D2.2: Gap Analysis Report

EO Best Practice – Agro-Insurance

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EO Best Practice – Agro Insurance

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Acronyms and Abbreviations

ASV	Austrian Hail, Swiss Hail, Vereinigte Hagel Insurance
CCI	Climate Change Initiative
CHIME	Copernicus Hyperspectral Imaging Mission
DEM	Digital Elevation Model
DMP	Dry Matter Production
EARSC	European Association of Remote Sensing Companies
EEA	European Environment Agency
EO	Earth Observation
EO4I	Earth Observation best practices for agro-insurance
ESA	European Space Agency
FAPAR	Fraction of Absorbed Photosynthetic Active Radiation
IPCC	Intergovernmental Panel on Climate Change
LPIS	Land Parcel Identification System
LST	Land Surface Temperature
LSTM	Copernicus Land Surface Temperature Monitoring
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
R&D	Research & Development
ROSE-L	L-band Synthetic Aperture Radar
SAR	Synthetic-aperture radar
VGT	Vegetation

1 Introduction

The ESA project "Earth Observation Best Practice for Agro-Insurance" (EO4I) aims at providing a roadmap with guidelines for the use of EO for the agro-insurance sector. To get sector insights the consortium collaborates with a working group of three European agro-insurance companies (Austrian Hail Insurance, Swiss Hail Insurance and Vereinigte Hail Insurance), hereafter named as the "Working Group ASV".

In support of this roadmap, two main tasks have been defined:

- Task 1: Analysis of the geoinformation needs of the sector;
- Task 2: Analysis of current EO capabilities relevant to the needs, and assessment of capability gaps.

In Task 1, documented in the "D1.2 Geoinformation Requirement Report", four activities (two workshops, online user survey and dedicated interviews with the ASV group) were undertaken to obtain the most recent insights in the geoinformation needs from the sector. This report provides an insight of the identified key geo-information requirements of the sector.

The objective of Task 2 is to identify and characterize existing EO-based information products and services relevant to the agro-insurance sector, and to assess in discussion with the ASV group and other stakeholders of the sector to what extent the current capabilities fit their requirements. In order to achieve this, five activities are undertaken:

- Definition of EO-based information products
- Gap analysis
- Workshop with the industry
- Establish EARSC user platform
- User engagement
- Identification of prototype services

The first step of Task 2 was to identify and characterize existing and available EO-based products relevant for the sector. The resulting "D2.1 Current EO capabilities report" provides a portfolio of identified relevant Earth observation-based products.

This report documents the Gap Analysis, whereby the sector's key-geoinformation requirements are matched against current Earth observation capabilities (Chapter 2). Identified gaps are described, including the situation at this moment and how this could change in coming years, considering new data sources and technologies (Chapter 3).

2 Matching agro-insurance requirements and EO capabilities

2.1 Approach

This chapter documents the matching of identified agro-insurance requirements against Earth observation capabilities. The two main inputs for this analysis are:

- The D1.2 Geoinformation Requirement Report, which provides an overview of 26 key geo-information requirements. These are considered as the thematic building blocks supporting the development of Earth observation-based products and services for the sector.
- The D2.1 Current EO Capabilities Report, which contains a portfolio of 20 currently existing Earth observation products relevant for the agro-insurance sector.

This chapter provides first an overview of the Earth observation product portfolio, and next a table whereby these EO products are matched against the key geo-information requirements with a more detailed description of the gap analysis of each requirement. The objective of this work is to provide an overview at the thematic level where the sector's geo-information requirements overlap with existing Earth observation products, and to identify the gaps. In order to assess the suitability for an actual uptake of the Earth observation products in the agro-insurance's business processes, a case by case analysis is required. The project activities, which include the interaction with the ASV group and service demonstration aim to trigger discussions on how existing Earth observation products could fit into their workflow and see where adaptations and new technologies are needed.

2.2 Overview of EO product portfolio

Table 1: Overview of identified EO products

Product ID	Earth Observation Product
P01	Vegetation Indices
P02	Vegetation growth monitoring
P03	Date of Emergence
P04	Crop Type Detection
P05	Field Boundaries
P06	Early Vegetation Stress
P07	Yield Estimation
P08	Biomass production estimation
P09	Drought Indicators
P10	Soil Moisture
P11	Crop damage zones detection
P12	Crop growth zone detection
P13	Irrigation mapping
P14	Grassland Mowing Cycle
P15	Greenhouse Early Warning
P16	Near Real Time (NRT) Service
P17	Gap filled time series of High-Resolution biophysical parameters
P18	Digital Elevation Model (DEM)
P19	Water bodies detection
P20	Evapotranspiration
P21	Monitor and forecast weather events

2.3 Overview of geo-information requirements and linked EO products

Table 2: Overview of key geo-information requirements and linked EO products. For each requirement, supporting EO products are listed. If no corresponding products were found, the cell was left empty.

