D2.1 Current EO capabilities report

EO Best Practice – Agro Insurance

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14 April 2020

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EO Best Practice – Agro Insurance

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Acronyms and Abbreviations

ASV	Austrian Hail Insurance, Swiss Hail Insurance and Vereinigte Hail Insurance
BOA	Bottom of Atmosphere
DIAS	Data and Information Access Services
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
EARSC	European Association of Remote Sensing Companies
EO	Earth Observation
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
GRD	Ground Range Detected
HH	Single polarisation SAR Horizontal
HV	Dual polarisation SAR Horizontal Vertical
IR	Thermal infrared bandwidth
K	Kelvin
LWIR	long wave infrared
MODIS	Moderate Resolution Imaging Spectroradiometer
MWR	Microwave Radiometer
NDVI	Normalized Difference Vegetation Index
NIR	Near-infrared bandwidth
NOAA-AVHRR	National Oceanic and Atmospheric Administration Advanced Very High-Resolution Radiometer
NRT	Near Real Time
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land Imager
SAR	Synthetic Aperture Radar
SLSTR	Sea and Land Surface Temperature Radiometer
SM	Stripmap mode
SMOS	Soil Moisture and Ocean Salinity satellite
SRAL	SAR Altimeter
SWIR	Shortwave infrared bandwidth
TIRS	Thermal Infrared Sensor
TOA	Top of Atmosphere
VH	Dual polarisation SAR Vertical Horizontal
VIS	Visible bandwidth
VV	Single polarisation SAR Vertical

1 Introduction

The ESA "Earth Observation (EO) best practices for the agro-insurance sector" (EO4I) project aims to consolidate a roadmap with guidelines for EO usage by the agro-insurance sector. To support this kind of activity, ESA and the project consortium (GeoVille, VITO and CGI) work together with 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 assess capability gaps

In Task 1, documented in the D1.2 Geoinformation Requirement Report, four main activities (a workshop at the Living Planet Symposium, an online user survey, dedicated interviews with the ASV working group as well as a workshop with key experts from the agro-insurance, Re-insurance and the EO sector)) were undertaken to obtain the most recent insights in the geoinformation needs from the sector.

The objective of Task 2 is to identify and characterize existing EO-based information products and services that are relevant for 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:

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

This report is the outcome of defining and characterizing existing and available EO-based products relevant to the sector. The following chapter provides a high-level summary of earth observation satellites relevant for developing products for the agro-insurance sector. Chapter 3 provides a portfolio of identified earth observation-based products.

2 EARSC-website

Content / Navigation

All outcomes of the above mentioned Task 1 (Analysis of the geoinformation needs of the sector) and Task 2 (Analysis of current EO capabilities relevant to the needs and assess capability gaps) will be published after approval by ESA on a dedicated website, hosted by EARSC.

The website will also have a navigable map similar to the corresponding website of the ESA project "EO geospatial products for the Oil & Gas Industry". However, this map will navigate from the identified business processes of the agro-insurance industry via corresponding challenges to currently available EO-products, that address these challenges (see Figure 1). Nonetheless, not all challenges could be linked to current EO capabilities.

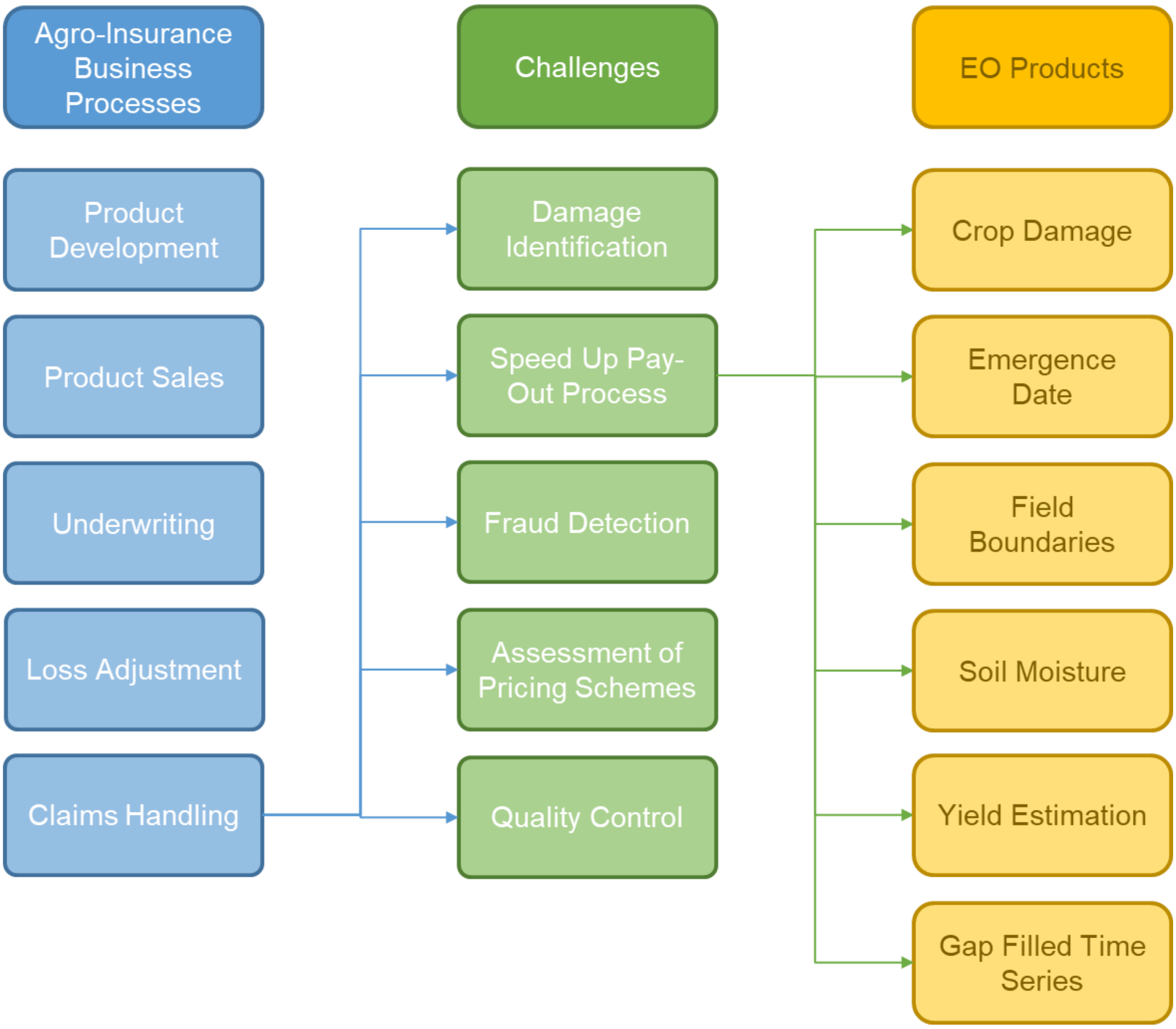


Figure 1: Navigation on EARSC-website

EO-products will also link back to the addressed challenges and business processes. For better readability this is not included in the figure. Clicking on a business process or a challenge will move the user to the next lower level with the product sheets as lowest and most detailed level. With a click onto a specific product, the website will open the corresponding product website where there will also be an opportunity to download the product specifications as PDF.

With this navigation, an interactive link between identified user-requirements and current EO-products will be established.

Both user-requirements and current EO-capabilities will also be available on the website as static reports (Deliverables D1.2 & D2.1). Missing links between user-requirements and current EO-products will be available as a Gap-Analysis Report (Deliverable D2.2). This will also include probable links from user-requirements to future EO-missions, capabilities and products.

Further details about EO-products uploaded onto the website can be found in chapter 4 "EO product portfolio"

Engaging EO-industry

A crucial part of this project is not only to identify user-requirements but also to disseminate them within the EO-industry. Therefore, all EARSC members will be informed about the establishment of the project website and the content. Furthermore, an online forum is available for any kind of discussion between users and providers.

3 High-level summary of the relevant EO satellites

3.1 Sentinel-1

Sentinel-1 is a high-resolution satellite carrying a C-band Synthetic Aperture Radar (SAR) instrument sensitive to the C-band spectrum (+- 5.405 GHz) (Torres et al., 2012). The mission consists of two polar-orbiting satellites: Sentinel-1A and Sentinel-1B. The satellites were launched as part of the Copernicus program with the main objective to monitor land and ocean surfaces. Moreover, the development of the mission was necessary to success older C-band SAR satellites like ERS-2 and ENVISAT so that a continuous SAR data provision is ensured. The all-weather capability of SAR allows to provide suitable earth surface information at every pass. Furthermore, the Sentinel-1 mission is of interest for both scientific and practical applications due to the long-term continuity of measurements for at least the coming 20 years, and its high spatial and temporal resolution. Moreover, Sentinel-1 is the first satellite which will provide high resolution and temporal earth information at no cost for a long time period.

Satellite specifications:

- Orbit: near-polar, sun-synchronous passing at 18:00 local solar time with 175 orbits per cycle.
- Launch date(s): Sentinel-1A: 03/04/2014 & Sentinel-1B: 25/04/2016
- Temporal resolution: 6 days (constellation). Higher latitudes more frequent coverage.
- Spatial resolution(s): <20 m azimuth and <5 m ground range resolution, actual resolution dependent on the image acquisition mode.
- (Primary) image acquisition mode(s): Interferometric wide swath mode is primary used over continental areas (IW), Stripmap mode (SM) is used to map small island or in emergence cases due to the off-nadir possibility. Both modes support single and dual polarization mapping (HH, VV, VH, HV).
- Sensor characteristics: C-band SAR sensor (+-5.405 GHz)
- Satellite products: Different acquisition modes are available in different levels of processing and resolutions. The most commonly used product for agricultural applications is the IW Level-1 Ground Range Detected (GRD) full resolution product, which provides ground projected imagery at a grid spacing of 10 x 10 m.
- Archive availability: Free data availability since 2015 until present. A product availability of 95% is achieved. Data is available commonly within less than 3 days after observation. Sentinel-1 data can be retrieved at different data access points:
    - Copernicus Open Access Hub
    - Google Earth Engine
    - SentinelHub
    - TerraScope
    - DIAS
- Data continuity: Data continuity of C-band SAR imagery was one of the main goals of the missions due to the retirement of ERS-2 and ENVISAT. The in-orbit Sentinel-1 satellites will have an expected lifetime of at least 10 years. Furthermore, successor of the current Sentinel-1 satellites are planned in the future (Sentinel-1C & Sentinel-1D) to provide data continuity.

Used sources:

R. Torres et al., "GMES Sentinel-1 mission," Remote Sens. Environ., vol. 120, pp. 9–24, 2012.

ESA website: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/

https://sentinel.esa.int/web/sentinel/missions/sentinel-1

3.2 Sentinel-2

The Sentinel-2 mission consists of a constellation of two optical satellites, called Sentinel-2A & Sentinel-2B. These satellites were launched as part of the Copernicus program with the aim to monitor variability in land surface conditions. The development of the Sentinel-2 mission was required to provide continuity for services relying on multi-spectral high-resolution optical imagery. In this way, it provides continuity of SPOT and Landsat satellite imagery data. The Sentinel-2 sensor consists of many high-resolution bands ranging from the visible, near infrared and shortwave infrared, which allows to analyse vegetation health and growth at unprecedented spatial level. Furthermore, the mission was developed to provide at least 15 years such high-resolution optical data, which makes it suitable for historical or long-term data analyses.

Satellite specifications:

- Orbit: sun-synchronous orbit with a 180° phased difference between both satellites, equatorial crossing at 10:30h local solar time.
- Launch date(s): Sentinel-2A: 23/06/2015 & Sentinel-2B: 07/03/2017
- Temporal resolution: 5 days (constellation) at the equator and even faster revisit at higher latitudes. Revisit time of 5 days is reached since February 2018.
- Spatial resolution(s): Between 10 and 60 m according the spectral band.
- Sensor characteristics: Multispectral instrument sensitive to 13 spectral bands ranging from the visible (4 bands) and the near infrared (5 bands) up to the short-wave infrared (4 bands) and 3 bands in the red edge part of the spectrum.
- Satellite products: Two different types of Sentinel-2 products are provided: Level-1C product and Level-2A product. In both product types data is provided in tiles of 100 x 100 km ortho-images in UTM/WGS84 projection. In the Level-1C, Top-Of-Atmosphere (TOA) reflectance are given while for the Level-2A an atmospheric correction was applied to obtain Bottom-Of-Atmosphere (BOA) reflectance.
- Archive availability: Availability of Sentinel-2 data since 2015 with in total 97% of the acquired observations are made available to the user. The latency of the Sentinel-2 data is mostly within 24 hours. The archive can be retrieved by different data access points:
    - Copernicus Open Access Hub
    - Google Earth Engine
    - SentinelHub
    - TerraScope
    - EarthExplorer
    - DIAS
- Data continuity: Sentinel-2 provides data continuity for the SPOT and Landsat satellite imagery data. The operational lifetime of the Sentinel-2 mission is foreseen at 15 years with

a nominal lifetime of 7.25 years of each satellite (Drusch et al.,2012). The Sentinel-2C and Sentinel-2D will be the successors of the current Sentinel-2 satellites

Used sources:

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2/Plant_health

https://sentinel.esa.int/web/sentinel/missions/sentinel-2/

M. Drusch et al., "Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services," Remote Sens. Environ., vol. 120, pp. 25–36, 2012.

