience	• Damage to plant/tree cover - visual damage, decreased plant growth • Number of days to recover from weather event - flood water reduction, surface water levels increase after draught event, plant health/growth increase - Low/reduced recovery time is indicator of	Farm	Farms can monitor the damage to crops/vegetation/trees and can monitor recovery time by monitoring land cover, plant growth indicators, soil moisture and surface water levels. This information can be used to inform the farm's climate resilience mitigation strategies and targets.	Land cover Surface Soil Moisture Normalized Difference Water Index (NDWI) Damage assessment service (i.e., flooding)	NDVI

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			increased resilience				
NEW	-	The business has a diverse cropping approach - using intercropping or crop rotations.	Diversity in cropping - the farm intercrops at least 2 crop species or has crop rotations	CB	CBs can verify that farms use intercropping or crop rotations (no monocropping).		Cultivated crop type map
2. Soil Management and Fertility							
Use EO to meet existing requirement - v16	2.1	There is an implemented Soil Management Plan (including a descriptive map).	N/A	Farm	Develop map required in Soil Management Plan		Use visual map from platform
Use EO to monitor existing requirement - v16	2.2	Measures are taken to conserve and build up soil organic matter.	Changes in Soil Organic Carbon - indicate build up of soil organic matter	Farm & CB	Farms and CBs can monitor SOC to evaluate whether or not measures to build organic matter in the soil are effective.	Fertilisation mapping	Soil Organic Carbon

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Use EO to monitor existing requirement - v16	2.3	There is an implemented Integrated Nutrient Management Plan. • Plan shows an emphasis on effective use of nutrients and enhancing overall efficiency (e.g., optimal use of inputs)	Reduced amount/applications of nutrients - indicates effective efficiency strategies	Farm	Monitor crop nutrient requirements by monitoring plant growth & NDVI to improve efficiency of application & assist calculation of nutrients required, leading to reduced application of nutrients.		NDVI / Vegetation status
Use EO to monitor existing requirement - v16	2.7	The risk of soil degradation is assessed prior to operations being carried out to ensure the timing, field conditions, equipment and soil management techniques are appropriate.	Indicators of soil degradation - erosion and compaction, bare ground	Farm & CB	Farms can monitor for soil degradation before/during/after harvest. CBs can monitor for soil degradation, to assess whether appropriate operations/management techniques were utilised.	Surface Soil Moisture Services to indicate if conditions are good to enter parcel	Revised Universal Soil Loss Equation
Use EO to monitor existing requirement - v16	2.14	Soil health is measured.	Increases in Soil Organic Carbon - can indicate build up of soil organic matter and increase in soil health	Farm & CB	Farm and CB can monitor SOC as an indicator of soil health. However, farms must also use additional measures such as visual assessments or soil testing.		Soil Organic Carbon
4. Pollution Control and By-Product Management							

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Use EO to monitor existing requirement - v16	4.5	There is a Pollution Risk Assessment that identifies, documents and records all potential pollutants on a map. • All types of pollution are referenced, including air (to include GHG emissions), light, noise, soil, surface and/or ground water, and diffuse and point source pollution • Assessment includes variation in pollution risk over time (e.g. from unloading to disposal of potential pollutants, seasonal variation) • Assessment identifies pollution risks and indicates the probability and severity of each risk • Assessment identifies steps to reduce or avoid the impact of all pollution risks to the environment	Monitor number and types of pollution events: - water (nutrient pollution/eutrophication, chemical pollution negatively impacting vegetation near water bodies) - GHG emissions	Farm & CB	Farms can monitor pollution events and risks to inform Pollution Risk Assessment. CBs can monitor pollution events to verify risks and evaluate effectiveness of prevention measures.	Suspended Particulate Matter (SPM) Colour Dissolved Organic Matter (CDOM) Chlorophyll monitoring GHG emissions	NDVI Revised Universal Soil Loss Equation
5. Animal Husbandry							
Use EO to monitor existing requirement - v16	5.1	Measures are taken to avoid damage to grassland by livestock and to optimise biodiversity.	Indicators of soil degradation - erosion and compaction	Farm & CB	Farms can monitor for soil degradation before/during/after grazing. CBs can monitor for soil degradation, to assess whether appropriate operations/ management techniques were utilised.		Grassland mowing event

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Use EO to monitor existing requirement - v16	5.5	Dirty water and silage effluent are collected and safely recycled.	Monitor for water pollution events - indicators for nutrient pollution/eutrophication	Farm & CB	Farms and CBs can monitor water pollution events where dirty water is stored/processed near water courses.	Suspended Particulate Matter (SPM) Colour Dissolved Organic Matter (CDOM) Chlorophyll monitoring	
6. Energy Efficiency							
Use EO to monitor existing requirement - v16	6.3	On farm Greenhouse Gas (GHG) emissions are recorded. • GHG emission records are used to inform strategies for improvement	GHG emissions measurement	Farm & CB	Farms and CBs can monitor GHG emissions and changes in emissions levels to assess the effectiveness of reduction strategies.	GHG emissions	
7. Water Management							
Use EO to monitor existing requirement - v16	7.7	Water quality is monitored.	Monitor water pollution to indicate water quality: - water (nutrient pollution/eutrophication, chemical pollution negatively impacting vegetation near water bodies)	Farm & CB	Farms can monitor water pollution indicators to assess water quality. CBs can monitor pollution events to evaluate quality and effectiveness of prevention measures.	Suspended Particulate Matter (SPM) Colour Dissolved Organic Matter (CDOM) Chlorophyll monitoring GHG emissions	NDVI
8. Landscape and Nature Conservation							

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Use EO to meet existing requirement - v16	8.1	There is a documented Landscape and Nature Conservation Audit (including map).	N/A	Farm	Farm can use ENVISION platform map to map key environmental features on site.		Use visual map from platform
Use EO to monitor existing requirement - v16	8.7	Measures are taken to protect and enhance habitats in field and/or site boundaries and other landscape features.	No reduction in vegetation, tree cover or hedgerows in boundaries	CB	CBs can monitor for the disruption of habitat features in field/site boundaries.	Land cover Monitor land conversion/ deforestation	NDVI
Use EO to monitor existing requirement - v16	8.11	In-field trees and trees in boundaries and hedgerows are retained.	No reduction in tree cover or hedgerows	CB	CBs can monitor for the removal of trees and hedgerows.	Land cover	NDVI
Use EO to monitor existing requirement - v16	8.12	Deep cultivation under the canopy of trees is avoided.	No signs of cultivation under in-field trees	CB	CBs can monitor for signs of deep cultivation under trees.		NDVI
Use EO to monitor existing requirement - v17	8.14	Field margins and/or site boundaries are under sympathetic management. • Field margins maintained to be at least two- metres wide, measured from the middle of the permanent boundary feature (e.g. hedge, fence, stone wall, or watercourse), unless: - fields are less than two hectares with permanent boundary features - fields have no boundary feature, and the natural habitat extends from the crop or crop headland	Measure that field margins are 2 metres wide	CB	CBs can measure that margins are appropriate for the setting.	Distance measurement	