	Key Geo-information requirements	Linked EO products
1	Obtain uninterrupted consistent long data series (high temporal/spatial resolution)	P01, P17
2	Obtain detailed topographic characteristics	P18
3	Obtain detailed imagery of the surface	
4	Identify soil types (mineralogy, structural properties of near surface)	
5	Identify soil moisture contents	P10
6	Obtaining information on parcel location and boundaries	P05
7	Identify crop type	P04
8	Obtain historical crop production (crop, area, yields)	P04, P07
9	Crop vegetation monitoring	P01, P02, P03, P06, P16, P17

10	Monitoring stress in vegetation	P01, P02, P06, P07, P09, P11, P20
11	Identify the crop emergence and harvest date	P03
12	Crop yield monitoring	P07
13	Estimating yield losses	P07, P11
14	Identify crop damages	P01, P02, P09, P11, P12, P16
15	Identify effects of various risks (frequency, severity, area covered by each risk event)	P01, P02, P09, P10, P11
16	Obtain detailed land use information (crop production landscape, etc.)	P04, P05
17	Identifying agricultural practices (irrigation, fertilisation)	P13, P14, P20
18	Obtain detailed imagery of assets (property, machinery, other field infrastructure)	
19	Identify location and condition of infrastructure objects (irrigation, greenhouses, water wells, etc.)	P15
20	Identify water boundaries (flooded areas, etc.)	P19
21	Identify livestock movements	
22	Identify pastures biomass (yield potential)	P01, P07, P08
23	Identify waves height, currents' energy and thermal data	
24	Identify water flora/fauna (algae, etc.)	
25	Identify forests characteristics (area, boundaries, timber type, etc.)	P08
26	Monitor and forecast weather events	P21

2.4 Discussion of gap analysis per key geo-information requirement

1. Obtain uninterrupted consistent long data series (high temporal/spatial resolution)

Summary:

- Currently there are time series of vegetation indices (P01) available already at different spatial and temporal resolutions.
- The currently available datasets each have their own specifications combining several of the conditions specified in this requirement, e.g.:
    - Sentinel-2: High spatial resolution (10m) and 2 to 3-day revisit time, available since 2016.
    - Landsat: High spatial resolution (25m) long historical time series, revisit times 2x/month.
    - Copernicus Global Land Service: Low/medium resolution (1km/300m) vegetation indices at 10-daily timestep since 1999 derived from SPOT-VEGETATION and Proba-V.
    - MODIS: 8 daily medium resolution (250m) data available since 2000.
    - AVHRR NDVI historical archive (1981-2015) of biweekly NDVI data from NOAA-AVHRR satellites at 8 km resolution.

Limitations:

- Currently available EO datasets do not combine all conditions as specified in this key geo-information requirement: uninterrupted (e.g. gap-filled), consistent (inter-sensor calibration required), long (multiple decades available) at high temporal and spatial resolution.
- The revisit time of the high spatial resolution imagery from Sentinel 2 and especially Landsat may not be sufficient for the insurance needs. Especially in cloudy periods, data gaps of two or more weeks may be possible.

Possible Fall-back solutions:

- Land-based (e.g. weather station records) and in-situ (e.g. farm's weather/yield data) datasets (if available) that should be qualified for applicability in case EO datasets become unavailable
- Based on the application of the datasets, alternative data sources and methods of land-based/in-situ data collection / storage must be developed and applied for the specific purposes the data applied (e.g.: crop monitoring and index-based insurance product will need different guidelines and methods related to datasets, that are considered as an alternative or complimentary to the EO data).

2. Obtain detailed topographic characteristics

Summary:

- EO based Digital Elevation Models (DEM, P18) provide a digital representation of elevation, the most important characteristic of topography. Publicly available datasets have spatial accuracies from 30m-90m, which allow to assess the topography surrounding crop parcels.

Radar and optical remote sensing data are increasingly used to support landslide risk management due to their multispectral and textural characteristics, high revisiting cycles, wide area coverage and high spatial resolution (Casagli et al., 2016).

Limitations:

- Different methods used during the creation of the DEM's, which makes it difficult to combine multiple sources.

Possible Fall-back solutions:

- Overlay with existing topography data at the respective agencies in the country.
- Drone survey for areas (topography) affected by natural calamities.

3. Obtain detailed imagery of the surface

Summary:

- There are currently several satellite-based very high-resolution (<1m) true colour image layers available, which can be used for visual interpretation. For example, the Google Earth Maps (google.com/earth) derived from DigitalGlobe Quickbird provides imagery at 65 cm resolution and is freely available. These layers are however not available in real time and thus could only be used for visual interpretation of historical imagery. This could be useful to collect ancillary information on the insured entities, such as the identification of field parcels, inspecting infrastructure etc. Commercial EO service providers such as Planet (https://www.planet.com/products/hi-res-monitoring/) offer sub-meter resolution imagery for insurance companies, which could be used for real time detection of crop damages etc. These data are however costly and currently not often used by agricultural insurances.

Limitations:

- Cloud covered areas might cause data gaps.
- Revisit time. For certain insurance products a revisit frequency of 2 or 3 days may be required with no cloud cover interference. Possible applications include fire damage or frost. Depending on satellite used, such a high revisit time might (even up to one day) or might not be reached.
- Timely very high resolution imagery is only available through commercial providers and hence includes a cost for the agro-insurance company.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Self-service by a farmer – photo or video with GPS real time data captured

4. Identify soil types (mineralogy, structural properties of near surface)

Summary:

- R&D on remotely sensed soil type mapping is often focused on classification methods based on near surface spectroscopy or using hyperspectral data for the estimation of quantitative soil properties (e.g. soil organic carbon or clay content).

Limitations:

- There are currently no established methods to accurately identify soil types from in space missions.
- Remote sensing could support the estimation of soil properties and stratification of soil sampling.

Possible Fall-back solutions:

- Application of available in-situ data from farm and state authorities.

5. Identify soil moisture contents

Summary:

- The ESA Climate Change Initiative (CCI) provides a +40-year dataset of soil moisture at 0.25°. These data could be used to define drought indices at larger scales but do not meet the need for real-time soil moisture information at field level.
- Recently, higher resolution (e.g. 100x100m) near real time soil moisture products are being made available using the Copernicus Sentinel Constellation and offered by commercial companies such as Vandersat (vandersat.com/soil-moisture-monitoring).
- Products with a higher resolution of 10x10m are based on Sentinel-1 imagery combined with other sensor's time series and point based in-situ measurements. These products are commercially available through EO companies such as GeoVille (www.geoville.com).
- The currently available products indicate the surface soil moisture, commonly assumed is a depth of roughly 5 centimeter. However, the desired output as identified in the different user meetings would be a product showing the root zone soil moisture. Via indirect ways the water content for the rootzone, up to 50 cm deep could be estimated based on the topsoil measurements.