3.3 Sentinel-3

The Sentinel-3 mission is an ocean and land mission, which consists at the moment of two satellites in orbit: Sentinel-3A & Sentinel-3B. The mission was designed to provide data continuity for the ERS, ENVISAT and SPOT satellite. Every Sentinel-3 satellite is composed of multiple sensing instruments to achieve different goals:

- SLSTR (Sea and Land Surface Temperature Radiometer)
- OLCI (Ocean and Land Colour Instrument)
- SRAL (SAR Altimeter)
- DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite)
- MWR (Microwave Radiometer).

These instruments make the satellite suitable to monitor and understand large-scale global dynamics. Furthermore, it can provide vegetation state information in near-real time. Especially, the first two instruments, which are optical will be of main interest for agricultural purposes. The OLCI instrument is a medium resolution spectrometer consisting of 21 spectral bands. This instrument is the successor of MERIS on-board the ENVISAT satellite. The instrument consists of an extremely sensitive and stable radiometry and is suitable for deriving information like phenology of terrestrial and ocean biomass. On the other hand, the SLSTR instrument is mainly designed to provide global surface temperature information and data continuity since it is the successor of the (A)ATSR series (available since 1991) on-board ENVISAT and ERS. The instrument is able to retrieve temperatures with zero bias and an uncertainty of +- 0.3 K. A spatial scanning procedure (two independent scans) allows to provide identical and contemporaneous coverage with the OLCI instrument. In this way, synergized products between the two instruments can be made. Furthermore, SLSTR products like land surface temperature and fire location can be of high importance for the agro-insurance sector.

Satellite specifications:

- **Orbit:** near-polar sun-synchronous orbit with equatorial crossing at the same time (10:00h local solar time).
- **Launch date(s):** Sentinel-3A: 16/02/2016 & Sentinel-3B: 25/04/2018
- **Sensor characteristics:**
    - OLCI: Medium resolution optical spectrometer with 21 spectral bands ranging from visible (VIS) until shortwave infrared (SWIR) between 400 to 1200 nm.
    - SLSTR: Temperature radiometer with 11 spectral bands ranging from the vegetation Near-infrared (NIR) (550-900 nm) until the thermal infrared (IR) (3700-12000 nm).

- **Temporal resolution**: The temporal resolution differs among the different instruments:
  - OLCI ocean colour instrument: <1.9 days (day only) at equator for two-satellite constellation, more frequent revisit time at higher latitudes.
  - OLCI land colour instrument: <1.1 days (day only) at equator for two-satellite constellation, more frequent revisit times at higher latitudes.
  - SLSTR instrument: <0.8 days at equator (day and night) for two-satellite constellation, more frequent revisit time at higher latitudes.
- **Spatial resolution:** The spatial resolution is dependent on the kind of spectral bands and the sensor instrument of interest:
  - OLCI: 500 m for the 21 spectral bands
  - SLSTR: 0.5 km for the spectral bands in the visible near infrared (VNIR) and SWIR and 1 km for the bands in the thermal IR.
- **Satellite products:** Different data products in two levels of processing (Level-1 & Level-2) for the Sentinel-3 instruments are provided. Furthermore, synergy products between OLCI and SLSTR are generated. Please consult the following link to obtain detailed information on the Sentinel-3 data products. For the agro-insurance sector, the NDVI product obtained from the synergy can be particularly useful, but also the land surface temperature information.
- **Archive availability:** All the Sentinel-3 data products are freely available to the user since the first mission observations. The provided data is of high accuracy and reliability and in total for more than 95% of the observations data is available. Furthermore, the satellite data can be made available in three levels of timeliness. In case of near real time (NRT) requirements, the data can be provided to the user within 3 hours after the acquisition. Secondly, for short time critical products data can be provided within 48 hours after acquisition. Finally, in the other cases data is provided within 1 month after acquisition. The Sentinel-3 data can be accessed and analysed at different **data access points**:
  - Copernicus Open Access Hub
  - SentinelHub (SLSR & OLCI)
  - Google Earth Engine (only Sentinel-3 OLCI)
  - DIAS
- **Data continuity:** The mission was developed to provide data continuity for the satellites ERS, ENVISAT and SPOT. The expected operational lifetime of the Sentinel-3 satellites will be 7.5 years. In the future two more Sentinel-3 satellites are planned to launch: Sentinel-3C and Sentinel-3D.

Used sources:

C.Donlon et al., "The Global Monitoring for Environment and Security (GMES) Sentinel-3 mission", Remote Sens. Envrion., vol.120, pp.37-57, 2012.

https://sentinels.copernicus.eu/web/sentinel/news/-/asset_publisher/xR9e/content/copernicus-sentinel-3-provides-added-capability-in-land-monitoring

https://sentinel.esa.int/web/sentinel/missions/sentinel-3/

3.4 Landsat

The Landsat missions provide the longest available archive of optical based satellite data. Since 1972 data on the earth surface was continuously provided by these missions. Currently, two satellites of the mission are active: Landsat 7 and Landsat 8. The Landsat 8 satellite has two instruments on-board: The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). In total these instruments can image the earth in 11 bands ranging from the VIS part up to the thermal IR part of the spectrum, including one high resolution panchromatic band. Whereas the Landsat 7 satellite consists of an Enhanced Thematic Mapper Plus (ETM+) instrument which has some similarities compared to the Landsat 8 satellite. Furthermore, the satellite flies in the same orbit but with an offset of half of the revisit time, which allows to upscale the temporal resolution by a factor 2. However, synergistic use of both sensors will require some additional processing steps. Landsat imagery can be particularly useful to track vegetation health information and crop development due to the medium resolution bands in the VIR and NIR spectrum.

Satellite specifications:

- Orbit: Sun-synchronous near-polar orbit with equatorial crossing at 10:00 AM solar time, offset of 8 days between Landsat 7 & Landsat 8.
- Launch date(s): Landsat 7: 15/04/1999 & Landsat 8: 11/02/2013
- Sensor characteristics:
  - Landsat 7: Enhanced Thematic Mapper plus (ETM+) is a multispectral radiometer with eight bands (one panchromatic) in the VIS (3 bands), NIR (2 bands), SWIR (2 bands) and long wave infrared (LWIR) (1 band).
  - Landsat 8: Equipped with two instruments (OLI and TIRS). OLI is able to map the earth in the VIS (4 bands), NIR (2 bands), SWIR (2 bands) spectrum and one panchromatic band. The TIRS sensor has two thermal bands in the thermal part.
- Temporal resolution: Global coverage every 16 days for each of the satellites. The combined use of both satellites can reduce the revisit time to 8 days.
- Spatial resolution(s):
  - Landsat 7: 7 spectral bands with resolution of 30 m, one panchromatic band of 15 m.
  - Landsat 8: 9 spectral bands of 30 m resolution with one panchromatic band of 15 m included. Two thermal bands of 100 m resolution.
- Satellite products: Two different kinds of satellite products (Level-1 & Level-2) depending on the level of processing. In the Level-1 products the data is radiometrically corrected and orthorectified (UTM projection) providing TOA reflectance, while Level-2 provides the BOA reflectance data.
- Archive availability: A long data archive of Landsat imagery is freely available with data since 1972. The data latency is usually less than one day. The Landsat data can be retrieved at different data access points:
  - Earth Explorer
  - GloVis (only Level-1)
  - LandsatLook (only Level-1)
  - ESPA (only Level-2)
  - SentinelHub

  - Google Earth Engine
  - CREODIAS
  - ONDA DIAS
- **Data continuity:** The Landsat missions are developed to guarantee data continuity of the former Landsat series. The lifetime of the Landsat satellites is quite long as the Landsat 7 satellite is already operational since 1999. In the future, Landsat 9 satellite will be launched to replace the Landsat 7 satellite.

Used sources:

D. P. Roy et al., "Remote Sensing of Environment Landsat-8: Science and product vision for terrestrial global change research," Remote Sens. Environ., vol. 145, pp. 154–172, 2014.

D. Scott, J.C. Storey, M.J. Choate., R.W. Hayes. "Four Years of Landsat-7 On-Orbit Geometric Calibration and Performance", IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, vol.42(12), pp.2786,2795, 2004.

https://landsat.gsfc.nasa.gov/the-enhanced-thematic-mapper-plus/

https://www.usgs.gov/land-resources/nli/landsat/landsat-7?qt-science_support_page_related_con=0#qt-science_support_page_related_con

https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con

3.5 Proba-V

Proba-V is an optical medium resolution satellite which was launched in 2013. The mission was mainly developed to allow daily or two to three-daily monitoring of vegetation at a global scale. In this way, this mission can further extend long datasets of vegetation imagery established by satellites like SPOT. Furthermore, the satellite was designed as preparation of the later planned Sentinel-3 satellite (see above). The satellite consists of 3 cameras each with a multispectral sensor of 4 bands in the VIS and the SWIR part of the spectrum. These specific bands make the satellite suitable for the detection of different land cover types and to obtain their health status. The satellite only image the land surface and specific calibration areas.

Satellite specifications:

- **Orbit:** Sun-synchronous near polar orbit with equatorial crossing at 10:30 AM.
- **Launch date(s):** 07/05/2013
- **Sensor characteristics:** Medium resolution multispectral camera of 4 bands ranging from the VIS (3 bands) up to the SWIR (1 band).
- **Temporal resolution:** Daily coverage above 35° latitude due to the very wide swath. At other latitudes at least three-daily coverage is provided.
- **Spatial resolution:** Spatial resolution of about 100 m for the three bands in the VIS spectrum and 200 m for the thermal band.
- **Satellite products:** Proba-V data is available in different levels (Level 1C, Level 2A & Level 3) of processing and resolutions. Data is made available in 100 m, 300 m and 1 km resolution.

The Level-1C data will provide the TOA reflectance data while the Level-2A BOA reflectance. The Level-3 product is a synthesis product providing TOA, top of canopy (TOC) reflectance and NDVI information. The data is all projected to WGS 84.

- **Archive availability:** Proba-V archive data (since 2013) is freely available to the user. However, for the 300 m and 100 m product are only made available to the user one month after the acquisition. NRT products are only commercial. The Proba-V data can be retrieved by following **data access points**:
    - PROBA-V MEP
    - Product distribution portal
    - Copernicus Global Land Service
    - Google Earth Engine
- **Data continuity:** Proba-V was developed to fill the gap between the former SPOT missions and the recently launched Sentinel-3 satellite to monitor vegetation at a high temporal scale. In 2020 Proba-V will go on retirement. Nevertheless, in 2020 CubeSats will be launched, which can complement and further expand the PROBA-V observations in the visible and thermal part of the spectrum.

Used sources:

https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/proba-v

https://eo.belspo.be/en/satellites-and-sensors/proba-v

http://proba-v.vgt.vito.be/en

https://earth.esa.int/web/sppa/mission-performance/esa-3rd-party-missions/proba-v

3.6 MODIS

MODIS (Moderate Resolution Imaging Spectroradiometer) is an imaging sensor on-board the Terra and Aqua satellites. Both satellites were launched by NASA in 1999 and 2002 for the Terra and Aqua satellite, respectively. The satellites are able to capture the earth in 36 spectral bands ranging from the VIS up to the MIR. The large swath of the satellite allows to map the entire earth within 1-2 days. Therefore, the satellite is suitable for monitoring the earth's biosphere.