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Use EO to monitor existing requirement - v17	8.23	10% or more of the farm/ site land is managed as a habitat area. (Recommended only)	Measure that 10% of farm area is habitat area	CB	CBs can verify farms have 10% habitat area/no changes to habitat area.	None currently identified	
Use EO to monitor existing requirement - v17	8.27	At least one representative species or habitat, that can be justified in environmental terms, is monitored on the farm.	Monitoring indicators of vegetation health in habitat areas	Farm	Farms can monitor the health of vegetation in habitat areas.		NDVI Biomass index
Use EO to monitor existing requirement - v17	8.28	Conversion of natural ecosystems for agricultural use only occurs where there is compliance with national and/or global commitments and minimal negative environmental impact.	No tree cover loss (deforestation) No indicators of habitat vegetation loss (natural ecosystem conversion)	CB	CBs can monitor for signs of deforestation and conversion of natural ecosystems.	Land cover Monitor land conversion/ deforestation	NDVI
Use EO to monitor existing requirement - v17	8.29	Protected and/or high conservation value areas, are protected and managed appropriately.	No tree cover loss (deforestation) No indicators of habitat vegetation loss (natural ecosystem conversion) No indicators of water pollution in protected waterbodies	CB	CBs can monitor protected/high conservation value areas for signs of deforestation, conversion of natural ecosystems and water body pollution.	Land cover Suspended Particulate Matter (SPM) Colour Dissolved Organic Matter (CDOM) Chlorophyll monitoring Monitor land conversion/ deforestation	NDVI

Table 2: Results of LEAF Marque Standard v16.0 review and Identification of outcome-based requirements for monitoring by EO and ENVISION services.

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3.5 Discussion

After conducting an in-depth review of version 16.0 of the LEAF Marque Standard, LEAF was able to identify requirements across seven sections of the standard that could potentially incorporate EO to monitor new outcomes and the implementation of existing practice-based requirements. This would enable the LEAF Marque Standard to transition to become a hybrid standard, such that the standard consists of both practice-based and outcome-based requirements, and would enhance the ability of LEAF Marque certified farms to implement and measure progress toward their sustainability objectives.

LEAF's evaluation found that EO could enable the monitoring of new requirements and outcomes related to climate resilience, a critical area for farms to engage with as they increasingly experience the direct impacts of climate change through fluctuating climatic conditions and extreme weather events. EO could also allow certain existing practice-based requirements to become outcome-based requirements. Currently, the LEAF Marque Standard requires farms to measure their GHG emissions once per year, an assessment which is based on energy records and fuel use. However, EO could enable the continuous monitoring of direct GHG emissions on site and support the assessment of potential emissions impacts in real-time. EO could also enable the monitoring of Soil Organic Carbon (SOC). Whilst the standard requires farms to take measures to sequester carbon where possible, there is no existing requirement to measure carbon in the soil. This is a difficult measurement to produce in a consistent manner, however, with the advancements being made in EO technology to monitor SOC, EO could enable LEAF Marque to include this as a requirement within the standard.

The use of EO in LEAF Marque would enable new ways for different stakeholders to implement and monitor requirements. As LEAF identified new outcomes and modifications to existing outcomes in the Standard requirements, LEAF evaluated how certification bodies and farms could utilise EO in the LEAF Marque assurance process. LEAF assessed how certification bodies could use EO to monitor farm compliance with the standard, and how farms could use EO to measure outcomes and provide evidence to certification bodies that they are meeting the requirements. LEAF determined that farms and certification bodies could use EO to measure outcomes directly and indirectly. Direct measures include monitoring GHG emissions, Soil Organic Carbon and land use changes. These direct measurements also enable the monitoring of trends in the outcomes over time, to assess for increases and reductions across these measures, and thus can be used to identify areas for improvement in farms' approaches to managing sustainability risks. Indirect measures can be used as indicators to monitor the climatic resilience of farms, such as the number and types of extreme weather events, and the amount of time taken to recover from these.

Farms could also use the ENVISION platform to meet existing requirements in the Standard that are not outcome-based. For example, generating maps that are required in certain sections of the LEAF Marque Standard, where farms must identify key features, infrastructure and areas of environmental significance on the site.

Once the new outcomes and user requirements were defined, LEAF, with input from the ENVISION technical partners, determined which EO services could be used to measure and monitor the

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outcomes and requirements. LEAF identified potential opportunities for adding other EO products to the ENVISION services, to improve the capacity of the platform to monitor more sustainability issues and outcomes on farm. Several services and EO monitoring techniques used by ENVISION were selected, including cultivated crop type mapping, vegetation status mapping, Revised Universal Soil Loss Equation, Soil Organic Carbon and grassland mowing events. Other EO products not currently offered by ENVISION that were identified by LEAF could enable better monitoring of pollution events and GHG emissions, land use changes and conversion of habitats and protected areas (see Table 2, column "ENVISION services" for the list of EO products). The service providers also informed LEAF about additional EO products, such as fertilisation mapping, weather forecasting and damage assessment services, that could be tested and utilised in the future to monitor supplementary outcomes and requirements in the Standard.

4 Evaluating the feasibility of incorporating EO into environmental assurance systems

Whilst the findings identified in the previous section highlight a number of opportunities to strengthen the LEAF Marque Standard requirements and assurance system using EO, as a global environmental standard it is important for LEAF to consider the feasibility of engaging with these opportunities.

4.1 Method

This study, within Task 6.5 in WP6, aimed to evaluate the feasibility of incorporating EO into environmental assurance systems, including the LEAF Marque system. A mixed-methods approach was applied to collect data from a range of LEAF Marque stakeholders. Quantitative and qualitative data were gathered via interviews and a survey.

Interviews

Stakeholder interviews were conducted by two members of the LEAF Marque team during the AgriCaptureCO_2 H2020 project, where LEAF are a participating project partner. The AgriCaptureCO_2 project aims to develop a robust and accessible way for farmers to implement and measure the impacts of regenerative agriculture, including through the use of EO monitoring. The interviews were conducted to better understand LEAF Marque stakeholder perspectives on the incorporation of EO into environmental standards and assurance systems. Given the equivalent relevance and alignment of these interviews with the objectives of this feasibility study, LEAF have included the results and findings from the interviews in this report.

The structured interviews were conducted with five farmers, two certification bodies and two environmental standards organisations. Four out of the five producers interviewed were LEAF Marque certified. The environmental assurance organisation interviews included an interview with the LEAF Marque Certification Manager. The interviews were held online between December 2022

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and January 2023 via Microsoft Teams. The interviews ranged in length from 20 minutes to 1 hour 30 minutes. They were conducted on days convenient to all parties during the working week.