Limitations:

- Freely available data from the CCI initiative does not meet the need for soil moisture information in real-time and at field level.
- Products with higher spatial and timely resolution need to be purchased from commercial providers.
- In-situ measurements required for data correlation purposes
- Currently available methodologies can be applied for surface soil moisture only, root zone soil moisture would be required.

Possible Fall-back solutions:

- Physical measurements by experts with applied methodology to match or correlate alternative or future EO data

6. Obtaining information on parcel location and boundaries

Summary:

- Recent technologies, which are being implemented on high resolution imagery such as Sentinel-2 data allow to delineate parcel boundaries (P05). These techniques are mostly operational over Europe with well-defined fields. In more challenging landscapes (heterogeneous with small fields), very high-resolution data (<5m) would be required and current methodologies need to be tested.
- The delineation of field parcels is a core service that can be combined with further data derived from Earth observation, such as crop type. This combination of data can be very useful for agro-insurance's purposes as much information is needed at field level.

Limitations:

- Minimum field size of 0.5ha is required for the identification of field boundaries on Sentinel 2 data.
- False detection of crop parcels for landscape features that have similar spatial patterns such as football fields, golf courses,…etc.
- No exact data on field/parcel location from the farmer or insurer.
- Possible issues for insurance's purposes when the field is split into sub-field level by the algorithm due to different management decisions on a field parcel.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo with GPS stamp)
- Apply incentives by insurance company to acquire field coordinates or shape file or digital maps at the time of application for insurance.
- Self-service by a farmer – photo or video with GPS real time data captured
- Publicly available datasets such as LPIS (Land Parcel Identification System).

7. Identify crop type

Summary:

- Crop type mapping (P04) is a field of research since decades on data derived from satellites such as Landsat. Since the operational data delivery from Sentinel-1 and Sentinel-2, there has been a great step forward in the accuracy and timeliness of crop type maps. Several EO service provider companies now offer crop type mapping services, mostly via on demand services for specific regions.
- Several EO service providers offer EO in-season crop type services at high accuracy and resolution.

Limitations:

- Qualitative EO based crop type maps can only be generated when there is sufficient coverage on the crop parcel.
- Established crop type mapping services exist for a number of main crop types (e.g. maize, potato, cereals, rice, …). For less common crops additional in-situ data may be required.
- When crop type mapping methodologies are extrapolated outside their calibration/validation environment, quality checks should be performed and additional in-situ data (provided by farmer or publicly available datasets) may be required.
- Machine learning datasets are highly dependent on their input datasets. The crop type classification can be improved with available in-situ data.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Digitized maps (shapefiles) provided by farm with crop indicated for each field/plot
- Publicly available datasets such as LPIS (Land Parcel Identification System).

8. <u>Obtain historical crop production (crop, area, yields)</u>

Summary:

- In order to obtain information on historical crop production at regional level information on the crop type, crop area and historical yields are required. As mentioned above ("7. Identify crop type"), the quality of crop type maps has been drastically improved with the availability of Sentinel-1 and Sentinel-2 data, which is only available since 2016 onwards. In order to generate historical crop production information over a region, one thus should rely on older EO data sources (e.g. the Landsat archive) to generate crop type maps for which the quality of the crop type maps will be lower (e.g. Johnson, D. 2019). For historical yields EO can't provide accurate estimates, hence official statistics or machinery based yield estimates should be considered as proxy.

Limitations:

- Reliability of official statistics or other in-situ data applied as proxy for yield estimation.
- Accuracy of EO yield estimates: e.g. due to certain risk events NDVI index may be high but the actual yield might be very low
- Accuracy of crop type identification for cereal crops (difficulty to accurately identify wheat/rye/triticale/barley and receive high accuracy in yield estimates for each crop)

Possible Fall-back solutions:

- Application of data collected by agricultural machinery (tractors, combines, etc.)
- Autonomous drone survey (long-, mid-range drones)

- Physical assessment by an expert (short-range drones, photo)
- Collection of crop data from the farmers (last 5 seasons) with AI re-analysis of historical data and machine learning based on the EO historical data for the area insured

9. Crop vegetation monitoring

Summary:

- Since Sentinel-2 is operationally working and delivering data, it is possible to monitor crop growth at unprecedent level and such services are being provided by several Earth Observation service providers.
- The main drawback is that these crop monitoring services are 'blind' in cloudy weather, which could result in large gaps in the observational data produced. Hybrid approaches, where Sentinel-1 radar data, which can see through clouds is used in combination with Sentinel-2 optical data provide promising results.

Limitations:

- Limited application for variety of crops (vines, horticulture, vegetables, etc.) because the relation between the greenness indicated by EO vegetation indices may not always reflect the impact on the actual crop conditions.
- Cloud coverage could impact the near real-time information flow and cause data gaps.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo, manual calculations)
- Self-service by a farmer via established protocol or special apps on smartphone
- Hybrid approaches using both, optical and radar imagery, are very promising. Since radar satellites send their own signal, they do not rely on weather conditions and hence are overcoming the problem of cloud cover.