Satellite specifications:

- **Orbit:** Sun-synchronous near-polar circular orbit with equatorial crossing of Terra and Aqua at 10:30 AM and 1:30 PM, respectively.
- **Launch date(s):** Terra satellite: 18/12/1999 & Aqua satellite: 02/05/2002
- **Sensor characteristics**: Moderate resolution imaging spectroradiometer of 36 spectral bands ranging from VIS up to SWIR.
- **Temporal resolution**: Global coverage within 1-2 days due to the wide swath.
- **Spatial resolution:** Bands 1-2: 250 m, bands 3-7: 500 m, bands 8-36: 1000 m.
- **Satellite products**: MODIS data is freely available since 2000 and can be accessed in different products with different levels of processing (Level-1A & Level-1B) and resolutions. The Level-1B product provides the calibrated radiances for the 36 bands. Level-1A provides reformatted

and packaged data from the raw data. The data is provided in 250, 500 and 1000 m resolution. Furthermore, 8 to 16 daily NDVI composites are generated.

- Archive availability: MODIS data is freely available since 2000 and almost 80% of the acquired data by MODIS is available within a few hours after acquisition and the remaining part within a few days. The data can be retrieved by following **data access points**:
  - LAADS DAAC
  - Google Earth Engine
  - Microsoft Azure
  - EarthExplorer
  - SentinelHub
- Data continuity: MODIS is operational since 2000 although the expected lifetime was only 6 years. Nevertheless, in 2011 a successor was launched in order to guarantee data continuity. This successor is the Visible Infrared Radiometer Suite (VIIRS). In comparison to MODIS the same spectral information is acquired, but with improved spatial resolution.

Used sources:

https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/modis-L0L1/

https://terra.nasa.gov/about/terra-instruments/modis

https://aqua.nasa.gov/modis

https://nsidc.org/nsidc-monthly-highlights/2017/08/modis-viirs-building-time-series).

3.7 NOAA-AVHRR

NOAA-AVHRR (National Oceanic and Atmospheric Administration Advanced Very High-Resolution Radiometer) is a broad-band sensor of which in total three different instruments were developed. The instruments are able to capture the earth in 4 to 6 spectral bands (VIS up to thermal) depending on the model. The AVHRR instruments are put on-board of different NOAA platforms. Each time at least two of these platforms carrying AVHRR instruments were operational. At the moment only the NOAA-18 and NOAA-19 are still providing suitable information coming from the AVHRR instrument. The AVHRR sensor is able to scan the entire earth surface twice a day (day and night). The main objective of this instrument is to provide radiance information for cloud investigation, snow and ice extent, surface temperatures, etc.

Characteristics of satellite:

- Orbit: Sun-synchronous orbit with different equatorial crossing among the active NOAA satellites.
- Launch date(s): NOAA-18: 20/05/2005 & NOAA-19: 06/02/2009.
- Sensor characteristics: Broad band sensor with spectral bands in the VIS (1 red band), NIR (1 band), mid infrared (MIR) (1 band) and thermal (3 bands) part of the electromagnetic spectrum. The MIR band is only available for the latest version of AVHRR instruments.

- **Temporal resolution:** The AVHRR instrument can cover the entire world twice a day (day and night). The 2-satellite constellation of NOAA satellites can even result in an image every 6 hours, resulting in 4 coverages a day.
- **Spatial resolution:** All the bands have a spatial resolution of about 1 km.
- **Satellite products:** Different data products are made available, but the most commonly used one are the weekly and biweekly NDVI composite at 1 km derived from the Level-1 pre-processed data.
- **Archive availability:** AVHRR data is made freely accessible to the user and provides continuous data since 1981. Preliminary products are available within 24 hours after sensing. The data can be retrieved by following **data access points**:
    - EarthExplorer
    - EOWEB
    - NCEI
    - Google Earth Engine
- **Data continuity:** Continuous replacement of AVHRR instruments to follow-up the retired ones. For the most recent NOAA (NOAA-20) launched in 2017, the AVHRR instrument is replaced by VIIRS due to better performances. Nevertheless, the AVHRR instrument is now put on the MetOP series of EUMETSAT and so will provide further data in the future.

Used sources:

https://wdc.dlr.de/sensors/avhrr/

https://www.avl.class.noaa.gov/release/data_available/avhrr/index.htm

https://gisgeography.com/avhrr-advanced-very-high-resolution-radiometer/

https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/noaa-avhrr

https://directory.eoportal.org/web/eoportal/satellite-missions/m/metop

https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.ncdc:C00680

3.8 SMOS

The SMOS satellite (Soil Moisture and Ocean Salinity satellite) of ESA is a satellite carrying an interferometric radiometer which operates in the L-band (1.4 GHz). The satellite was designed to make global observations of soil moisture over land and salinity measurements over oceans. Soil moisture can be provided every 3 days with an accuracy of about 4% and at a resolution of 50 km.

Satellite specifications:

- **Orbit:** Sun-synchronous circular polar orbit with equatorial crossing at 06:00 AM.
- **Launch date(s)**: 02/11/2009
- **Sensor characteristics**: Interferometric radiometer operating in the L-band spectrum (1.4 GHZ) with dual polarization measurement.
- **Temporal resolution**: 3-daily coverage at the equator.
- **Spatial resolution**: Soil moisture measurement at a spatial resolution of about 50 km.

- **Satellite products**: Different data products exist but only Level-1 (TOA) and Level-2 products are available to the user. The Level-2 products consist of a soil moisture and sea surface salinity product. These products contain already soil moisture or salinity in the suitable units. From this product other ancillary data like surface temperature is derived and included in the product. Furthermore, a Level-3 and 4 data product of soil moisture and sea salinity exists, which are improved data products to enhance the robustness and quality of soil moisture and salinity retrievals. For the Level-3 and Level-4 products nine-day averaged, monthly, seasonal and yearly maps are produced.
- **Archive availability**: SMOS data is archived since 2010 and is freely available for the user. For about 99% of the measurements the data is made available and within 8-12 hours after data acquisition. The NRT products of Level-1 and Level-2 data can provide satellite data within a few hours after sensing. However, the NRT data is not free of charge. The SMOS data can be accessed by following **data access points**:
    - SMOS Online Dissemination Service (Level-1, Level-2 & Level-3c sea ice thickness)
    - CATDS (Level-3 & Level-4 salinity and moisture)
    - SMOS CP34 (Level-3 & Level-4 salinity and moisture)
    - Google Earth Engine (Level-2 soil moisture)
- **Data continuity**: Continuous measurements of sea salinity and soil moisture since 2010 and despite the design life of 5 years it performs still well at present (2020). Currently, no information about a potential successor of SMOS is communicated. However, the SMAP (Soil Moisture Active Passive) satellite of NASA launched in 2015 can also map soil moisture although at lower temporal resolution (2-3 days) but higher spatial resolution (36 km).

Used sources:

https://www.esa.int/Applications/Observing_the_Earth/SMOS/Introducing_SMOS

https://earth.esa.int/web/eoportal/satellite-missions/s/smos

https://www.earth-syst-sci-data.net/9/293/2017/essd-9-293-2017.pdf

https://smap.jpl.nasa.gov/

3.9 Planet Labs

Planet Labs is a commercial satellite operator, which operates different satellite constellations: PlanetScope, RapidEye and SkySat. PlanetScope consists of multiple constellations of miniaturized Triple-CubeSats satellites, called Doves. In total more than 120 Cubesats are operational within the constellation since the first launch in 2014. In case of the RapidEye constellation about 5 of them are operational and they were all launched in 2008. Finally, the SkySat constellation consists of 15 operational satellites with the first one launched in 2013. All of the operated satellite constellations by Planet Labs can provide (very) high spatial and temporal resolution and are therefore useful for monitoring of the earth surface at high precision.

Satellite specifications:

- Orbit:
  - PlanetScope: Sun-synchronous orbit with equatorial crossing between 9:30 – 11:30 AM (local solar time) or International Space Station Orbit with variable equatorial crossing.
  - RapidEye: Sun-synchronous orbit with equatorial crossing at 11:00 AM
  - SkySat: Sun-synchronous orbit with equatorial crossing at 10:30 AM local time
- Launch date(s):
  - PlanetScope: 2014 - … (still launching new ones)
  - RapidEye: 29/08/2008
  - SkySat: 2013- … (still launching new ones)
- Sensor characteristics:
  - PlanetScope: 4 spectral bands of which 3 are the standard RGB wavelengths and one NIR band.
  - RapidEye: 5 spectral bands of which 3 are the standard RGB wavelengths, one band in the red edge and one in the NIR spectrum.
  - SkySat: 5 spectral bands of which 3 are the standard RGB wavelengths, one NIR band and one panchromatic band.
- Temporal resolution:
  - PlanetScope: Daily (constellation) revisit at nadir (since 2017) for the sun-synchronous orbiting cubes and variable revisit for the cubes in the International Space station orbit.
  - RapidEye: Daily revisit (off-nadir) and 5.5 days at nadir.
  - SkySat: Sub-daily for the constellation and 4-5 days for the individual satellite.
- Spatial resolution:
  - PlanetScope: 3 m resolution for the International Space Station orbit and about 3.7 m for the sun-synchronous orbit.
  - RapidEye: 6.5 m resolution at nadir.
  - SkySat: Sub-meter scale.
- Satellite products:
  - PlanetScope: PlanetScope data is provided to the user in two kind of products: Level-1B basic scene & Level-3B ortho scene. The first product provides scaled TOA radiance but without geometric correction or cartographic projection. The Level-3B

product is radiometrically, sensor and geometrically corrected and is projected into a cartographic projection. Both products are available in 3.7 m resolution.
  - RapidEye: Level-3A Ortho tile products are available for the user. In these products both Visual (natural colours) and Analytical (multispectral) data are available. The Level-3A product is radiometrically, sensor and geometrically corrected and projected to a cartographic projection at resolution of 6.5 m.
  - SkySat: The available SkySat products are the Level-2B SkySat Basic Scene Product, the Level-3B SkySat Orthoscene Product and the Level-3B SkySat OrthoCollect Product. The Level-2B is the raw data product and is available as analytic with the RGB and NIR band information and as panchromatic containing the panchromatic information. The SkySat Ortho Scene Product is radiometrically, sensor and geometrically corrected and is projected into a cartographic projection. Within this product different product types are available. The resolution for the multispectral data in these products is about 1 m and for the panchromatic data 0.72 or 0.86 m.
- Archive availability: Planet data can only be accessed after payment since Planet is a commercial operator. The PlanetScope data is available since 22-06-2016 until present, the RapidEye archive since 01-02-2009 until present and SkySat from 13-11-2013 until present. The data can be accessed by following **data access points**:
  - Planet Explorer
  - ESA site (free for scientific and application development, but limited number of products per project)
- Data continuity: For PlanetScope and SkySat new satellites will be launched in the future to ensure data continuity. On the other hand, for the RapidEye constellation no information about potential successors is given at the moment despite the satellite lifetime of 7 years.

Used sources:

https://www.planet.com/products/satellite-imagery/files/1610.06_Spec%20Sheet_Combined_Imagery_Product_Letter_ENGv1.pdf

https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/skysat

https://earth.esa.int/web/guest/data-access/view-data-product/-/article/planetscope-full-archive

https://earth.esa.int/web/guest/-/rapideye-products

https://earth.esa.int/web/guest/-/skysat-full-archive-and-new-tasking

3.10 DEIMOS-2

DEIMOS-2 is a very high-resolution satellite of the commercial operator Deimos Imaging, just like the earlier launched medium resolution satellite DEIMOS-1. The DEIMOS-2 satellite was launched in 2014 and can provide multispectral satellite images at sub metric scale. Besides the high spatial resolution, the off-nadir possibility of the satellite enables also a high temporal resolution. Furthermore, the satellite was designed in such a way it can provide fast access to very high-resolution imagery based on user request. Therefore, it can provide NRT pre-processed satellite images for a specific area of interest (off-nadir possibility) to the user.

Satellite specifications:

- **Orbit:** Sun-synchronous near-circular orbit with equatorial crossing at 10:30 local solar time.
- **Launch date(s)**: 19/06/2014
- **Sensor characteristics**: Imaging radiometer with one panchromatic band and 4 spectral bands of which 3 are the RGB spectral colours and one NIR band.
- **Temporal resolution**: 2-day average revisit time worldwide (off-nadir) and one-day at midlatitudes.
- **Spatial resolution**: 4 m resolution for the 4 spectral bands and 75 cm for the panchromatic band.
- **Satellite products**: Deimos-2 data is provided in different products and in two processing levels (Level-1B (native) & Level-1C (orthorectified)). The products include a pan-sharpened, panchromatic, multispectral, bundle (panchromatic + multispectral) and stereo pair product. The Level-1B product provides a calibrated and radiometrically corrected product which is not resampled. On the other hand, Level-1C contains a calibrated and radiometrically corrected product which is orthorectified. In this product the multispectral bands are available in 3 m resolution and the panchromatic one at 75 cm resolution.
- **Archive availability**: The full archive since the launch until present is available only after payment. Nevertheless, ESA offers the data for free for scientific research and application development via their site or on ONDA DIAS. However, these free data are limited to a certain number of products per project The Deimos-2 can be assessed by following **data access points**:
  - Deimos catalogue (not for free)
  - ONDA DIAS (free for scientific and application development)
  - ESA site (free for scientific and application development)
- **Data continuity:** The mission lifetime was expected at 7 years, with the goal to reach 10 years. However, at present no information about a successor in the future is yet announced.