The questions for each demographic group were same with minor differences in wording to account for the different groups. The questions were developed based on the findings of the literature reviews carried out by LEAF in the AgriCaptureCO_2 project. Within the farmer interviews, LEAF Marque certified businesses were asked questions pertaining to the LEAF Marque standard, whereas the non-certified business was asked about environmental assurance more broadly.

The interviews were recorded, and the transcripts were analysed to identify themes present in the responses. These themes were then quantified and added to an excel spreadsheet, from which graphs were created to visually present the findings. The results were presented in the report and discussed, drawing comparisons across demographic groups.

Survey

Given their significant role in the LEAF Marque assurance system, an anonymous survey was conducted with LEAF Marque-approved certification bodies to understand in greater depth their perspectives on using EO in the LEAF Marque system.

The survey was distributed to 22 certification bodies that are approved to carry out LEAF Marque audits. The survey remained open for four weeks from March 2023 to April 2023. Survey respondents did not receive any compensation to complete the survey. The survey consisted of nine questions, including three multiple choice questions, four free response questions and two demographic questions. The second demographic question allowed respondents to provide the name of their certification body organisation to evidence their participation in ongoing professional development activities for LEAF Marque.

A total of ten certification body staff members from eight different certification body organisations completed the survey.

4.2 Results

4.2.1 Opportunities and benefits to using EO in environmental assurance systems

Farmer Interviews

Farmers identified the following benefits to using EO in environmental assurance systems:

- Having data to prove what is being implemented on-farm.
- Ability to assess and monitor natural disasters/climatic events and their impacts on farm.

One farmer noted that EO will have benefits only if the data is accurate enough. Another farmer was unsure what the benefits of using EO would be.

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Certification Body Interviews

Certification bodies reported that benefits could include monitoring farms throughout the year, not only during one season, and that continuous monitoring could enable the tracking of trends on farms over time.

Environmental Assurance Organisation Interviews

Similar to the certification bodies, the representatives from the environmental assurance organisations indicated that EO would enable oversight of farm compliance throughout the year instead of only one season.

Certification Body Survey

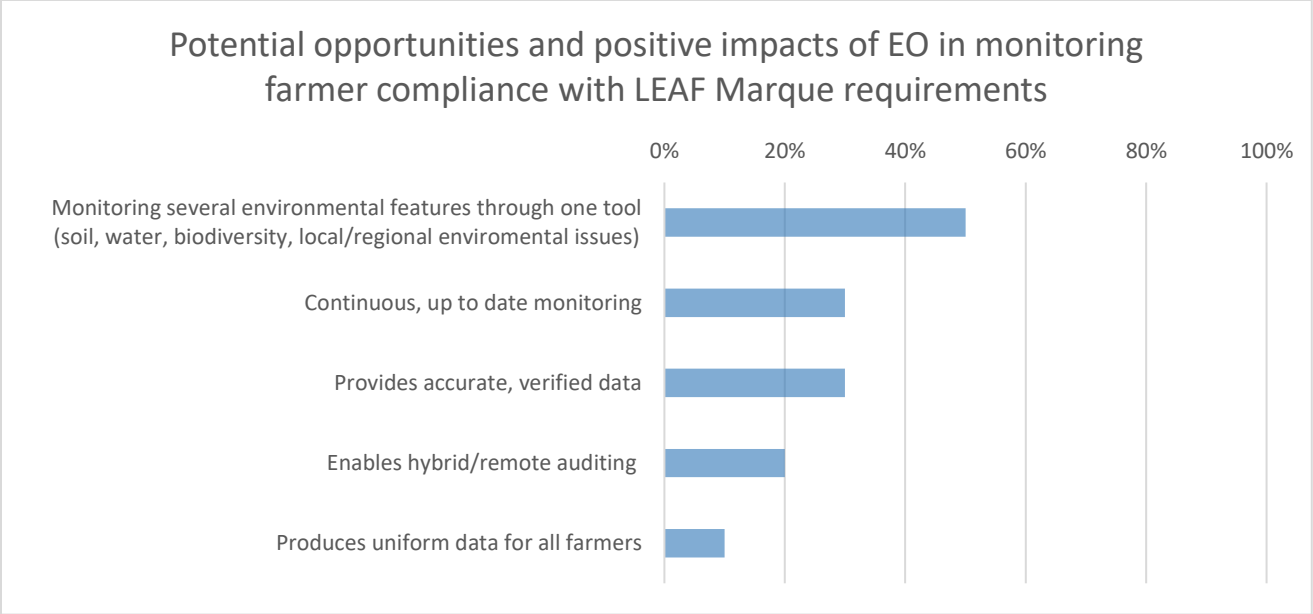

Figure 1: Potential opportunities and positive impacts of EO in monitoring farmer compliance with LEAF Marque requirements.

Certification body survey respondents identified several potential positive impacts and opportunities of using EO to monitor compliance with LEAF Marque requirements: 50% of certification bodies reported that using EO would make it easier to monitor several environmental features simultaneously using one tool (i.e., the ENVISION platform), including monitoring outcomes for soil, water, biodiversity and regional environmental issues that could provide important context during an audit; 30% of certification bodies agreed that using EO would enable continuous, up-to-date monitoring as well as provide more accurate and verified data; 20% of certification bodies said using EO would enable hybrid and remote auditing, and 10% noted that EO could produce more uniform data for all farmers.

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4.2.2 Challenges to using EO in environmental assurance systems

Farmer Interviews

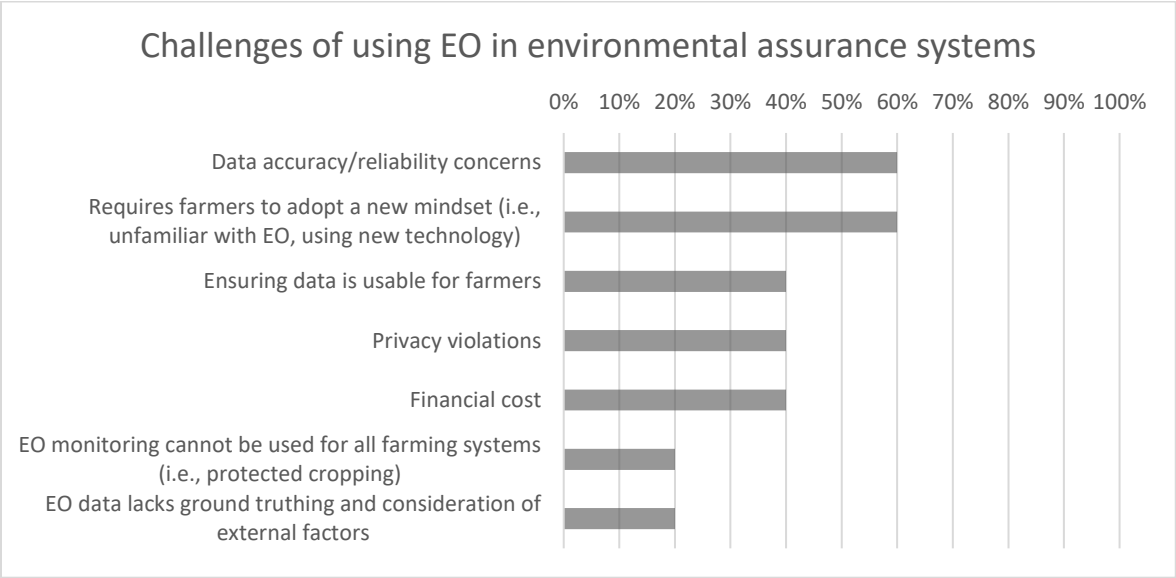

Figure 2: Challenges of using EO in environmental assurance systems.