10. Monitoring stress in vegetation

Summary:

- Classical crop monitoring services mostly use vegetation indices such as NDVI and FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) derived from optical imagery such as Sentinel-2. Such vegetation indices can reflect vegetation stress at longer terms (>1 week), e.g. persistent drought or disease outbreak, but are less suitable to capture timely (e.g. upcoming disease) and short-term vegetation stress (short term water deficit stress).
- Land surface temperature (LST) has the potential to detect short term vegetation stress. The current in space missions however do not provide sufficient temporal (e.g. Landsat) or spatial detail (e.g. Sentinel-3) to build operational crop monitoring services for early stress detection.

Limitations:

- Insufficient temporal (e.g. Landsat) or spatial detail (e.g. Sentinel-3) to build operational crop monitoring services for early stress detection.

Possible Fall-back solutions:

- Physical assessment by an expert

11. Identify the crop emergence and harvest date

Summary:

- Deriving phenology indicators is a fairly well matured field of R&D. Established and commonly used methods (such as Timesat, http://web.nateko.lu.se/timesat/) are capable to detect start and end of the growing season from time series of EO based vegetation indices. Recently, such methods are applied on Sentinel-2 data with success (Jonsson, et al. 2018), hereby focusing on detecting a general green-up and senescence of the vegetation. In order to detect more specific events related to crop growth (crop emergence & harvest) two main requirements should be met:
    - A high density of Sentinel-2 observations at the key phenological stages. This could be problematic in cloud abundant regions. Hence, also R&D is being done to develop crop phenology procedures on Sentinel-1 (e.g. Mercier et al. 2019)
    - Finding the right configuration (parameters) to translate time series of vegetation indices into crop specific events. This will often require local testing & evaluation against in-situ data.

Limitations:

- Data gaps in satellite imagery might be caused due to cloud cover.
- Outputs rely on the quality and reliability of available in-situ data.
- Calibration of EO data with expert physical visits
- Different varieties or hybrids of the same crop will have different timelines (e.g. short and long season varieties). These cycles may also naturally change due to temperatures or/and water availability.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Self-service by a farmer via established protocol or special apps on smartphone
- Apply insurance application data for crop emergence monitoring. With some products (eg. multi-peril crop insurance) insurer may require early registration and application. If the field coordinates and crop type (including variety or hybrid name) known, it may be possible to identify crop emergence relatively easy.

12. Crop yield monitoring

Summary:

- Parcel level yield monitoring has been an extensive field of research for several years and is currently offered as a service by a number of EO service providers, e.g. Watchitgrow.be for Sentinel-2 based Belgian potato monitoring. The main challenge of EO based yield prediction is feeding sufficient ground truth data into the yield models. Hence mostly reasonable accuracies can be obtained only on local scale.

Limitations:

- Quality of services strongly depends on the availability and quality of in-situ or other proxy data applied for high level of correlation with actual crop yields.

Possible Fall-back solutions:

- Physical measurements by experts with applied methodology to match or correlate with EO data
- AI re-analysis of historical data and machine learning based on the EO and insurer historical data for the area insured.

13. Estimating yield losses

Summary:

- Yield models could provide estimates of the yield potential and actual yield of a certain crop and hence could give a proxy on the yield which was not realized. Earth observation could contribute to these modelling by providing information on historical vegetation performance (yield potential) or actual vegetation state (actual yield). Estimating the impact of an extreme weather event on the yield is however strongly dependent on the crop type, even up to crop variety and phenological stage of the crop.

Limitations:

- Risks with a high correlation of their effects on yields is limited at the moment.
- Currently, applicable methods are limited to a few special crop types

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Machine learning – If crop types are identified accurately, one can estimate yields per crop type at the regional basis. This will allow seeing yield variations at the regional level which will provide useful information to loss adjusters and underwriters.

14. Identify crop damages

Summary:

High resolution data such as Sentinel-2 is capable to detect crop damage and is already used by insurance companies (e.g. Austrian Hail). There are however currently a number of challenges, which could hamper the operational use of the data.

Limitations:

- Spatial resolution might be insufficient to detect small patches of crop damage (e.g. caused by a storm).
- It is difficult to identify the cause of crop damage (e.g. hail, storm…). Supporting weather data could be used to verify if extreme weather events occurred (e.g. storm damage via wind speed, hail via energy within the atmosphere and presence of weather systems over the field location, frost via temperature measurements).
- Crop damage detection within a field could be confused with natural field heterogeneity caused by e.g. soil characteristics.
- Data gaps due to cloudy periods during a crop damage event (e.g. storm, hail) impact the timeliness of the crop damage estimates

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- AI and machine learning to match damage in time with certain weather parameters

15. Identify effects of various risks (frequency, severity, area covered by each risk event)

Summary:

- Long time series of historical Earth observation data can be used to calculate anomalies in vegetation growth. These anomalies could then be used to assess the frequency and severity of less performing years. These methods have been applied on medium-low resolution imagery to assess the historical crop damage frequency at regional scale (e.g. Piccard et al. 2010). These methods however still have a number of limitations.

Limitations:

- Existing methods do not provide information at the parcel level (e.g. due to different soil conditions).
- Currently, the differentiation between different types of risks is not possible.