Used sources:

http://elecnor-deimos.com/portfolio/deimos-2/

https://directory.eoportal.org/web/eoportal/satellite-missions/d/deimos-2

https://eo.belspo.be/nl/satellites-and-sensors/deimos-2

https://www.planetek.it/sites/default/files/DEIMOS-2_Imagery_User_Guide_v2.0_2015-08.pdf

3.11 Pléiades 1A/1B

Pléiades is a constellation consisting of two broad-swath satellites Pléiades 1A and Pléiades 1B flying in the same orbit as the SPOT 6/7 satellites but with a phase difference. The agility of the Pléiades satellites allows off-nadir possibility which can drastically reduce the revisit time. Furthermore, the satellites are able to map the earth surface at high spatial resolution and can dynamically change their acquisition program which makes them suitable for emergency mapping. The Pléiades satellites have also the ability to provide high resolution stereo imagery in one pass.

Satellite specifications:

- Orbit: Sun-synchronous orbit with equatorial crossing time at 10:30 local solar time with the two satellites of the constellation phased 180° apart.
- Launch date(s): Pléaides-1A: 17/12/2011 & Pléaides-1B: 02/12/2012.
- Sensor characteristics: Optical sensor with one panchromatic and 4 spectral bands of which 3 consist of the RGB wavelengths and one of the NIR band.
- Temporal resolution: Global coverage of 13 days for the constellation at a viewing angle of 5°. Off-nadir possibility increases revisit time to even four days global coverage for the constellation with a twice daily revisit capacity.
- Spatial resolution: Multispectral resolution of 2.8 m and panchromatic resolution of 0.7 m.
- Satellite products: Pléiades data is available in different product and at different processing levels. The product types consist of a panchromatic image at 0.5 m, pansharpened image at 0.5 m, multispectral image of the 4 bands at 2m and a bundle (0.5 m panchromatic + 2 m multispectral). There are three different processing levels: primary, ortho and tailored ortho. For the primary product the provided data is free of all radiometric distortions and is close to the natural image obtained by the sensor. The ortho product is georeferenced and corrected for acquisition and terrain off-nadir effects. The tailored ortho differs from the standard ortho by the possibility of using a custom ortho based on a 3D model.
- Archive availability: The full Pléiades archive is available to the user since April 2012 until present, but the data is not distributed for free. Nevertheless, ESA provides the Pléiades archive for free in case the data will be used for scientific research and applications development. However, this free data is limited to a certain number of products per project the satellite data is available in the archive within less than 6 hours after acquisition to allow emergency mapping. The Pléiades data can be retrieved by following data access points:
    - Airbus (Geostore ordering) after payment
    - Request by ESA for scientific research and applications development
    - EO CAT (after registration by ESA)
- Data continuity: The lifetime of the Pléiades was expected at 5 years, but they are still operational. In 2020 the Pléiades Neo will be launched as successor of the current Pléiades.

Used sources:

https://eos.com/pleiades-1/

https://earth.esa.int/web/eoportal/satellite-missions/content/-/article/pleiades

https://earth.esa.int/web/guest/-/pleiades_esa

3.12 SPOT 6/7

The SPOT 6/7 satellites joined the Pléiades constellations and were designed to continue the older SPOT missions (e.g. SPOT-5). The SPOT 6/7 are 180° degrees phased from each other. The agile SPOT satellites use weather forecast information in order to optimize the image tasking and so increase the number of cloud-free images. The satellites allow multiple tasking plans per day in order to meet user requests. In addition, the satellite data is automatically processed and immediately online delivered allowing rapid data provision in case of emergency.

Satellite specifications:

- Orbit: Sun-synchronous circular orbit with 180° phase difference between SPOT-6/SPOT-7.
- Launch date(s): SPOT-6: 09/09/2012 & SPOT-7: 30/06/2014.
- Sensor characteristics: Sensor consisting of one panchromatic and 4 spectral bands of which three are the standard RGB wavelengths and one NIR band.
- Temporal resolution: Global revisit time of one day for the constellation and between 1-3 days for each of the satellites.
- Spatial resolution: Panchromatic band: 1.5 m and multispectral bands: 6 m.
- Satellite products: SPOT data is available in different products and at different processing levels. The product types consist of a panchromatic image at 1.5 m, pansharpened image at 1.5 m, multispectral image of the 4 bands at 6m and a bundle (1.5 m panchromatic + 6m multispectral). There are three different processing levels: primary, ortho and tailored ortho (same processing as with Pléiades).
- Archive availability: SPOT satellite data is available from 2012 until present, but the data is not distributed for free. Nevertheless, ESA can provide these data for free for scientific research and applications development. However, this free data is limited to a certain number of products per project. Most of the data is accessible within 3 days in the data archive. The data can be retrieved by following data access points:
    - Request by ESA for scientific research and applications development (request is limited by a certain number of products)
    - Airbus (Geostore ordering) after payment
    - EO CAT (after registration by ESA)
- Data continuity: Expected data provision of SPOT-6/7 until 2023. SPOT-6/7 are the successors of earlier SPOT missions providing a long archive of SPOT satellite data with the first SPOT launched in 1986. Currently, no information on a successor of the SPOT-6/7 is announced.

Used sources:

https://directory.eoportal.org/web/eoportal/satellite-missions/s/spot-6-7

http://www.intelligence-airbusds.com/files/pmedia/public/r2928_9_int_012_spot6-7_en_low-2.pdf

https://eos.com/spot-6-and-7/

https://earth.esa.int/web/guest/data-access/browse-data-products/-/article/spot-6-and-7-archive-and-new

References:

R. Torres et al., “GMES Sentinel-1 mission,” Remote Sens. Environ., vol. 120, pp. 9–24, 2012.

M. Drusch et al., “Sentinel-2: ESA’s Optical High-Resolution Mission for GMES Operational Services,” Remote Sens. Environ., vol. 120, pp. 25–36, 2012.

C.Donlon et al., “The Global Monitoring for Environment and Security (GMES) Sentinel-3 mission”, Remote Sens. Envrion., vol.120, pp.37-57, 2012.

D. P. Roy et al., “Remote Sensing of Environment Landsat-8: Science and product vision for terrestrial global change research,” Remote Sens. Environ., vol. 145, pp. 154–172, 2014.

4 EO product portfolio

In chapter 3 "High-level summary of the relevant EO satellites", earth observation satellites relevant for developing products for the agro-insurance sector, have been listed in summary form.

As these satellites "only" deliver raw data (optical, radar) that basically doesn't provide value added information suitable for addressing agro-insurance challenges, this data is processed by service providers of the EO-industry. The following products derived from this data are state of the art and commercially available. They are structured as product sheets, containing this information:

Detailed description of the EO based products:

- Category: Corresponding business processes of the agro-insurance industry
- Description: Information about the product itself (use, content of the product, brief description of data processing, interdependencies to other products)
- Challenges / Use Cases: Information about probable use cases and challenges identified within the business processes of the agro-insurance sector.
- Input data sources: information about primary used data (e.g. Sentinel-2) and (secondary) additional data (e.g. meteorological data)
- Spatial Resolution and Coverage: Information about the size of a pixel that it represents in reality and the availability on local, regional and global level.
- Frequency / Timeliness: information about the temporal density or resolution of the data and the expected availability after a specific event.
- Delivery / Output Format: Information about standardised or not standardised data of the output data and specific available data formats.

All product sheets can be found in ANNEX: Product sheets containing these products:

- Biomass Production Estimation
- Crop Damage Zone Detection
- Crop Growth Zone Detection
- Crop Type Detection
- Date of Emergence
- Digital Elevation Model
- Drought Indicators
- Early Vegetation Stress
- Evapotranspiration
- Field Boundaries
- Gap Filled Time Series
- Grassland Mowing Cycle
- Greenhouse Early Warning
- Irrigation Mapping
- Monitor and Forecast Weather Events
- Near Real Time Service
- Soil Moisture

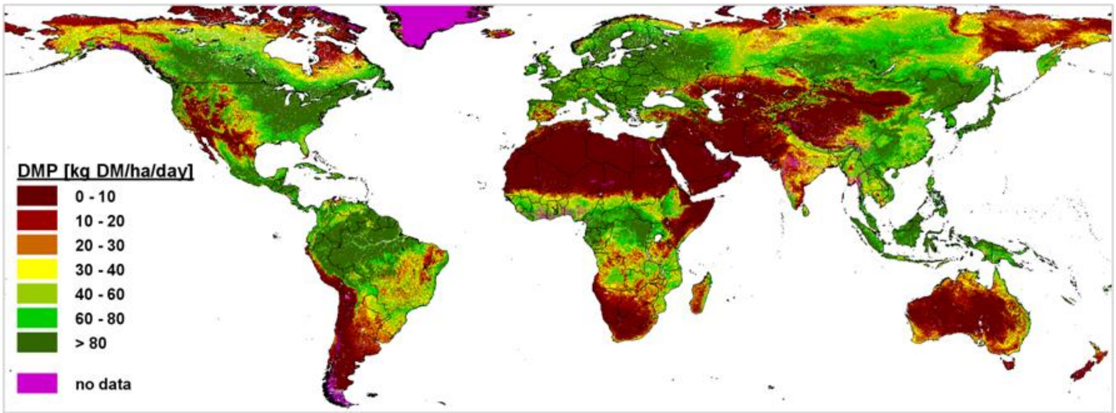
- Vegetation Growth Monitoring
- Vegetation Indices
- Water Bodies Detection
- Yield Estimation

5 Conclusion

This report provides a high-level overview of operational satellites and describes an earth observation product portfolio. Sentinel 2 can be considered as the satellite with the highest impact on agro-insurance applications, providing the temporal and spatial detail required to generate crop monitoring products at the parcel level. The technical readiness level of the earth observation products described in this report cover operational products (e.g. crop type mapping, field delineation, etc.) and products in development (e.g. crop growth zone detection). A gap analysis, matching the portfolio of EO products against the identified key geo-information requirements, will be performed in the next phase of the project.

ANNEX: Product sheets

BIOMASS PRODUCTION ESTIMATION



Vegetation Dry Matter Productivity (DMP) expressed in kg DM/ha/day (Source: VITO)

CATEGORY

☒ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

Monitoring biomass with Earth observation data is done with two different approaches: estimating the amount of actual standing biomass or providing indicators on biomass production. In this product sheet we focus on the second as it is the most matured, operationally available and most relevant for agro-insurance applications.

Biomass production is defined here as the increase in biomass, dry matter or carbon over time over a certain area. It is typically expressed as gram carbon per square meter per day (g C/m2/day) or kilogram dry matter per hectare per day (kg DM/ha/day) for agronomic purposes. When aggregated over time, these products give an indication of the seasonal increase in biomass, which could be related to pasture availability, crop yields or increase in timber in forestry.