Farmers identified a number of challenges to using EO in environmental assurance systems: 60% of farmers expressed concerns about the accuracy and reliability of EO data, and also highlighted that using EO would require farmers to adopt a new mindset to use new technology; 40% of farmers reported it would be challenging to ensure EO data is usable for farmers, and that financial costs and privacy violations could present challenges; 20% of farmers noted that EO could not be used to monitor different farming systems like protected cropping systems, and that EO data lacks ground truthing and does not consider other external influencing factors.

Certification Body Interviews

The certification bodies interviewed reported that the primary challenges include ensuring the reliability and understandability of EO data as well as the costs required for certification bodies to implement EO. One certification body expressed that if the costs are too high then the cost burden would likely be passed on to the farmers.

Environmental Assurance Organisation Interviews

The environmental assurance organisations identified a number of challenges to incorporating EO into environmental assurance systems:

- High costs for standards organisations or certification bodies would likely be passed to producers, which could drive them away from certification.
- EO data must be auditable by certification bodies.
- EO data and compliance monitoring must be robust.

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- The farming sector needs to first come to a consensus on industry challenges before new technology like EO can be widely adopted, including by assurance systems.
- Assurance organisations need to invest in extensive training for existing staff or hiring new staff with the proper knowledge and skills to design appropriate EO-based requirements and parameters for assessing compliance with the requirements.
- Certification bodies need to invest in extensive training for existing staff or hiring new staff with the proper knowledge and skills to interpret EO data and use it to assess farm compliance.
- EO is not accessible to farms with limited resources, including smallholders. Requiring the use of EO would be discriminatory to those who do not have access.
- EO is not applicable to many farming systems that are certified.
- EO monitoring could never fully replace onsite audits because auditors need to be able to inspect buildings, chemical stores, etc.

Certification Body Survey

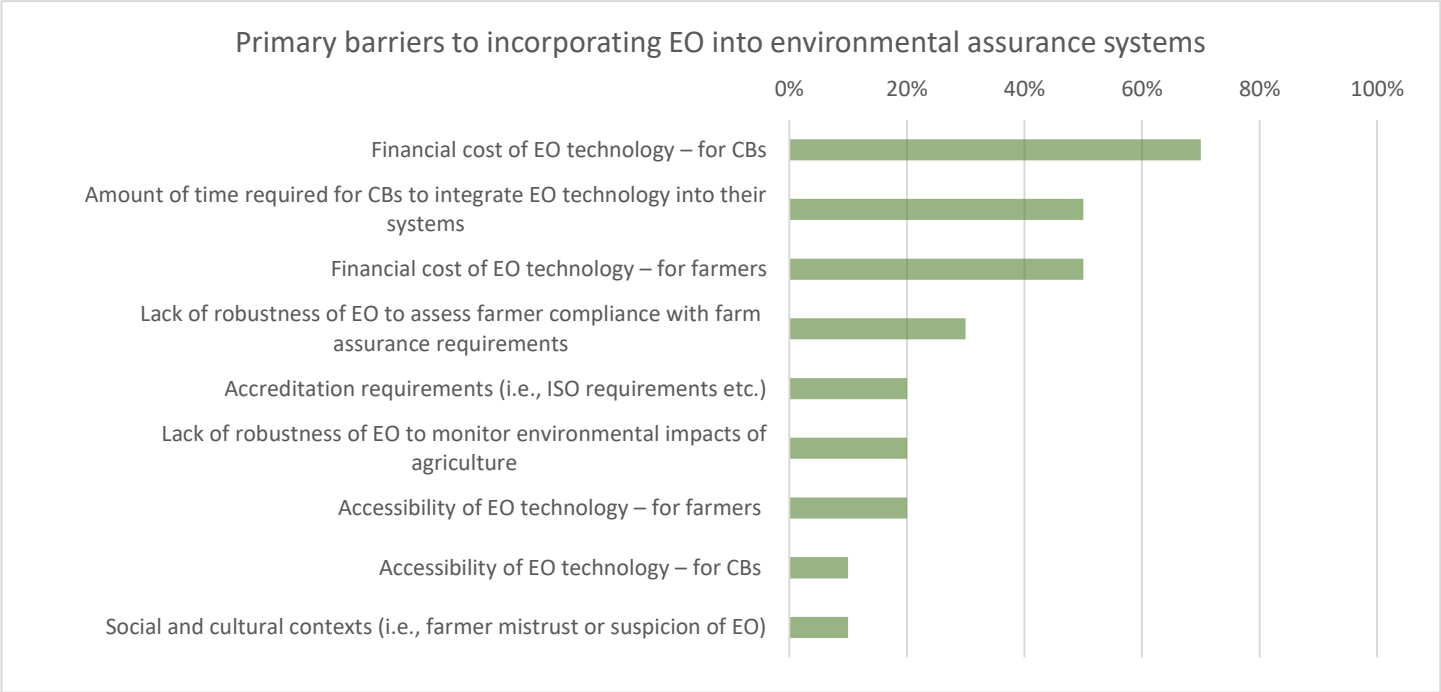

Figure 3: Primary barriers to incorporating EO into environmental assurance systems.

Certification bodies identified several factors that could act as barriers to incorporating EO into environmental assurance systems: 70% of certification bodies agreed that the financial cost for certification bodies to use EO technology is a primary barrier whilst 50% agreed that the financial cost of EO technology for farmers is a barrier; 50% of certification bodies indicated that the amount of time required for certification bodies to integrate EO technology into their systems and workflows is a barrier; 30% of certification bodies reported that a lack in EO robustness to assess farmer compliance is a barrier, whilst 20% reported that a lack in EO robustness to monitor the environmental impacts of agriculture is a barrier; 20% of certification bodies identified that accreditation requirements could be a barrier; 20% of certification bodies expressed that the accessibility of EO technology for farmers is a barrier, whilst 10% expressed that the accessibility of

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EO technology for certification bodies is a barrier; 10% of certification bodies agreed that social and cultural contexts may be barriers, for example farmer mistrust or suspicion of EO technology.