Possible Fall-back solutions:

- Physical measurements by experts with applied methodology for differentiation of risk effects and their severity on the specific crop.
- Benchmarking using weather data correlations (e.g. significant deviation of a certain weather parameter matching with changes in NDVI index)

16. Obtain detailed land use information (crop production landscape, etc.)

Summary:

- Historical dataset such as the CORINE Land Cover database, which provides high resolution land cover maps in frequent intervals since the 1990's are valuable sources of information. These products focus however mostly on land cover rather than on land use. The novel CLC+ will be a major upgrade of this European Land Cover/Land Use information basis. This next generation Corine Land Cover product, code-named CLC+, is being designed as a logically structured series of subsets, ranging from VHR input layers (CLC-backbone, vector) into a core LC/LU graphical database (CLC-core, grid) to instances, which become on-demand end user products (CLC+, CLC-heritage). https://land.copernicus.eu/user-corner/technical-library/upcoming-product-clc

Limitations:

- Actual land use requires specific algorithms to interpret the land cover data for the agro-insurance needs.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)

17. Identifying agricultural practices (irrigation, fertilization)

Summary:

- Agricultural practices can't be observed directly with Earth observation data and can only be identified in indirect ways. For example, EO based rainfall estimates can be used in combination with EO based evapotranspiration estimates to give an indication of irrigation practices. These methods are suitable for larger scale irrigation mapping (area based) in semi-arid and arid regions (e.g. http://www.fao.org/in-action/remote-sensing-for-water-productivity/wlpa-introduction/wapor-applications/monitoring-irrigation-areas/en/).
- The mapping of agricultural practices at field level is being tested in projects such as SEN4CAP: http://esa-sen4cap.org/content/agricultural-practices.

Limitations:

- No direct observations are possible, hence only proxies on agricultural management could be estimated.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Provision of irrigation logs/reports by the farmer

18. Obtain detailed imagery of assets (property, machinery, other field infrastructure)

Summary:

- Earth observation data at very high resolution (<1m) resolution could be used to assess insurance assets. These layers are however costly for real-time monitoring.

Limitations:

- Very high resolution imagery is needed to obtain information timely and detailed enough which is associated with additional costs for the data.
- Identification of various property types is hard to derive automatically.
- Identification of different machinery items (e.g. if the farmer has several similar pieces of equipment) is currently not possible

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)

19. Identify location and condition of infrastructure objects (irrigation, greenhouses, water wells, etc.)

Summary:

- Earth observation data at very high resolution (<1m) resolution can be used to assess insurance assets. These layers are however costly for real-time monitoring.

Limitations:

- Very high resolution imagery is needed to obtain information timely and detailed enough which is associated with additional costs for the data….

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Self-service by a farmer via established protocol or special apps on smartphone

20. Identify water boundaries (flooded areas, etc.)

Summary:

- SAR data such as Sentinel-1 or TerraSAR-X provides a valuable source for flood mapping and established methods have been developed for this (e.g. http://www.un-spider.org/advisory-support/recommended-practices/recommended-practice-flood-mapping/step-by-step).

Limitations:

- Ancillary data such as field observations, civil protection reports, geolocated photos are required for the validation of products.
- Empirical flood mapping methodologies may require local parameterization.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)

- Physical assessment by an expert (short-range drones, photo)
- Self-service by a farmer via established protocol or special apps on smartphone

21. Identify livestock movements

Summary:

- Earth observation data is not capable to detect the actual movement of livestock.

Limitations:

- This requirement could be only addressed indirectly with current EO capabilities, e.g. by providing information on pasture biomass (see below).

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Application of satellite-tracked GPS sensors
- Use of RFID or other ear-tags with virtual boundaries/fences (Though, this may not be suitable for free-range practices or mountains where cattle may be fattening for extended periods of time.).

22. Identify pastures biomass (yield potential)

Summary:

- Earth observation data has proven useful for operational grassland monitoring since several years. For example, the medium resolution EO based Copernicus Global Land Service Dry Matter Production (DMP) product has been used to indicate pasture biomass hotspots & deficits in support of a pastoralist surveillance system in West Africa (Ham, et al. 2011).
- EO based vegetation indices have been used to develop operational index insurance programs for grasslands (e.g. Punalekar, et al. 2018).

Limitations:

- In-situ data or proxy data may be required to check the accuracy for local scale applications.
- The methods are often based on optical imagery, hence cloud coverage could hamper the biomass monitoring.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert, applying the agreed methodology and censors to possibly substitute EO data used for building index programs (short-range drones equipped with required censors)

23. Identify waves height, currents' energy and thermal data

Summary:

- Sentinel-3 provides operational data on sea surface temperature, which could be used for risk assessment for fisheries (e.g. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/applications/maritime-monitoring/sea-surface-temperature).

Limitations:

- Cloudy periods may hamper operational observations

Possible Fall-back solutions:

- Data from land-based marine survey and research
- Autonomous drone survey (long-, mid-range drones)

24. Identify water flora/fauna (algae, etc.)

Summary:

- Sentinel-2 data has been used to monitor algae bloom extent and severity by estimating chlorophyll-a (chl-a) concentration (e.g. German et al. 2019).
- Furthermore, Sentinel-3 is well suited for water quality monitoring.

Limitations:

…cloudy periods may hamper operational observations

Possible Fall-back solutions:

- Data from land-based marine survey and research
- Autonomous drone survey (long-, mid-range drones)

25. Identify forest characteristics (area, boundaries, timber type, etc.)

Summary:

- High and very high-resolution optical Earth observation data can be used for visual interpretation of forest area, boundary and providing an indication on forest type.
- Existing high-resolution land cover maps such as the European Land Cover map can provide a good indication of the forest area in a region.

Limitations:

- Existing mature EO capabilities focus mostly on detecting the forest area and boundaries. For more detailed characteristics such as timber type etc. no operational EO based methods exist.

Possible Fall-back solutions:

- Autonomous drone survey (long-, mid-range drones)
- Physical assessment by an expert (short-range drones, photo)
- Self-service by a farmer via established protocol or special apps on smartphone

26. Monitor and forecast weather events

Summary:

- Earth observation data (e.g. METOP-AVHRR) is being used operationally to support numerical weather forecasts. These forecasts typically provide information at coarse grid scale (>5 km). The agro-insurance sector could benefit from weather monitoring and forecasts at higher resolutions. R&D is being done to assess the use of EO data to downscale numerical weather forecasts (e.g. Lagasio, et al. 2019).