PRODUCT SPECIFICATIONS

Main processing steps	The products derived from satellites are generated by modelling primary production of plants by combining vegetation indices with meteorological information such as incoming radiation, temperature. Operational examples are the MODIS Gross Primary Production (GPP)/Net Primary Production (NPP) product and the Copernicus Global Land Service Dry Matter Production (DMP), focused on agriculture monitoring. These operational products are based on medium resolution satellite imagery and provide >10 years of information at 250m-1km resolution. Using Sentinel-2, biomass production indicators could be derived at 10m resolution at +- 5-10 days timestep.
Input data sources	Optical: Operational services available on Proba-V, Sentinel-3 and MODIS. Case studies on Sentinel-2 Radar: n.a. Supporting data: meteorological data (temperature, incoming radiation, vapor pressure)
Spatial resolution and coverage	Spatial resolution: 300m – 1 km Coverage: global Availability: Global medium resolution products at weekly to 10-day timestep are operationally available
Accuracy / constraints	Thematic accuracy: indication for biomass production

	Spatial accuracy: depends on input optical data and meteorological data grid resolution
Limitations	Gross Primary Production (GPP) data is often well calibrated and validated with in-situ measurements. GPP however only represents the potential biomass uptake and is not directly related to the availability of natural resources. Net Primary Production (NPP) or Aboveground biomass production (ABP) can be related more directly with crop yields, accumulation in forest biomass or pasture availability. Limited in-situ data is however available to develop these products hence a quality assessment is advised for the use of these products at local scale.
Frequency / timeliness	Frequency: 10 days Timeliness: <3 days after retrieval
Delivery / output format	Data type: Integer File format: NetCDF
Accessibility	Operational products over Europe are available at medium resolution grids (250m – 1km). Copernicus Global Land Service Dry Matter Production (DMP) & MODIS Gross Primary Production (GPP)/Net Primary Production (NPP) Dedicated products on high resolution (e.g. Sentinel-2) could be developed by service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analysis
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Elaboration of livestock profile: Cows, sheep, pigs, poultry
- Information on forest health and production at different temporal scales (real-time monitoring historical development)
- Identification of specific stresses and vegetation problems and their underlying causes

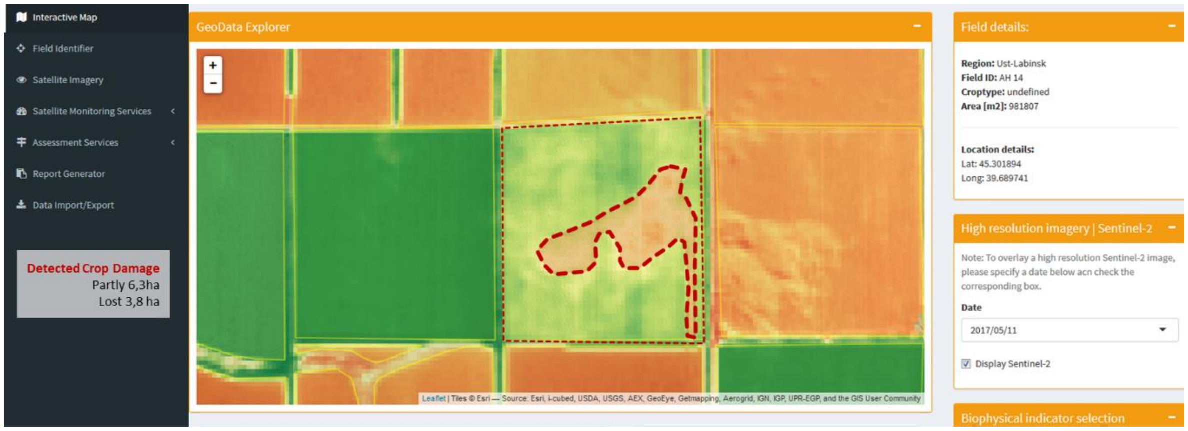
Underwriting:

- Seasonal portfolio mapping
- Risk / crop zoning

Loss Adjustment:

- Risk mapping against crop's vegetation stages
- Pasture biomass data

CROP DAMAGE ZONES DETECTION



Crop Damage Assessment Tool (Source: GeoVille)

CATEGORY

☒ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

On the one hand crop production is affected by a number of abiotic factors including soil type, its acidity and salinity, thermal and precipitation effects, application of various agricultural inputs as they affect all metabolic activities of the plant. One the other hand, crop production can also be affected by various weather events such as storm, flood, hail, drought, frost, etc.

This service will provide a mechanism for verifying crop damages through EO data at field scale and significantly contribute to efficient underwriting, loss adjustment and further claims handling. Crop damage zones details provided by the EO brings more efficiency and precision, especially for underwriting and loss adjustment purposes. Underwriters may prioritize the areas and allocation of human resources while loss adjusters may save time on crop survey and make more precise estimations of actual damage occurred at a given field.

PRODUCT SPECIFICATIONS

Main processing steps	The methodology is based on the use of time series of vegetation indices (e.g. FAPAR – Fraction of Absorbed Photosynthetically Active Radiation, NDVI – Normalized Differenced Vegetation Index or LAI – Leaf Area Index). Changes and anomalies within a defined area and over a period of time are then analysed to identify the zones where a damage has occurred using statistical thresholding.
Input data sources	Optical: Sentinel-2, VHR depending on availability (e.g., Planet, Pleiades, Worldview 3&4, RapidEye, SPOT 6&7) Radar: Sentinel-1 Supporting data: Meteorological data (temperature, precipitation, wind, hail), field parcel information such as LPIS
Spatial resolution and coverage	Spatial resolution: HR solution - 10m; VHR and HHR solutions (on demand) - 0,3 – 5m Coverage: Field Level (micro) Availability: globally available
Accuracy / constraints	Thematic accuracy: 85 % Spatial accuracy: 1,5 -2 pixel of input data

Limitations	To identify a reason of damage and to disentangle insured damages from mismanagement practices, additional weather data is needed to identify reason of crop damage.
Frequency / timeliness	Frequency: various time steps starting from daily observations Timeliness: near real-time for early damage detection
Delivery / output format	Data type: Vector; Raster; API (depending on customer needs) File format: GeoTIFF, shapefile, others on request (depending on customer needs)
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED

Product Development

- Index insurance: Risk / Crop modelling (correlation of EO data with in-situ data)
- Index insurance: Relation between weather and impact on crop productivity
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Parcel/Field and regional yield statistics
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Identification of specific stresses and vegetation problems and their underlying causes
- High accuracy of crop-specific yield for smaller crop parcels
- Radar data (eliminated cloud cover effects)

Underwriting

- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison)
- Risk / crop zoning
- Actual crop health (vegetation)
- Procure better reinsurance terms/capacity from better insurance practice
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and crop practices
- Regular assessment of risk pricing and product rating

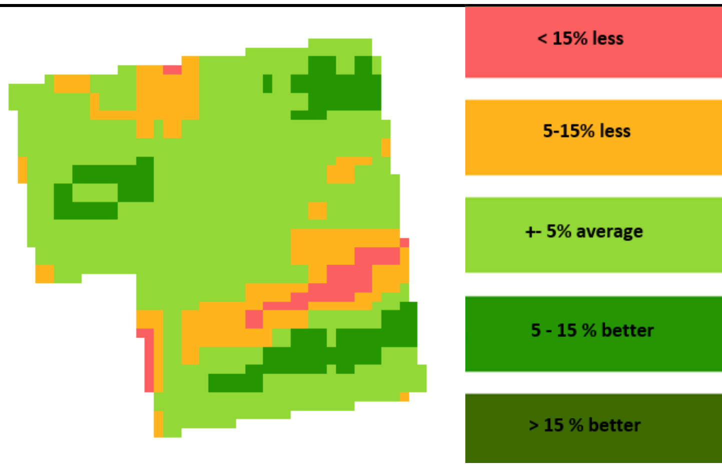
Loss Adjustment

- Workforce allocation and planning
- High accuracy of crop-specific yield for smaller crop / land parcels
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims Handling

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value))
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

CROP GROWTH ZONE DETECTION



Historical crop growth zone detection based on 5 years of Sentinel-2 data for a parcel in Belgium (Source: VITO, watchitgrow.be)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

A crop parcel is mostly uniformly treated by farmers and local weather conditions. Many fields however show a spatial variability in crop performance in the course of the growing season. Such variability is caused by a variety of natural and technology factors.

Where a multiyear recurrent variability is caused by differences in soil types, topography, weather micro-zones, crop growing technologies applied by the farmer, level of precipitation and irrigation access, while more abrupt and unexpected field variability could be caused by extreme weather events (e.g.: hail, storm, flood, drought, etc.).

Availability of crop growth zones is important for all stages of insurance product cycle, while the highest importance of such information is for agricultural underwriting and loss adjustment.

PRODUCT SPECIFICATIONS

Main processing steps	Satellite information derived from Sentinel-2 can support the evaluation of historical natural field variability as compared to the near real time detection of less/better performing zones within crop parcels.
Input data sources	Optical: Sentinel-2 Radar: n.a. Supporting data: for development: field yield samples
Spatial resolution and coverage	Spatial resolution: 10 m Coverage: crop parcel Availability: On demand
Accuracy / constraints	Thematic accuracy: The maps do not represent a physical quantity hence only a qualitative assessment is possible, e.g. by relating the maps with intra-field yield variability, detailed soil maps or crop damage maps. It is advised to perform an assessment with the service provider on a study area to evaluate the quality of the maps for a specific usage and region. Spatial accuracy: See Thematic accuracy.

Limitations	Challenging to detect the underlying processes of the intra-field variability: e.g. soil, agricultural management, crop damage. Ancillary information on weather conditions and crop type are required to interpret the detected crop growth zones.
Frequency / timeliness	Frequency: static maps or updated regularly (+- weekly) Timeliness: historical data or < 2 weeks
Delivery / output format	Data type: raster, vector File format: GeoTIFF, Shapefile
Accessibility	Available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather and impact on crop productivity
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables
- Information on forest health and production at different temporal scales (realtime monitoring, historical development)
- Radar data (eliminated cloud cover effects)
- Risk exposure (product design and customer communication)

Product Sales

- Client Outreach
- Pre-contractual Consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (vegetation stress, field boundary changes, comparison)
- Risk / crop zoning
- Actual crop health (vegetation)
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

Loss Adjustment:

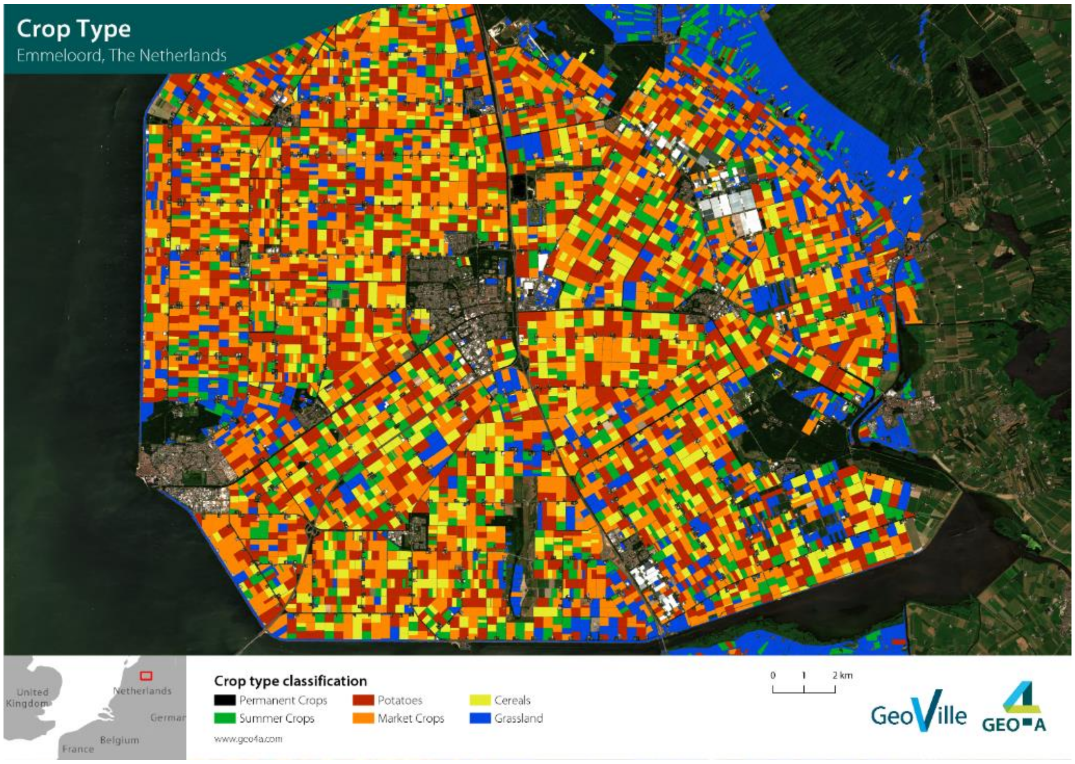
- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level

- Distinct field heterogeneity with crop damage

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value))
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

CROP TYPE DETECTION



Crop types in a selected area of interest (Emmeloord, The Netherlands) (Source: GeoVille/Geo4A)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

The crop type detection service provides information on types and location of crops grown with different levels of detail. Besides summer and winter crops, various types such as potatoes, maize, cereals, and others field crops can be detected using Earth observation techniques.

The classification of crop types is performed by using spectral information and temporal information about crop development. With this information it is possible to separate accurately different crop classes over large areas. To identify the different crop types a long and consistent time series of satellite imagery is needed. Taking a close look on the fields over a growing season is important as the differences between the crops become apparent based on their phenological development over the season. The later in the season, the more accurate the identification of crops gets, as there is more information available and the vegetation differences are more clearly recognisable.

Optical as well as radar satellites are used for this service. Radar imagery such as Sentinel-1 provide information on structural properties of crops and therefore optimise the results. Furthermore, the limitation of optical data due to cloud coverage can be overcome using radar data. Different levels of detail are possible: analysis may be performed on pixel or parcel level; also, generic grouped classes as well as specific crop types are feasible.