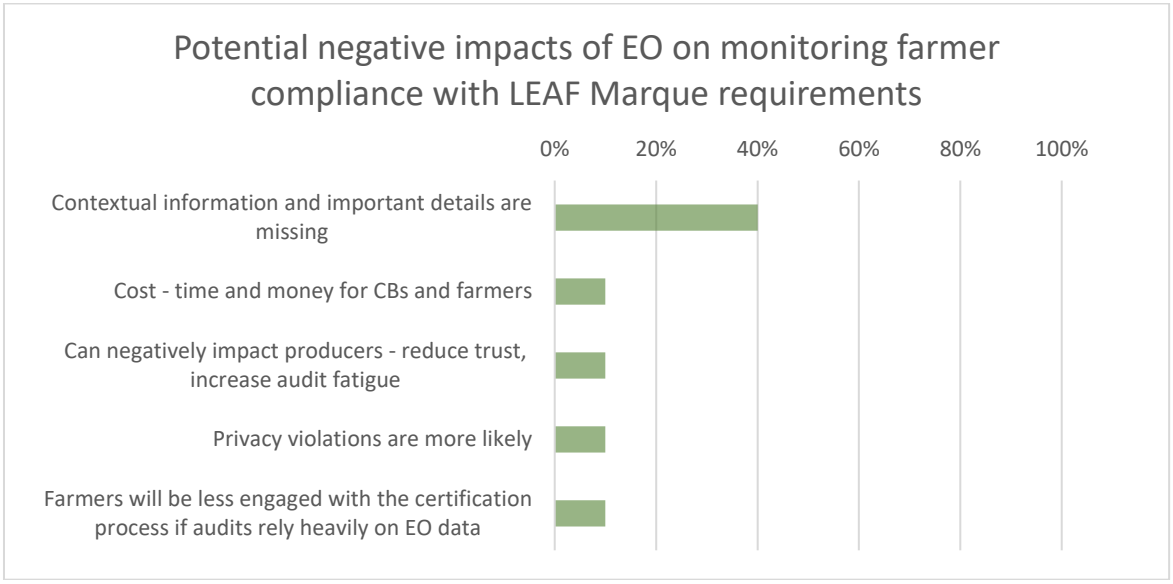

Figure 4: Potential negative impacts of EO on monitoring farmer compliance with LEAF Marque requirements.

Certification bodies reported several negative impacts that EO could potentially have on monitoring farmer compliance with LEAF Marque requirements: 40% of certification bodies expressed that contextual information and important details are missing from EO data; 10% of certification bodies also reported that using EO could negatively impact costs (financial and time) for farmers and certification bodies, farmer trust in the certification process, farmer audit fatigue and farmer engagement with the certification process; 10% of certification bodies also noted that privacy violations for farmers are more likely when using EO.

4.3 Discussion

The feedback collected during the survey and interviews provide valuable perspectives from key LEAF stakeholders on the integration of EO into environmental assurance systems and LEAF Marque. These insights will be used to inform LEAF's approach to incorporating EO into the LEAF Marque system. A number of benefits and challenges were identified by the stakeholders, demonstrating the range of understanding and perspectives on EO monitoring in agriculture.

The opportunities and benefits of EO that were highlighted by stakeholders centre around improved compliance verification and the ability to monitor key sustainability issues. Farmers see that EO would allow them to provide data in a LEAF Marque audit that effectively validates what they are implementing on farm. Not only would this be useful data to use during LEAF Marque audits, but also to demonstrate to customers and other stakeholders in the supply chain that they are improving their management strategies and taking action on specific sustainability issues. Further, they conveyed that EO would improve their ability to monitor and assess the impacts of natural disasters

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and climatic events, which is key to understanding climate risks and building mitigation strategies for climate resilience.

Certification bodies and assurance organisations agreed that EO monitoring would enable continuous monitoring of compliance throughout the year, instead of only once per year during an annual LEAF Marque audit. This would allow auditors to observe how standard requirements and management strategies are implemented during different seasons as well as their impacts on the environment over time.

Certification bodies identified other benefits which would improve the efficiency and accuracy of compliance monitoring, including enabling a hybrid remote auditing format, collection of uniform and accurate data, and simultaneous monitoring of multiple environmental features and issues. Improvements in these areas would also strengthen the robustness of the LEAF Marque assurance system.

A number of challenges to using EO in environmental assurance systems and LEAF Marque were also identified by stakeholders, which highlight the current limitations to using EO in the LEAF Marque system and areas where further testing of EO services is required. In many cases, farmers, certification bodies and environmental assurance organisations identified similar challenges. It is important to consider how these challenges, to incorporating EO, could negatively impact the ability of farmers to achieve their sustainability objectives, so that strategies can be developed to mitigate these challenges appropriately.

Farmers expressed concerns about the accuracy and usability of EO data, both of which would impact farmers' ability to demonstrate compliance with LEAF Marque requirements, and regarding the use of data to inform management strategies and decision making on-farm. Farmers' concerns about the cost to access EO technology as well as the adaptive mindset required to understand and use new technology stems from socioeconomic challenges in the sector. Farm businesses that generate thin profit margins are less financially able or likely to invest in new technological solutions than businesses with more financial flexibility. Despite other cost efficiencies that EO technology could help facilitate in the medium to long term, the up-front cost to access the technology and services remains a barrier.

It was expressed that whilst some farmers view and welcome EO as a technology to support their businesses, for many farmers there is still a lack of understanding about what EO is and its role in agriculture. There appears to be a knowledge gap between user and non-users and a perceived inability to close or reduce the gap. Further, farmers who are older in age or less educated are also less likely to, or less able to, access and use new forms of technology due to the knowledge and skills required to do so. Concerns about privacy violations were raised by farmers and certification bodies, a factor which can erode their trust in the technology and the intentions of the LEAF Marque assurance system to support their sustainability journey.

Farmers and environmental assurance organisations also raised that EO monitoring cannot be used for all types of production systems. Due to the wide variety of production systems that are LEAF

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Marque certified, this would mean that compliance monitoring methods for some of the LEAF Marque Standard requirements would differ for a proportion of certified farms, for example, protected and indoor farming as well as farms that are very small in size (i.e., less than 2 hectares). For these production systems, EO could be used to monitor pollution events, land conversion and climate resilience indicators. Soil or crop-based monitoring would be difficult or not possible to perform, for example, the measurement of SOC.

Farmers and certification bodies agreed that the remote nature of EO monitoring may lack "ground truthing" and the necessary contextual information required to accurately interpret what is occurring on farm and the reasons as to why farms implemented specific management strategies. An EO-based monitoring approach within the LEAF Marque assurance system would require improved mechanisms for communication between farmers and certification bodies to ensure accurate interpretations of EO data.