Limitations:

- Quality of land-based data
- The spatial detail of publicly available weather monitoring/forecast services may be too coarse in topographic heterogeneous landscapes such as mountainous areas.

Possible Fall-back solutions:

- Application of land-based weather station data (requires robust data quality check on a day-to-day basis.

3 Identifying future EO capabilities

3.1 Identification of future EO capabilities

3.1.1 Planned missions

3.1.1.1 Sentinels

ESA's Sentinel missions include radar and super-spectral imaging for land, ocean and atmospheric monitoring. Each Sentinel mission is based on a constellation of two satellites to fulfil and revisit the coverage requirements for each mission, providing robust datasets for all Copernicus services. Figure 1 shows an overview of the current in space missions (green) and in blue planned or tentative missions. The three missions most relevant for agro-insurance applications are Sentinel-1 (radar-based parcel level crop monitoring), Sentinel-2 (optical parcel level crop monitoring) & Sentinel 3 (large scale vegetation monitoring, data continuity of historical archive of SPOT-VGT/Proba-V time series). Each of these missions has an operational lifespan of 7-7.5 years with consumables for 12 years. The current in space constellations are expected to be operational at least until the early 2020's. Follow-up missions are planned to guarantee data continuity for these missions until at least 2030.

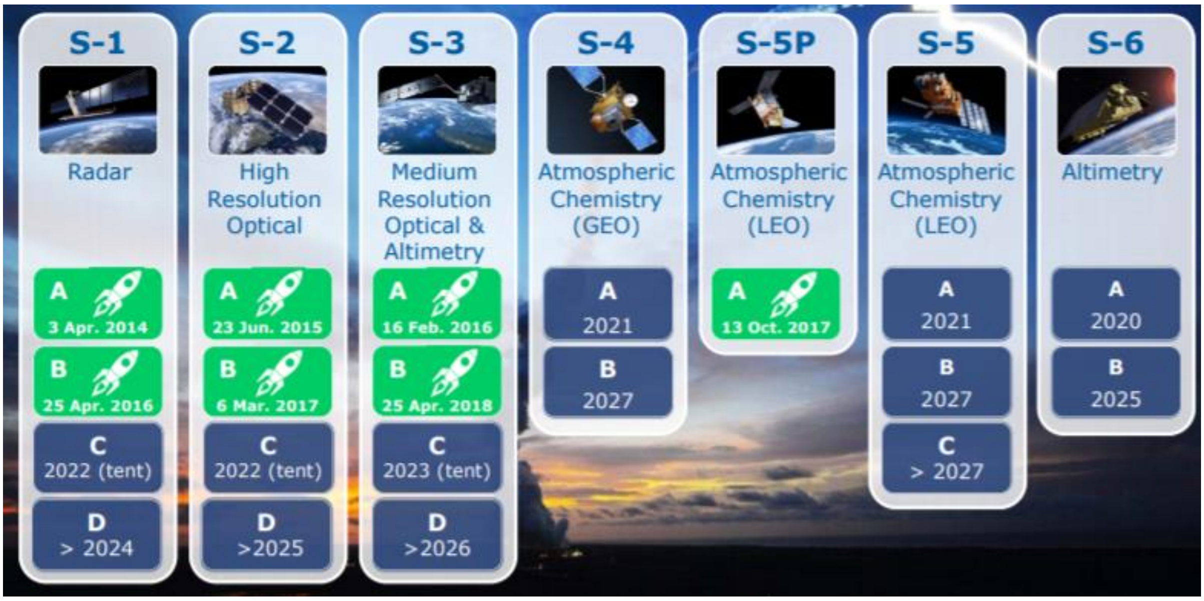

Figure 1: Overview of Sentinel Missions and Satellites: in space (green) and planned (blue). Source: http://emits.sso.esa.int/emits-doc/ESTEC/News/ESACopernicusIndustryDaysPresentation.pdf

3.1.1.2 Biomass

BIOMASS is an Earth observing satellite planned for launch by ESA 2023. The mission will provide the first comprehensive measurements of global forest biomass. The mission is meant to last for five years, monitoring at least eight growth cycles in the worlds' forests. Its basic resolution is 50m, but the biomass maps will be 200m and be provided each 6 months. The standing biomass, biomass change & forest height maps can be used for forest characterization.
Reference:
https://www.esa.int/Applications/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Biomass

3.1.1.3 Flex

The Fluorescence Explorer (FLEX) mission has been selected as ESA's 8th Earth Explorer mission with a planned launch in 2023. The primary objectives of the mission are to provide global estimates of vegetation fluorescence, actual photosynthetic activity, and vegetation stress. The data will have a 300m resolution and a 1-month revisit time. This means it is most useful for larger scale analysis (e.g. landscape or regional scale) and to support ecosystem stress & production estimates. The data will be less suitable for operational crop growth stress monitoring at parcel level.

Reference:

https://earth.esa.int/web/guest/missions/esa-future-missions/flex

3.1.1.4 Landsat 9

Landsat 9 is a planned mission in the NASA Landsat series, scheduled for launch in March 2021. It will contain four visible spectral bands, one near-infrared spectral band, three shortwave-infrared spectral bands at 30 m spatial resolution, plus one panchromatic band at 15 m spatial resolution, and two thermal bands at 100 m. It will contribute the long historical archive of the Landsat legacy and thus support historical analysis. The single mission will have a 16-day revisit time and an 8-day in combination with Landsat 8. Currently, most operational optical crop monitoring in Europe is done with Sentinel-2 as it outperforms the spatial and temporal resolution of Landsat. This is not expected to change with the launch of Landsat 9. It is however a valuable back-up mission for European crop monitoring and can be used in addition to Sentinel-2. The thermal data, which will be provided by Landsat at 100m resolution, could be of use for evapotranspiration or early stress detection.