The service is applied within a specified area of interest. Analysis is possible in different regions with some region-specific adjustments. To distinguish the different crop types more accurately, training data from regions and within the season is needed.

PRODUCT SPECIFICATIONS	
Main processing steps	Satellite Data -> Pan-sharpening / resolution merge -> Indices calculation -> Statistics Calculation -> machine learning algorithms
Input data sources	Optical: Sentinel-2, Landsat-7, Landsat-8, or commercial VHR / HHR satellite data Radar: Sentinel-1 Supporting data: Field parcel delineation; in-situ crop type information such as LPIS
Spatial resolution and coverage	Spatial resolution: 10m Coverage: Regional/national level Availability: Globally available
Accuracy / constraints	Thematic accuracy: variable, >90% for major crops and crop groupings (end of season) Spatial accuracy: 1.5 - 2 pixels of input data
Limitations	Machine learning datasets are highly dependent on their input datasets. The crop type classification can be improved with available in-situ data.
Frequency / timeliness	Frequency: various time steps Timeliness: from the beginning of the respective growing season
Delivery / output format	Data type: GIS-ready data formats; Raster; API (depending on customer needs) File format: GeoTIFF
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development

- Market analysis
- Index insurance: Risk / Crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Parcel/Field and regional yield statistics
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Information on crop rotation
- Information on crop (seasonal) calendar
- High accuracy of crop-specific yield for smaller crop parcels
- Risk exposure (product design and customer communication)
- Radar data (eliminated cloud over effects)

Product Sales:

- Client Outreach
- Pre-contractual Consulting (show-case risk exposure)
- Farm Structure / Management Practice (linking to Cadaster)
- Regular market penetration review

Underwriting

- Seasonal portfolio mapping
- Online platforms or easy-to-use interfaces integrating various data sources (vegetation stress, field boundary changes, comparison)
- Risk / crop zoning

- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Identification of productive units
- Identification of crops grown
- Information of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and crop practices
- Regular assessment of risk pricing and product rating

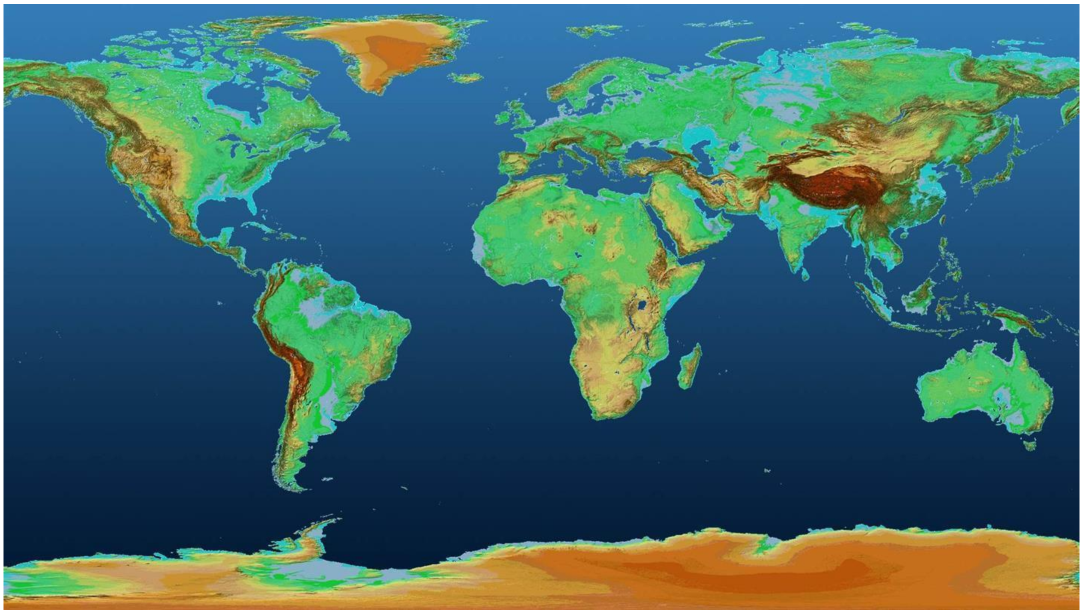
Loss Adjustment

- Workforce allocation and planning
- High accuracy of crop-specific yield for smaller crop / land parcels
- Regularly updated consistent long time series of reliable data for index insurance
- Benchmark physical field observations against yield loss detection (e.g. product calibration
- Risk mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualizations to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims Handling

- Identification of actual damage size (tones (volume) / ha (area) / price (yield value)
- Quality control assessment of claims before pay-out
- Fraud detection

DIGITAL ELEVATION MODEL (DEM)



Global TanDEM-X Elevation Model (Source: DLR)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

Different ways are currently established to model elevation: The Digital Elevation Model (DEM), the Digital Surface Model (DSM) and the Digital Terrain Model (DTM). Digital Terrain Models capture the ground and picture the bare Earth's surface as its reference; whereas, Digital Surface Models take into account natural and built surface features such as buildings and trees. Often, these terms are interchangeable; the term DEM is also widely used as a generic definition to describe DSM and DTM.

Currently, various data sets are globally available such as the TanDEM-X, SRTM DEM, ASTER GDEM and the ALOS World 3D. Most of them can be obtained at different resolutions.

PRODUCT SPECIFICATIONS

Main processing steps	Two methods are used to derive these types of elevation models. Some models are based on radar data, using InSAR Interferometric synthetic aperture radar data. For these models, two radar images from different sensors that are captured at the same time are used and combined. For models based on optical data, also two optical images from different angles are combined using Ground Control Points to locate the model.
Input data sources	Optical: ASTER, SPOT, Pléiades Radar: TanDEM-X, SRTM Supporting data: topographic maps, optical images, etc.
Spatial resolution and coverage	Spatial resolution: 1m – 1km Coverage: global Availability: globally available
Accuracy / constraints	Thematic accuracy: n.a.

	Spatial accuracy: Copernicus DEM: horizontal and vertical accuracy ranges between max. 6 m
Limitations	In densely vegetated areas it is not possible to capture the ground and picture the bare Earth's surface. For processing with optical satellite imagery, two good quality images from different directions are needed. Cloud cover and shadows are sometimes a limiting factor as well.
Frequency / timeliness	Frequency: depending on satellite revisit rate Timeliness: within a few days
Delivery / output format	Data type: raster formats File format: GeoTIFF
Accessibility	Usually, models with a coarser resolution are freely available, others must be purchased commercially. As an example, the Copernicus DEM 90 m dataset with global coverage is freely available, the global 30 m dataset as well as the 10 m dataset covering the European area have a restricted access. Also, the ASTER GDEM is available for free at resolution of 30 m.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market Analysis
- Information on forest health and production at different temporal scales (realtime monitoring, historical development)
- Forestry: Infrastructure & Management
- Risk exposure (product design and customer communication)

Product Sales:

- Client Outreach
- Farm Structure / Management Practice (linking to Cadaster)
- Regular market penetration review

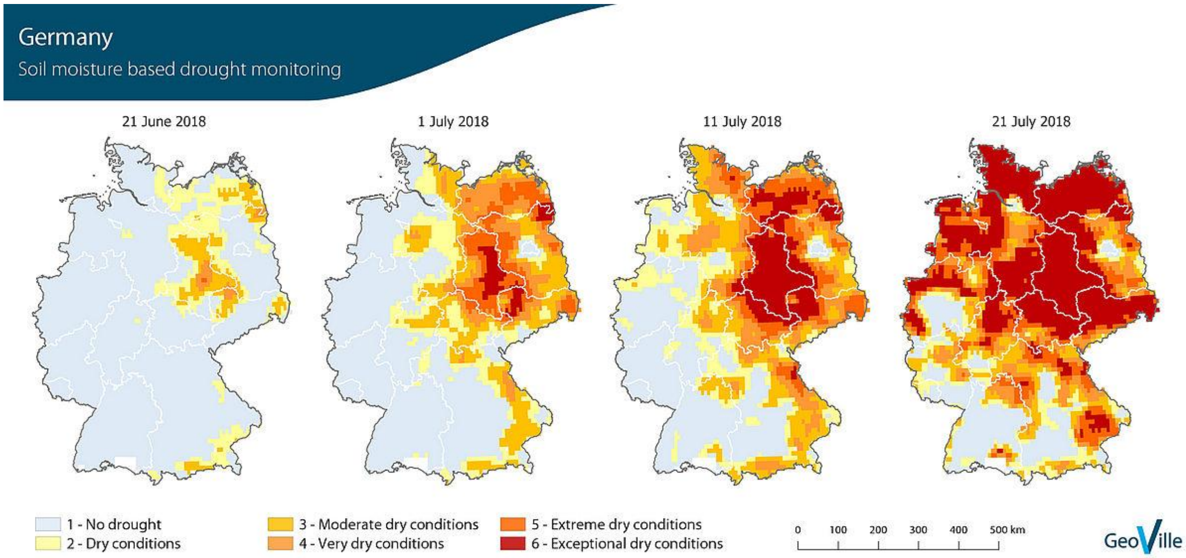
Underwriting:

- Seasonal portfolio monitoring
- Risk / crop zoning

Loss Adjustment:

- Workforce allocation and planning
- High accuracy of crop-specific yield for smaller crop / land parcels
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk mapping against crop's vegetation stages

DROUGHT INDICATORS



Soil moisture-based drought monitoring, June–July 2018, Germany (Source: GeoVille)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Droughts are prolonged periods of time when an area or region receives shortages in the water supply, whether atmospheric (below-average precipitation), surface water or ground water.

In most cases drought is referred as a large-scale (systemic) risk, as it covers larger production areas affecting all farms and crops in the region. Although the early effects of droughts are hard to identify, the longer a drought persists the greater are the effects for crops, if they are irrigated or not.

Drought indicators are variables or parameters used to describe drought conditions. Examples include precipitation, temperature, streamflow, groundwater and reservoir levels, and soil moisture.

Drought indices are typically computed numerical representations of drought severity, assessed using climatic or hydrometeorological inputs including the indicators listed above. They aim to measure the qualitative state of droughts on the landscape for a given time period. Indices are technically indicators as well.

EO data correlation with the actual drought conditions for specific crops represents the major challenge for the industry. Different crop types (and their varieties) may react differently to drought effects, showing different yield capacity decrease, which requires additional calibration of drought datasets and parameters interpretation by algorithms for the needs of a specific crop (insurance) needs.

PRODUCT SPECIFICATIONS

Main processing steps	Drought indices are amongst others based on long time series of rainfall, soil moisture and vegetation data. Anomalies compared to the long-term average highlighting areas under drought conditions.
Input data sources	Optical: Sentinel-2, Landsat-8, MODIS, Geostationary satellites (IR/visible) Radar: MetOp ASCAT, SMAP, TRMM, SSM/I Supporting data: in-situ information of drought parameters
Spatial resolution and coverage	Spatial resolution: 10 m – 25 km Coverage: National/regional/local level

	Availability: globally available
Accuracy / constraints	Thematic accuracy: depending on observed variable. Spatial accuracy: depending on observed variable.
Limitations	Depending on the drought indicator/index the limitations vary. A good overview on nearly 50 indicators/indices is provided in this WMO publication: https://www.droughtmanagement.info/literature/GWP_Handbook_of_Drought_Indicators_and_Indices_2016.pdf
Frequency / timeliness	Frequency: daily and more at regular intervals Timeliness: near real-time
Delivery / output format	Data type: Raster formats File format: GeoTIFF, NetCDF
Accessibility	Commercially available on demand from EO service providers. Publicly available data can be obtained through the Copernicus European Drought Observatory (https://www.copernicus.eu/en/european-drought-observatory).

CHALLENGES ADDRESSED – USE CASE(S)

Product Development

Index insurance:

- Index insurance: Toolbox for indices
- Index insurance: Risk / Crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather events and impact on crop productivity
- Identification of specific stresses and vegetation problems and their underlying causes
- Risk exposure (product design and customer communication)

Product Sales:

- Pre-contractual Consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Risk / crop zoning
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Regular assessment of risk pricing and product rating

Loss Adjustment

- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualizations to support loss adjustment communication to farmer)

Claims Handling

- Quality control assessment of claims before pay-out
- Fraud detection
- Timely, reliable and consistent data to speed-up the indemnity pay-outs

EARLY VEGETATION STRESS

Performance of crop fields (Source: GeoVille)

CATEGORY

☐ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

This service provides information on vegetation stress based on long time series of optical satellite data. Information on a long-time scale and range of spatial scales can be derived. Vegetation trend observation can be a helpful tool of where to focus further investigations, potentially as the basis for possible interventions.