Certification bodies and environmental assurance organisations identified several additional challenges that are primary barriers to incorporating EO into environmental assurance systems like LEAF Marque. The most significant barriers for certification bodies are the financial cost and the amount of time required to integrate EO into their systems. Whilst certification bodies need to invest in extensive training for staff or hiring new staff with the proper knowledge and skills to interpret EO data and use it to assess farm compliance, assurance organisations equally need to build the capacity of their staff to design appropriate EO-based requirements and parameters for assessing compliance with the LEAF Marque Standard requirements. The knowledge and skills gap for certification bodies and environmental assurance organisations to use EO requires significant time and resource to fill to ensure EO can be integrated into the LEAF Marque assurance system at scale. Similarly, whilst certification bodies agree that EO can improve the quality of compliance monitoring, the use of EO may not necessarily decrease the amount of time required to prepare for and conduct LEAF Marque audits.

Certification bodies and environmental assurance organisations also see cost as a barrier for farmers, and there is a risk that the cost burden for certification bodies to implement EO technology may be passed on to farmers via higher audit fees.

Concerns about the robustness of EO to monitor compliance with assurance requirements were identified by both environmental assurance organisations and certification bodies. For EO to be incorporated into the LEAF Marque assurance system, EO monitoring needs to demonstrate an equal or higher level of robustness in verifying farm compliance with the LEAF Marque Standard requirements than current methods used by certification bodies. Based on the challenges and outcomes of LEAF's trial audit during the ENVISION project, it is evident that further modifications to the LEAF Marque system and testing of the ENVISION services under various conditions are required to test the robustness of EO monitoring for LEAF Marque certified farms.

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5 Conclusion

The results from LEAF's research under Task 6.5 suggest that there are a number of opportunities and challenges to incorporating EO and ENVISION services into environmental assurance systems like LEAF Marque. EO enables farms to monitor performance outcomes for key sustainability issues, which can be used to support continuous improvement by evaluating and informing decision making and management strategies on-farm. Due to the importance of managing these sustainability issues to mitigate the effects of climate change and environmental degradation, it is becoming increasingly important that activities and outcomes related to these issues can be monitored consistently and robustly. EO could significantly increase the capacity of LEAF Marque certified farms, to monitor the impacts and outcomes of the activities they are implementing to address these issues.

Further, this data can be used to provide evidence to demonstrate compliance with outcome-based requirements in environmental standards and to simultaneously evidence the sustainability requirements of other stakeholders in the supply chain. Monitoring sustainability outcomes at the farm level is difficult given the current lack of standardised monitoring parameters and uncertainty around how to select appropriate monitoring tools. Thus, EO and the ENVISION services can help to close these gaps and provide a multifunctional tool to make monitoring more efficient for farms.

Whilst EO and ENVISION services stand to significantly improve the quality of monitoring sustainability outcomes and compliance with standard requirements, several existing challenges need to be addressed before EO could be eligible to be incorporated into the LEAF Marque assurance system. EO could never fully replace in-person LEAF Marque audits because auditors need to inspect elements such as chemical storage facilities. Further, the LEAF Marque requirements are implemented by farms in different ways according to their context, however EO does not necessarily account for these contextual factors that are often addressed during on-farm audits. Due to the high costs associated with using EO technology and lack of farmers' awareness and understanding of EO, it is not feasible for LEAF to require certified farmers to use EO to monitor their sustainability progress and outcomes. Similarly, because LEAF and the LEAF Marque certification bodies are new users of EO and do not have the systems and structures in place to fully use the ENVISION services and EO products to monitor farm compliance with the LEAF Marque Standard, time and resources would be required to make the necessary modifications to the assurance system to enable the use of EO and ENVISION services.

Given LEAF's lack of expertise and experience with EO and with utilising technological solutions within our assurance system, it was an ambitious aim for LEAF to be able to incorporate ENVISION services/EO into the LEAF Marque assurance system by the end of the ENVISION project. LEAF is not currently in a position to be able to do this. However, after participating in the ENVISION project, conducting research for T6.5 and seeing the results from the other business cases, LEAF do still see the value of integrating this type of technology into the auditing process to monitor a subset of specific requirements in the LEAF Marque Standard. LEAF have been investigating new potential case study trial audit approaches we could take in the UK and EU (UK, Poland, Greece, Spain) with LEAF Marque certified farms, however this will not necessarily solve the problem of LEAF having a lack of

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expertise and capability to fully utilise EO effectively. Thus, LEAF are reviewing how new case studies could align with the aims and projects occurring within England's Department for Environment, Food and Rural Affairs (Defra) Earth Observation Centre of Excellence (EOCE), which the Rural Payments Agency (RPA) also participates in. By partnering and collaborating with organisations within the EOCE, LEAF would not be on the EO journey alone and can significantly benefit and learn from these types of collaborations. This approach would help to build LEAF's EO knowledge and capabilities, and thus opportunities to potentially incorporate EO into our system in the future.

It is important to note that LEAF would not be able to move forward with another EO-focused project immediately after the ENVISION project ends due to a number of high priority development activities happening within LEAF/LEAF Marque in the next 12-18 months. Due to LEAF's current lack of EO capabilities, appropriate time and resources would need to be dedicated to investigating and building an EO solution for our assurance program.

With that said, LEAF has added Appendix 8.3 to highlight key findings about the use of EO by England's RPA which might be informative to the ENVISION project. In the post-Brexit era, as the UK moves away from the Basic Payment Scheme (BPS) that was determined by the CAP, it appears EO will have an increased role within the RPA as its current EO program is being modified to enable the monitoring of sustainable agriculture requirements in the new Sustainable Farming Incentive (SFI) payment scheme that is one of the schemes replacing the BPS. Thus, there may be opportunities for ENVISION products to fill the gaps where the RPA's current monitoring capabilities are inadequate to monitor certain requirements of the SFI.

6 Limitations and Recommendations for future research

LEAF identified several limitations of the research methodologies utilised during the project and have also presented recommendations for future research to improve the approach and outcomes.

6.1 Stakeholder interviews and survey

The demographic group sizes for the stakeholder interviews were limited to five farmers, two certification bodies and two environmental assurance organisations. It was challenging to gain engagement from all these groups due to the time constraint of the allotted research period. Further, these participants were accessed primarily through the LEAF network, which limited the range of stakeholders the research could engage with. Thus, future replications of this research would need to access a wider community of stakeholders to gather a greater variety of perspectives. It is also recommended that future research utilise larger participant sample sizes to ensure the results are robust and representative of the different stakeholder groups.

It is recommended that future research allow more time for data collection, which could enable a greater number of interviews to be conducted across a more representative sample of production systems, including the recruitment of more international stakeholders who may provide valuable and unique perspectives that differ from UK-centric perspectives.

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There was only one female participant in the research, thus it is recommended that additional research projects recruit an equal amount of male and female or other gendered participants to ensure appropriate representation and participation of all individuals working in the sector.

Another limitation to the research was the lack of capacity for LEAF to investigate in greater depth the challenges to integrating EO into assurance schemes that were identified during the research. It would be very beneficial to understand the specific characteristics of the barriers identified, such as what type of technical skills and knowledge are required by different LEAF Marque stakeholders to use EO technology effectively.