Reference:

https://eospso.nasa.gov/missions/landsat-9

3.1.2 Candidate missions

3.1.2.1 CHIME: Copernicus Hyperspectral Imaging Mission

The CHIME mission would carry a visible to shortwave infrared spectrometer to provide routine hyperspectral observations to support agriculture and biodiversity monitoring, as well as soil property characterization. It will complement currently flying multi-spectral missions such as Sentinel-2. Compared to multi-spectral missions, CHIME will have an increased number of narrow spectral bands (spectral resolution of 10nm with no gaps between bands) in the visible-to-shortwave infrared range (400-2500nm), which will allow for a more accurate determination of biochemical and biophysical variables. Expected spatial resolution will be 20-30m with a revisit time of 10-12.5 days, using a synchronous overpass time of between 10.30-11.30 am. This spatial detail will allow to perform analyses at the parcel level. Given the revisit time, it is expected that downstream products could serve the agro-insurance sector mainly with geo-information for which the required timeliness or temporal detail is not within days (e.g. as in the case of crop damage assessment). There are however a number of potential applications that could provide new or enhanced services for the sector, such as:

- Improved Yield Assessment and Forecast
- Species identification (e.g. crop type (e.g. differentiate wheat & barley), invasive species)
- Crop health and damage (water and nutrient stress)
- Detection of weeds
- Crop water requirement
- Mapping soil properties: structure and texture
- Estimation of carbon storage in soils
- Soil Erosion and degradation mapping
- Detection of soil pollution and soil contamination

References:

http://esamultimedia.esa.int/docs/EarthObservation/Copernicus_CHIME_MRD_v2.1_Issued20190723.pdf

https://www.d-copernicus.de/fileadmin/Content/pdf/Forum_2018/2018_11_08_CHIME_Copernicus_Bonn_Vista.pdf

3.1.2.2 LSTM: Copernicus Land Surface Temperature Monitoring

The LSTM mission would carry a high spatial-temporal resolution thermal infrared sensor to provide observations of land-surface temperature (LST). The mission will allow enhanced agricultural monitoring at field-scale, mainly by providing information on drought stress and rates of evapotranspiration. The main characteristics are a revisit time of 1-3 days, a spatial resolution of 50 m and an early afternoon overpass. The minimum mapping unit (e.g. field size) for this spatial resolution is considered as 1 ha. Figure 2 (obtained from the Mission Requirements Document, see References) provides an overview of the percentage of fields >1ha on a 10x10km grid over Europe, as derived from the LPIS database.

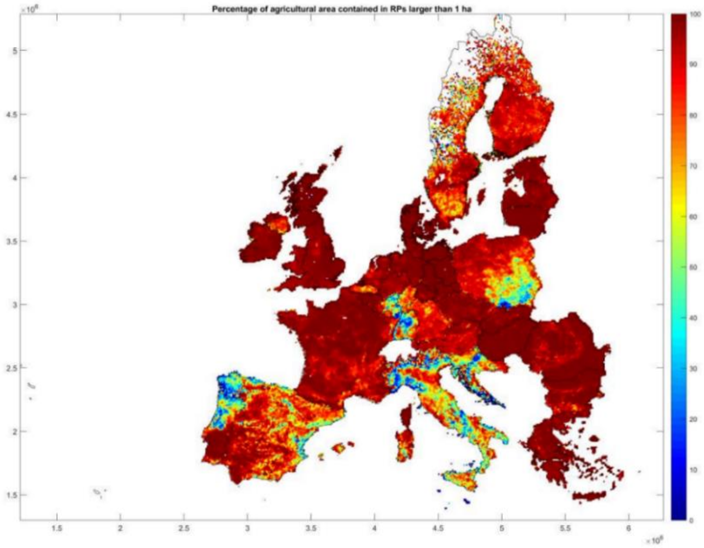

Figure 2: EU distribution of the percentage of agricultural area covered by reference parcels of more than 1 ha within a 10kmx10km grid (blue is 0% and red is 100%). Source: MRD.

Reference:

http://esamultimedia.esa.int/docs/EarthObservation/Copernicus_LSTM_MRD_v2.0_Issued20190308.pdf

3.1.2.3 ROSE-L: L-band Synthetic Aperture Radar

ROSE-L is an L-band SAR mission that will complement the current in space Sentinel-1 mission. For instance, ROSE-L's long wavelength will be able to measure surface deformation in vegetated areas currently. This will greatly extend the earthquake zones and regions at risk of landslides that can be systematically monitored from space. Information from ROSE-L will also improve the accuracy of measurements of forest biomass and changes in forest cover and condition across the globe. Other applications that benefit from the unique capabilities of ROSE-L include the mapping of soil moisture at field scale throughout the vegetation season, which will support improved agricultural crop monitoring and water use, as well as better land cover mapping. Over oceans ROSE-L will be used to monitor wave direction and wave heights. ROSE-L is currently expected to achieve complete coverage of Earth's surface every six days based on two satellites. Over Europe ROSE-L is expected to image all of Europe in 3 days or less and once per day in the Arctic. The spatial resolution is expected to be better than 50 m2, or roughly 2x better than the current Sentinel-1 IWS product. ROSE-L is expected to operate in the same orbit as Sentinel-1 providing frequent and complementary SAR coverage of Europe and the world. Potential applications for agro-insurance include:

- Evapotranspiration estimates
- Irrigation mapping
- Forest height, biomass, area and disturbance
- Land cover, crop type, crop status
- Agricultural Management Practices
- Soil moisture
- Monitor wave heights