Vegetation stress is derived based on different methodologies. Most of them use vegetation indices such as the Normalized Differenced Vegetation Index (NDVI), Leaf Area Index (LAI) or Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).

A long and consistent time series of satellite data is required to separate short term from long term vegetation stress. Additional data such as meteorological data is furthermore needed to distinguish between weather-induced short-term changes and long-term stress caused by other factors (e.g.: farm management, inputs application, soil specifics, etc.)

PRODUCT SPECIFICATIONS

Main processing steps	Processing is based on long and consistent time series of vegetation indices.
Input data sources	Optical: Sentinel-2 Radar: Sentinel-1 Supporting data: meteorological data
Spatial resolution and coverage	Spatial resolution: 10 – 300 m Coverage: National/regional/local level Availability: globally available
Accuracy / constraints	Thematic accuracy: > 85 %, depending on in-situ data availability Spatial accuracy: 1.5 - 2 pixels of input data

Limitations	To disentangle actual stress from normal but e.g. delayed vegetation growth or mismanagement requires not only long time series but also information about natural conditions such as rainfall deficits.
Frequency / timeliness	Frequency: depending on satellite revisit rates Timeliness: near real-time
Delivery / output format	Data type: Raster formats, vector formats File format: GeoTIFF, shapefile
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

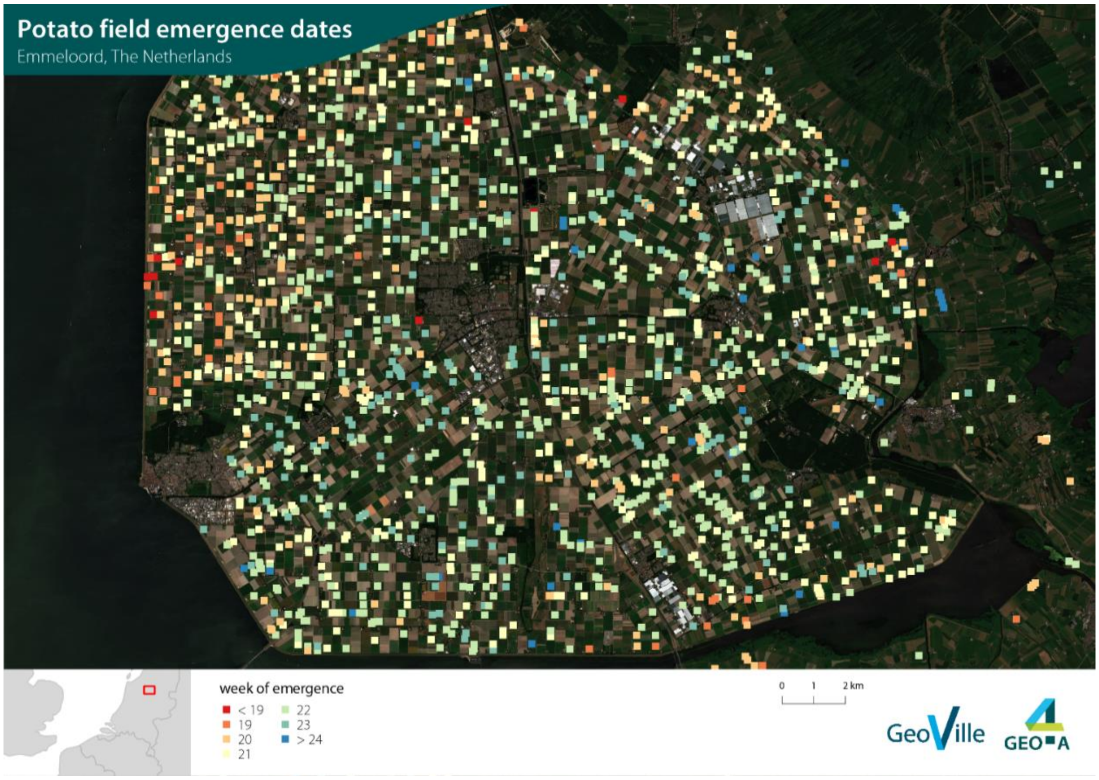
Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Actual crop health (vegetation)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Weather forecast tool

Loss Adjustment:

- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

DATE OF EMERGENCE



Week of emergence for potato crops (Source: GeoVille)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

The date of emergence of plants is important to determine the vegetation period and in understanding of the crop's development. This service provides information on the emergence of a specified crop type, indicating in which week the plants emerge above the ground on a certain field.

Date of emergence provides underwriters with a monitoring tool for the portfolio to observe possible losses due to insured/non-insured risks (e.g. wrong sowing dates, improper inputs/technology application, etc.). Early or late planting dates may be rated higher (e.g. +10-20%).

While assessing the damage, the information on crop's emergence may assist the surveyor in determining the actual vegetation stage at time of risk event. This will assist in better precision for assessment of the actual loss.

Furthermore, the data serves as input for other services such as crop growth monitoring and crop growth models.

PRODUCT SPECIFICATIONS

Main processing steps	The product is based on the processing of multi-spectral optical and radar satellite imagery. Consistent time series over the starting of the vegetation period is essential. The comparison of different time steps allows to differentiate between agricultural fields with emerged crop from other land cover such as bare soil. The identification of the week of emergence is based on the analysis of vegetation indices such as the NDVI or LAI.
Input data sources	Optical: Sentinel-2, Landsat 8 Radar: Sentinel-1

	Supporting data: meteorological data, field boundaries
Spatial resolution and coverage	Spatial resolution: 10 m Coverage: Local/Regional level Availability: globally available
Accuracy / constraints	Thematic accuracy: > 85 % depending on in-situ availability Spatial accuracy: field level
Limitations	Emergence date can only be confirmed if a sufficient amount of satellite observations is available. Optical data can be limited by cloud coverage, thus a hybrid approach using also radar data as well as additional modelling supports the timely detection.
Frequency / timeliness	Frequency: various time steps Timeliness: around six weeks after start of growing season
Delivery / output format	Data type: GIS-ready data formats; Vector; Raster; API (depending on customer needs) File format: GeoTIFF; Shapefile (depending on customer needs)
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Index insurance: Toolbox for indices
- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather and impact on crop productivity
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Information on crop (seasonal) calendar
- High accuracy of crop-specific yield for smaller crop parcels
- Radar data (eliminated cloud cover effects)
- Risk exposure (product design and customer communication)

Product Sales:

- Client outreach
- High accuracy of crop-specific yield for smaller crop parcels (penetration)
- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

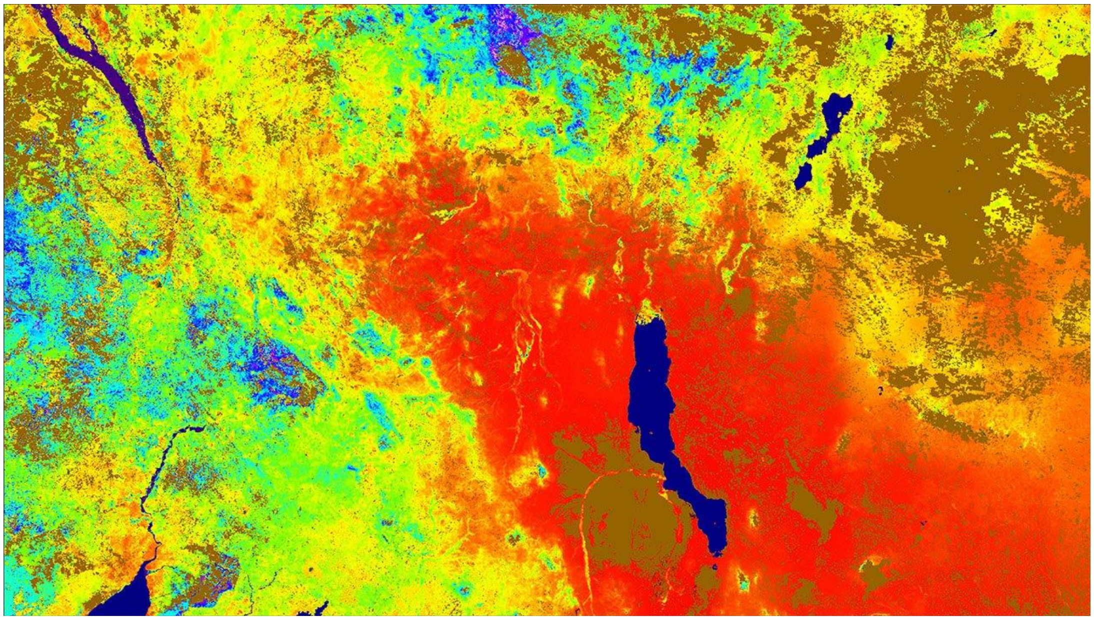
- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Actual crop health (vegetation)
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and crop practices

- Regular assessment of risk pricing and product rating

Loss Adjustment:

- Workforce allocation and planning
- High accuracy of crop-specific yield for smaller crop / land parcels
- Regularly updated consistent long time series of reliable data for index insurance
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

EVAPOTRANSPIRATION



Terra MODIS evapotranspiration (ET) data from the MOD16A2 product over east Africa from August 13 - 20, 2018 (Source: USGS)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Evapotranspiration quantifies the amount of water used in the plant production process. EO products show the terrestrial evapotranspiration from earth land surface that can be used to assess regional water and energy balance as well as the soil water status. Evapotranspiration is the sum of soil evaporation, canopy transpiration and interception. The sum of these three parameters quantifies the amount of water consumed by agricultural use.

PRODUCT SPECIFICATIONS

Main processing steps	Information on evapotranspiration uses Earth observation satellite data combined with several other data and indicators. Derived information is based on indicators such as soil moisture information and several vegetation indices such as the Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Fraction of Vegetation Cover (FVC). Also, meteorological data and indicators are used such as solar radiation, air temperature, vapour pressure, wind speed and precipitation. These data are combined and modelled to derive actual and potential evapotranspiration.
Input data sources	Optical: MODIS, Meteosat Radar: n.a. Supporting data: meteorological data
Spatial resolution and coverage	Spatial resolution: 250 m – 1 km Coverage: global Availability: globally available

Accuracy / constraints	Product accuracy has been estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program effort. The pixel level quality control layer (ET_QC_500m) is a copy of the quality control data layer of the corresponding input LAI/FPAR (MOD15A2H) granule of the same 8-day composite period and does not reflect the quality of the retrieved evapotranspiration. The current operational process does not generate pixel level science quality information. Users are advised to exercise caution while using the product in their application. https://lpdaac.usgs.gov/products/mod16a2v006/
Limitations	A large number of physical factors are involved in soil surface evaporation and plant transpiration processes, including microclimate, plant biophysics for site specific species and landscape heterogeneity, making accurate assessment of ET a challenge.
Frequency / timeliness	Frequency: daily Timeliness: near real-time
Delivery / output format	Data type: raster File format: GeoTIFF
Accessibility	Products derived from MODIS satellite data are freely accessible (https://lpdaac.usgs.gov/products/mod16a2v006/). Data for Africa can be accessed through an FAO data portal (https://wapor.apps.fao.org/catalog/WAPOR_2/1).

CHALLENGES ADDRESSED

Product development:

- Index insurance: Toolbox for indices
- Index insurance: Relation between weather events and impact on crop productivity
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Platform for crop health products
- Information on crop rotation
- Risk exposure (product design and customer communication)

Product Sales:

- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Actual crop health (vegetation)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Identification of productive units
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and crop practices

Loss Adjustment:

- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk mapping against crop's vegetation stages

- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims handling:

- Quality control assessment of claims before pay-out

FIELD BOUNDARIES

Field parcels detected in Emmeloord, The Netherlands (Source: GeoVille)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Information on field boundaries is highly important, especially in data sparse regions such as emerging markets. This service identifies agricultural field parcels within a selected area of interest. The detection of field parcels is based on their distinct management histories.

Furthermore, this data can be used as input for other satellite-derived information such as crop type detection, growth monitoring or crop health and more accurate assessment of the area and parts of fields damaged.