6.2 Trial Audit

A significant limitation of the research was that LEAF and its certification bodies do not have the capability to collect and store the necessary data that would enable the testing and use of more ENVISION services. Thus, it is critical to first design modifications to the LEAF Marque assurance system to enable this data collection, which could then be tested, along with the LEAF Marque requirements and EO services and products, during future case studies. Further, the delays in beginning the trial audit suggest more time is required to recruit participating farms and carry out future studies, to allow adequate time for resolving technical and logistical issues that arise.

7 References

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8 Appendices

8.1 Stakeholder interview questions

	Questions	
Stakeholder	**Opportunities and benefits of using EO in environmental assurance**	**Challenges of EO and barriers to integration in environmental assurance**
Farmers	Sub-questions: • Do you think there are benefits	Sub- questions: • Do you think there are any

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	to using EO? *Prompt: yields, water management, land use change, biodiversity trends, monitoring and responding to disasters, predicting, and mitigating climate change*	challenges to implementing EO within farming practices? *Prompt: for example, related to cost (high data cost)/actionable data to farm level/understanding of tool/feasibility* • What do you think the future of EO looks like? Do you see it being used in farming? *Prompt: How will it adapt to the challenges you've highlighted? Do you think it is necessary for the future of agriculture?*
Certification bodies	Sub-questions: • Do you think there are benefits to using EO? *Prompt: yields, water management, land use change, biodiversity trends, monitoring and responding to disasters, predicting, and mitigating climate change*	Sub-questions: • Do you think there are any challenges with the auditing of EO? • If implemented, what are the future challenges of auditing EO? *Prompt: for example, related to cost (high data cost)/actionable data to farm level/understanding of tool/feasibility*
Environmental assurance organisation	Sub-questions: • Do you think there are benefits to using EO? *Prompt: yields, water management, land use change, biodiversity trends, monitoring and responding to disasters, predicting, and mitigating climate change*	Sub-questions: • What do you perceive to be the challenges related to the inclusion of EO within environmental Standards? *Prompt: for example, related to cost (high data cost)/actionable data to farm level/understanding of tool/feasibility* • Do you think EO will be included in future versions of environmental Standards? *Prompt: How will it adapt to the challenges you've highlighted? Do you think it is necessary for the*

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		future of agriculture?

8.2 Stakeholder survey questions

Introduction

LEAF is currently involved in the "ENVISION – Monitoring of Environmental Practices for Sustainable Agriculture Supported by Earth Observation" Horizon 2020 project. The project explores how satellite data (Earth Observation – EO) can be used to assess farm environmental performance (for example, to monitor compliance with the CAP in the EU). In the project, LEAF is investigating the potential role of Earth Observation in farm assurance certification. Given their important role in farm assurance systems, we seek to understand Certification Bodies' perspectives on how Earth Observation can be used in certification processes. We invite you to complete a short anonymous survey to provide your feedback. The survey will take approximately 8-10 minutes to complete.

1	Does your organisation currently use Earth Observation data to monitor farm compliance with agriculture regulations and/or farm assurance standards (in any country you operate in)? a. Yes, we use EO to monitor compliance with agricultural regulations b. Yes, we use EO to monitor compliance with farm assurance standards c. No, we do not use EO. If no, has your organisation considered using EO?
2	Please indicate which of the following you think are primary barrier(s) to incorporating Earth Observation into farm assurance systems: a. Financial cost of EO technology – for CBs b. Accreditation requirements (i.e., ISO requirements etc.) c. Robustness of EO technology to monitor environmental impacts of agriculture accurately and reliably (i.e., where there is a lack of robustness) d. Robustness of EO technology to assess producer compliance with farm assurance requirements accurately and reliably (i.e., where there is a lack of robustness) e. Amount of time required for CBs to integrate EO technology into their systems and workflows (i.e., the amount of time it would take to integrate the technology, train staff, etc) f. Accessibility of EO technology – for CBs (i.e., physical access and availability of technology) g. Financial cost of EO technology – for producers h. Social and cultural contexts (i.e., producer mistrust or suspicion of EO monitoring) i. Accessibility of EO technology – for producers (i.e., physical access and availability of technology) j. Other:

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3	What positive impacts and opportunities could EO monitoring have if used to assess producer compliance with the LEAF Marque requirements?
4	What negative impacts could EO monitoring have if used to assess producer compliance with the LEAF Marque requirements?
5	What impact do you think the use of EO would have on the amount of time required for auditors to prepare for and complete a LEAF Marque audit? a. Using EO would likely not affect the amount of time auditors need to prepare for and complete the LEAF Marque audit b. Using EO would likely increase the amount of time auditors need to prepare for and complete the LEAF Marque audit c. Using EO would likely decrease the amount of time auditors need to prepare for and complete the LEAF Marque audit d. I am not sure
6	Currently, producer compliance with the LEAF Marque Standard is assessed annually during a single LEAF Marque audit. The use of Earth Observation could allow continuous monitoring of LEAF Marque compliance throughout the year, instead of assessing compliance once per year. a. Do you think the continuous review of producer performance throughout the year has a potential role in the certification process? What might the benefits and challenges of this be?
7	Do you have any additional comments?
8	What country(ies) does your organisation operate in?

8.3 Review of EO use and opportunities within Defra's EO Centre of Excellence and England's Rural Payment Agency

The UK government has invested approximately £1 billion in civil Earth Observation (EO) systems and technologies over the past decade, including the EU's Copernicus programme. In November 2022, the UK Government agreed to invest a further £315 million in EO and climate programmes (2023-2027), including £200 million of unused funds owing to continuing delays to UK participation in the EU Copernicus programme.

The Defra Earth Observation Centre of Excellence (EOCoE) has been running since 2016 and focuses on the use of Earth Observation for policy and operational decisions, particularly relating to achieving Defra's mission and objectives. The centre is concerned with the science of gathering evidence remotely which can support innovation and inform environmental monitoring, management, regulation, and enforcement.

The direct operational value of Earth Observation to the UK government is estimated at £64 million per year. With this insight, the Defra EOCoE has recently published a new roadmap for 2023-2028. The aim of the centre of excellence is to explore and provide evidence for how Earth Observation (EO) can maximise its offer for the environment, economy, science, and society in the next five years.

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The EOCoE has been and will continue to support supporting the delivery of various policies including the 25 Year Environment Plan, Natural Capital Ecosystem Assessment Programme, and Environmental Land Management Scheme.