References:

https://esamultimedia.esa.int/docs/EarthObservation/Copernicus_L-band_SAR_mission_ROSE-L_MRD_v2.0_issued.pdf

https://futureearth.org/publications/explainers/plans-for-a-new-wave-of-european-sentinel-satellites/

3.1.3 Publicly available products

3.1.3.1 Copernicus Global Land Service

The Copernicus Global Land Service has been providing operationally global products of biophysical parameters such as NDVI, FAPAR, fcover, … from Proba-V satellite imagery. This service will switch to Sentinel-3 data (from Q2 2020 onwards) to ensure data continuity for its users. These data provide both long historical archives (1999 – today), which could be used for historical analyses and near real time monitoring at medium resolution scale.

https://land.copernicus.eu/global/

3.1.3.2 High resolution Pan-European Service: Phenology

Started in early 2020, the European Environment Agency (EEA) has kicked off the development of a high-resolution Pan-European Sentinel-2 based phenology layer. The resulting maps, which will be produced yearly, will contain for each 10m x 10m the start, maximum and end of season. These layers could be used by the agro-insurance sector to have a general idea in a region on the crop growing season. The project will also deliver near real-time basic vegetation indices derived from level 2A Sentinel-2 data.

https://land.copernicus.eu/user-corner/technical-library/phenology

3.1.3.3 WorldCover

With the WorldCover project [2019-2021] ESA aims to deliver to the public a land cover map of the entire globe at 10m resolution based on its Sentinel-1 and 2 data. The map will include 10 predefined classes (based on IPCC Level 1) with an expected 75% overall accuracy. It will focus on the fast generation and validation (possibly less than 3 months after last data take). This map, which will be freely and publicly available could serve as a valuable source of information on land cover at global scale for the agro-insurance sector.

https://eo4society.esa.int/projects/worldcover/

3.2 Overview of identified future capabilities per geo-information requirement

Table 3: Overview of key geo-information requirements and relevant future EO capabilities.

	Key Geo-information requirements	Future capabilities
1	Obtain uninterrupted consistent long data series (high temporal/spatial resolution)	Copernicus Global Land Service Landsat 9
2	Obtain detailed topographic characteristics	
3	Obtain detailed imagery of the surface	CHIME
4	Identify soil types (mineralogy, structural properties of near surface)	CHIME
5	Identify soil moisture contents	ROSE-L
6	Obtaining information on parcel location and boundaries	
7	Identify crop type	CHIME
8	Obtain historical crop production (crop, area, yields)	Copernicus Global Land Service WorldCover
9	Crop vegetation monitoring	LSTM
10	Monitoring stress in vegetation	FLEX LSTM
11	Identify the crop emergence and harvest date	High resolution Pan-European Service: Phenology
12	Crop yield monitoring	FLEX CHIME
13	Estimating yield losses	
14	Identify crop damages	
15	Identify effects of various risks (frequency, severity, area covered by each risk event)	
16	Obtain detailed land use information (crop production landscape, etc.)	WorldCover
17	Identifying agricultural practices (irrigation, fertilisation)	LSTM
18	Obtain detailed imagery of assets (property, machinery, other field infrastructure)	
19	Identify location and condition of infrastructure objects (irrigation, greenhouses, water wells, etc.)	
20	Identify water boundaries (flooded areas, etc.)	ROSE-L
21	Identify livestock movements	
22	Identify pastures biomass (yield potential)	BIOMASS FLEX
23	Identify waves height, currents' energy and thermal data	ROSE-L
24	Identify water flora/fauna (algae, etc.)	
25	Identify forests characteristics (area, boundaries, timber type, etc.)	BIOMASS
26	Monitor and forecast weather events	CHIME

4 Conclusion

This report summarizes the gap analysis performed in the EO4I (Earth Observation best practices for agro-insurance) project. Prior to the gap analysis, activities were performed to identify the geo-information requirements and to describe the current EO capabilities. This report first provides an overview of how EO products match the identified geo-information requirements. Next, for each geo-information requirement, a gap analysis was performed by describing in more detail how existing EO capabilities could support the agro-insurance sector, and what the current limitations are. Some conclusions:

- Most of the geo-information requirements have corresponding EO products, which can be matched at a thematic level. But it often requires insights in the business processes in order to assess the actual fit. E.g. EO based "crop type mapping" matches the "Identify crop type" requirement. But the timing within the growing season defines the actual relevancy of these EO products for the sector. Crop type maps can be accurately produced from the moment there is a decent coverage of the field of the specific crop. But the sector could be most interested in this information very early in the season, even before the emergence of the crop.
- In order to assess the suitability for an actual uptake of the Earth observation products in the agro-insurance business process, a case by case analysis is required. The project activities, which involve the interaction with the ASV group and service demonstration aim to trigger discussions on how existing Earth observation products could fit into their workflow.

The second part of this report describes the future EO capabilities. A focus has been made on ESA planned and candidate missions. The major contribution to the current EO capabilities in the coming years will be the continuation of the high-resolution Sentinel-1 and Sentinel-2 missions. The BIOMASS mission can contribute to agro-insurance on forestry whereas the FLEX mission is mostly suited for larger scale analysis, e.g. to evaluate the impact of major droughts in a region. The candidate ESA missions CHIME, LSTM & ROSE-L could bring a contribution to the current identified gaps: CHIME by delivering information on soil, improved mapping of species, LSTM by providing parcel level information on evapotranspiration, which could be used for irrigation mapping, drought analysis, etc. and ROSE-L by supporting the current Sentinel-1 capabilities, e.g. for parcel level soil moisture estimates.

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