A key focus over the next 5 years is for the centre to provide a forum to continue to engage with stakeholders to share ideas, best practice, and to understand and realise the potential offered by Earth Observation. Outcomes of the EOCoE are to champion Earth Observation, provide leadership, research and innovate, develop analytical skills and set standards. This is in addition to driving opportunities and efficiencies to deliver advances in the strategic use of EO based data collection, and then use this data to inform UK policy. The centre provides seed-corn funding for innovative research and development projects undertaken by members. Members include:

- Department for Environment Food and Rural Affairs (Defra)
- Animal and Plant Health Agency (APHA)
- Centre for Environment, Fisheries, and Aquaculture Science (Cefas)
- Environment Agency
- Forest Research
- Geospatial Commission
- Historic England
- Department of Agriculture, Environment, and Rural Affairs (Northern Ireland)
- Joint Nature Conservation Committee
- Marine Management Organisation
- National Centre for Earth Observation
- Natural England
- Natural Resources Wales (Cyfoeth Naturiol Cymru)
- NatureScot (NàdarAlba)
- Rural Payments Agency
- Scottish Government
- South Downs National Park Authority
- Welsh Government

Over the next 5 years, the new 2023 strategic plan indicates that EOCoE members will continue to use Earth Observation in an operational capacity, and work to develop innovative uses of Earth Observation. A selection of the topics that will be progressed from across member organisations include:

- The Defra Earth Observation Data Service - innovative research and development projects, including proof of concept studies.
- Operational systems for agriculture, such as the Crop Map of England
- Operational systems for nature protection, including Living England, Living Wales, and habitat change.
- Operational systems for the environment and society, including flood mitigation and response, detection of illegal fishing activity, and drought and fire risk early warning evaluation and response.

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- Earth Observation tools to support to maximise impact across policy areas, including the Natural Capital Ecosystem Assessment programme, the development of a Data, Analytics and Science Hub Platform, and the Environmental Land Management Scheme and Sustainable Farming Initiatives.
- Scoping for the potential advancements using artificial intelligence with Earth Observation data.
- Portfolio champions are being introduced to facilitate the delivery of our plan for 2023 and ensure all members of the centre are engaged with our long-term priorities.

Overview of RPA use of EO

In reviewing the Rural Payment Agency's (RPA) utilization of Earth Observation (EO) technology up to this point, it's essential to understand the role of the RPA within the UK's Department for Environment, Food, and Rural Affairs (DEFRA). The RPA is tasked with the critical responsibility of disbursing subsidies and various payments to bolster the UK's agricultural and food industry while concurrently promoting positive environmental outcomes through these financial incentives and agricultural payment programs.

Across England, the RPA administers more than 40 schemes, with the majority focusing on financial support linked to land parcel size and usage. These include:

- The Basic Payment Scheme (BPS), which is the UK's successor to farming support payments as part of the EU's Common Agricultural Policy (which is being phased out).
- The Countryside Stewardship program, designed to encourage farmers, foresters, and land managers to adopt practices that enhance and protect the environment.
- The Sustainable Farming Incentive, a newly introduced scheme that compensates farmers for delivering public benefits, such as improving water quality, preserving biodiversity, promoting animal health and welfare, mitigating climate change, and, of course, food production.

Annually, the RPA disburses over £2 billion in support payments to English farmers. Farmers are required to apply for support, which is contingent on the extent of eligible land they cultivate and their adherence to environmentally sustainable practices. This underscores the need for the RPA to maintain an accurate, up-to-date database of agricultural land cover across England, with the data no more than three years old.

Since the mid-2000s, satellite imagery has played a pivotal role in the ongoing update and validation of the RPA's land database. Each year, the RPA systematically reviews and updates its land data through four primary methods:

- Proactive Land Change Detection (PLCD), which employs aerial photography, satellite imagery, and updates from Ordnance Survey MasterMap.
- Edits requested by farmers.
- Identifying changes during on-site farm visits conducted by field officers.
- 'Control with remote sensing' inspections that utilize commercially-procured, very high-resolution satellite imagery from sources like WorldView 2 and 3, as well as GeoEye-1.

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This data facilitates the detection of changes in land cover and boundaries, ensuring that farmers receive fair compensation based on their actual land usage. Since 2016, the RPA has made the Crop Map of England (CROME) data source available for public use, which greatly relies on Sentinel-1 satellite data. This success in employing satellite data for remote inspections has prompted the RPA to expand its use of satellite imagery.

In the winter of 2022, the RPA initiated a trial using Sentinel-2 satellite imagery to create what could be the nation's first comprehensive land monitoring system for the Sustainable Farming Incentive (SFI). This new initiative aims to assist farmers in managing their land in ways that enhance food production and environmental sustainability. For example, it involves verifying compliance with environmental standards, such as maintaining vegetative cover for soil health and stability during the winter, across all agricultural land parcels participating in the scheme throughout England. Satellite data will also be instrumental in monitoring and evaluating the scheme's effectiveness over time. Furthermore, the RPA envisions future expansions of satellite imagery data, such as validating additional aspects of the Countryside Stewardship scheme, including mowing events and buffer strips. Additionally, the RPA is collaborating with the Defra Earth Observation Centre of Excellence (EOCoE) to explore potential future applications within the DEFRA umbrella.

The Rural Payments Agency (RPA) Crop Map of England (CROME) is the most successful RPA earth observation project to date. This may be surpassed by the current project running to support SFI audits with satellite-based land monitoring systems.

The Rural Payments Agency use Earth Observation to create the Crop Map of England (CROME), which covers over 15 crop types, grassland, and non-agricultural land covers, with up to 95% accuracy in classification. Using CROME for Basic Payment Scheme (BPS) Greening and crop diversification as part of the Common Agricultural Policy schemes, crop classifications have seen a 9% improvement, rapid field visits were reduced by 34%, and follow-ups reduced by 8.5%. CROME resulted in savings of £12.3 million per year, with less need for field inspections and random checks.

Technical and policy discussions in the EOCoE supported the Rural Payments Agency in developing CROME. CROME is being adapted to support the monitoring of the current and new agri-environmental schemes such as Sustainable Farming Incentive, and Local Nature Recovery.

The first development phase of the Landscape Monitoring app was funded by the Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake. Subsequent development and scaling up was funded by Defra under the Natural Capital Ecosystem Assessment (NCEA) programme. User testing was carried out by habitat and site specialists at Natural England, NatureScot, Historic Environment Scotland, Natural Resources Wales and the Northern Ireland Environment Agency.

Overview of the benefits of the RPA using EO:

- Operational cost savings for government: efficient data collection, with satellite imagery covering extremely wide areas, saving taxpayer money.

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- Increased coverage of monitoring: Satellite data enables largescale data collection at a regular frequency (monthly or weekly), compared to manual inspections carried out once a year on <5% of claims.
- Delivering an equitable system: Widespread checking of land parcel accuracy leads to fewer errors, reduced fraud and a more equitable allocation of funds saving precious time for farmers.
- Traditional inspections require farm stoppages as farmers accompany a Field Officer around their farm: Remote inspections are automatic
- Increased transparency
- Digital maps are shared with farmers: they can understand why payment changes have been made and challenge decisions.

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