PRODUCT SPECIFICATIONS

Main processing steps	Analysis is based on satellite imagery using time-series and growing patterns to delineate the individual field parcels. Image segmentation is performed based on vegetation indices (such as NDVI) to detect differences between neighbouring fields. To ensure better accuracy, the segmentation sensitivity and time-frame selection can be adapted to account for regional differences.
Input data sources	Optical: Sentinel-2, VHR Radar: Sentinel-1 Supporting data: n.a.
Spatial resolution and coverage	Spatial resolution: field level Coverage: Regional/national level Availability: globally available

Accuracy / constraints	Thematic accuracy: > 85 %, within-season retrieval depending on weather conditions Spatial accuracy: 1.5 - 2 pixels of input data
Limitations	The detection of large fields can be challenging. To account for regional field variances, time-frame selection and segmentation sensitivity can be adapted.
Frequency / timeliness	Frequency: upon request – across growing season, within-season, annual, multi-annual Timeliness: near real-time
Delivery / output format	Data type: GIS-ready data formats; Vector; API (depending on customer needs) File format: Shapefile
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analytics
- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Information on crop rotation
- Information on crop (seasonal) calendar
- Radar data (eliminated cloud cover effects)
- Risk exposure (product design and customer communication)

Product Sales:

- Client outreach
- Pre-contractual consulting (show-case risk exposure)
- Landowner identification
- Farm structure / management practice (linking to cadastre)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Identification of productive units
- Regular assessment of risk pricing and product rating
- Crop calendar and practices

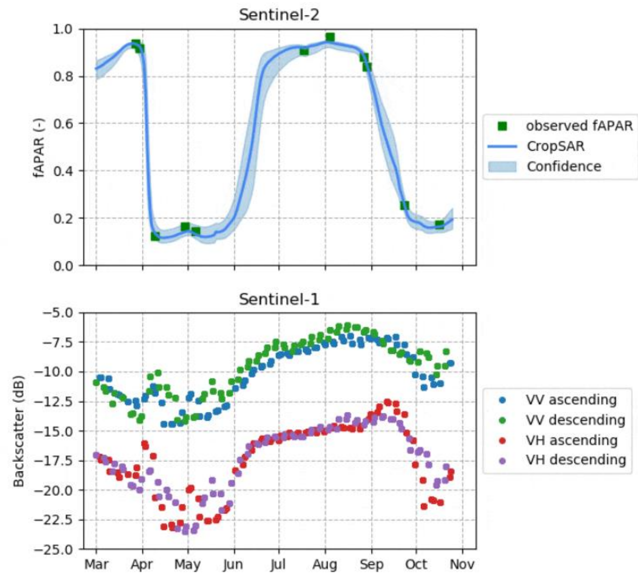
Loss Adjustment:

- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area / price (yield value)
- Quality control assessment of claims before pay-out
- Fraud detection

GAP FILLED TIME SERIES OF HIGH-RESOLUTION BIOPHYSICAL PARAMETERS



Description (Source: CropSAR VITO)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Optical sensors of high-resolution imagery such as Sentinel-2 are unable to look through clouds, resulting in cloud-induced gaps in observations, and hence making it impossible to retrieve the complete time series of a vegetation index. Typically gap-filling (e.g. linear interpolation) and/or smoothing procedures are used to reconstruct continuous growing curves on the available EO data. While this method provides reasonable results for dense time series such as provided by low resolution imagery, much less reliability is observed on the irregular observations from high resolution optical data (from e.g. Sentinel-2). Recent technologies such as CropSAR*, overcome this problem by taking advantage of the combined strength of optical Sentinel-2 data and the cloud-penetrating capacities of radar Sentinel-1 data.

* https://blog.vito.be/remotesensing/cropsar2019

PRODUCT SPECIFICATIONS

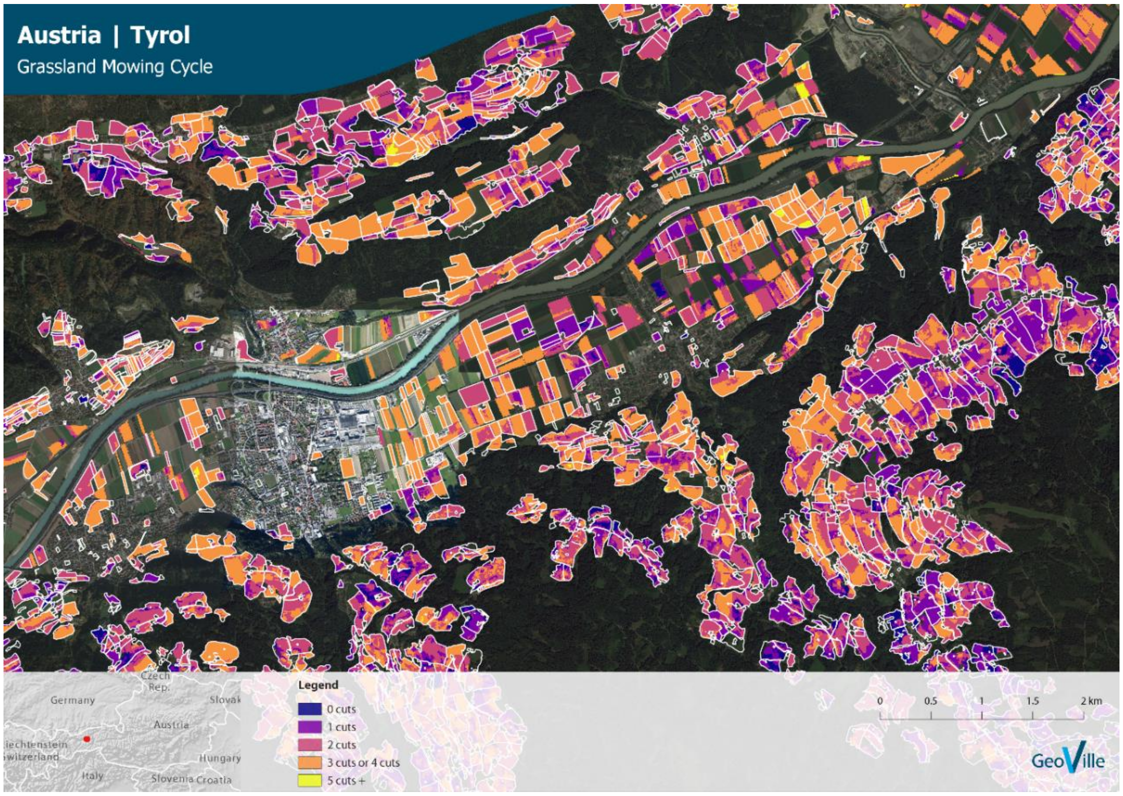
Main processing steps	Both datasets are fused in a deep learning framework resulting in Sentinel-2 like time series of vegetation parameters which are free of clouds, using the original Sentinel-2 and Sentinel-1 data.
Input data sources	Optical: Sentinel-2 Radar: Sentinel-1 Supporting data: Parcel boundaries
Spatial resolution and coverage	Spatial resolution: Field level Coverage: Global Availability: globally available
Accuracy / constraints	Thematic accuracy: Most mature over European cropland Spatial accuracy: one pixel

Limitations	Performance is crop type and crop stage dependent
Frequency / timeliness	Frequency: 3 days Timeliness: near real-time
Delivery / output format	Data type: 1-D time series of FAPAR & associated uncertainties File format: array or CSV.
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Consistent data to address challenges in all business processes

GRASSLAND MOWING CYCLE



Example for mowing cycle in Tyrol, Austria (Source: GeoVille)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

The cutting (here: mowing) of managed grassland to produce hay for livestock feed represents a major part of the total agricultural production in some regions. Therefore, it is valuable to monitor which areas of grassland are mowed to get information about hay production, and also how many times they are mowed in a growing season. The frequency and timing of mowing can also be used as evidence for possible damages on grasslands and monitoring the overall grassland productivity.

Reliable long-term data on grassland productivity and mowing cycles is used in agricultural insurance for development of index-based products for grasslands and pasture lands, monitoring grassland insurance portfolio by underwriters and assessment the scale and character of damage in loss adjustment.

Detailed information on grassland mowing cycle is an important service for all major stages of the product cycle (product development, risk pricing, underwriting, loss assessment, claim settlement). With grasslands mowing data agro-insurers are able to monitor the full cycle of the livestock fodder production.

PRODUCT SPECIFICATIONS

Main processing steps	The methodology of the automatic cut detection and counting algorithm is based on an analysis of optical and radar satellite imagery analysing temporal profiles over grassland parcels. It is based on a combination of various vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and multiple stages of cluster analysis. Analysis is based on a pixel-by-pixel computation considering administrative or other boundaries.

Input data sources	Optical: Sentinel-2 Radar: Sentinel-1 Supporting data: n.a.
Spatial resolution and coverage	Spatial resolution: 10m Coverage: Regional/national level (macro); Watershed/agro-ecological level (meso) Availability: globally available
Accuracy / constraints	Thematic accuracy: > 85 % Spatial accuracy: Absolute geolocation is constantly monitored for S2A and S2B. The long-term performance is close to 11 m at 95% for both satellites.
Limitations	Long-time gaps between observations due to cloud cover can make it impossible to detect cut events directly.
Frequency / timeliness	Frequency: upon request – across growing season, within-season, annual, multi-annual Timeliness: near real-time
Delivery / output format	Data type: GIS-ready data formats; Raster; API (depending on customer needs) File format: GeoTIFF, ESRI Grids, others on request (depending on customer needs)
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analysis

Product Sales:

- Farm structure / management practice (linking to cadastre)
- Regular market penetration review

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison etc.)
- Risk / crop zoning
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Identification of farmer's production practice (technology, infrastructure, property, machinery, etc.)
- Identification of productive units
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

Loss Adjustment:

- Risk mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show pictures to support loss adjustment communication to farmer)

Claims Handling:

- Identification of actual damage size (tons (volume / ha (area) / price
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

GREENHOUSE EARLY WARNING

Greenhouse Early Warning (Source: CGI)

CATEGORY

☐ Product Development ☒ Product Sales ☒ Underwriting ☐ Loss Adjustment ☒ Claims Handling

DESCRIPTION

The Greenhouse Early Warning Service (GEWS) has been developed by CGI Netherlands in close collaboration with PinC Agro, an Achmea Company and an (innovative) risk management consulting firm in the agricultural sector. This GEWS provides the Greenhouse Owners information based on the subscribed services.

At the moment the GEWS provides the following services:

- **Subsidence measurement** of Greenhouses.
  Greenhouses in the Netherlands have the challenge of maintaining their structural integrity in relation to the soft earth the greenhouses are built upon. The subsidence leads to broken windows in the greenhouse, again causing heat-leaks leading to crop-growth-disturbance: loss of yield.
  As well, water-management inside a greenhouse is a critical process that is greatly hindered by uneven floors, causing irrigation problems for the crops.
- **Heat detection**: By mapping the heat distribution of the greenhouse, identifying hot- and cold-spots, energy leaks or energy-screen issues.
- **Damage detection**: Damage detection of greenhouses is important both to the greenhouse owner, risk prevention companies and insurance companies. The damage detection can give an estimate of the total damaged area, useful to calculate financial damage, and allocate resources. For all the stakeholders, early damage detection means an as fast as possible recovery and know the full extent of the damage to the greenhouse.
- **Algae detection** in water basins: All Greenhouses are by law required to have and maintain a water basin to irrigate the greenhouse. These basins are usually in open air, and algae can easily disperse in areas. Early detection of the algae can allow for timely measurements, that will allow crops to be watered to the optimum.

<u>User Requirement/Need:</u>

Grip in continuity is considered highly important for greenhouse owners. Their asset is extremely vulnerable towards weather, flooding, plant diseases. Any information that enables greenhouse owners to prepare for and react on any elements with negative impact to their crops and therefore their yield is positively welcomed.

PRODUCT SPECIFICATIONS	
Main processing steps	These products are delivered as a service to the end customers. The customers subscribe to this service and the receive the products on a regular basis for their greenhouse.
Input data sources	Optical: Landsat 8 and 9 thermal bands, Sentinel 2 multiple bands Radar: Radarsat-2 Ultra Fine Mode, Sentinel -1 Interferometric Wide Swath SLC Supporting data: data sets from growers
Spatial resolution and coverage	Spatial resolution: multiple (from 3m x 3m to 100m x 30m) Coverage: This service has global coverage. Products are delivered per greenhouse. Availability: As requested by our customers the products are delivered on a monthly basis
Accuracy / constraints	Thematic accuracy: products are validated with in-situ data Spatial accuracy: products are delivered per greenhouse
Limitations	Products are available on a monthly basis via subscription
Frequency / timeliness	Frequency: monthly Timeliness: day
Delivery / output format	Data type: API based customized interface to end-users File format: API based customized interface to end-users
Accessibility	Products are available on a monthly basis via subscription

CHALLENGES ADDRESSED – USE CASE(S)

Product Sales:

- Pre-contractual consulting (show-case risk exposure)
- Farm structure / management practice (linking to cadastre)

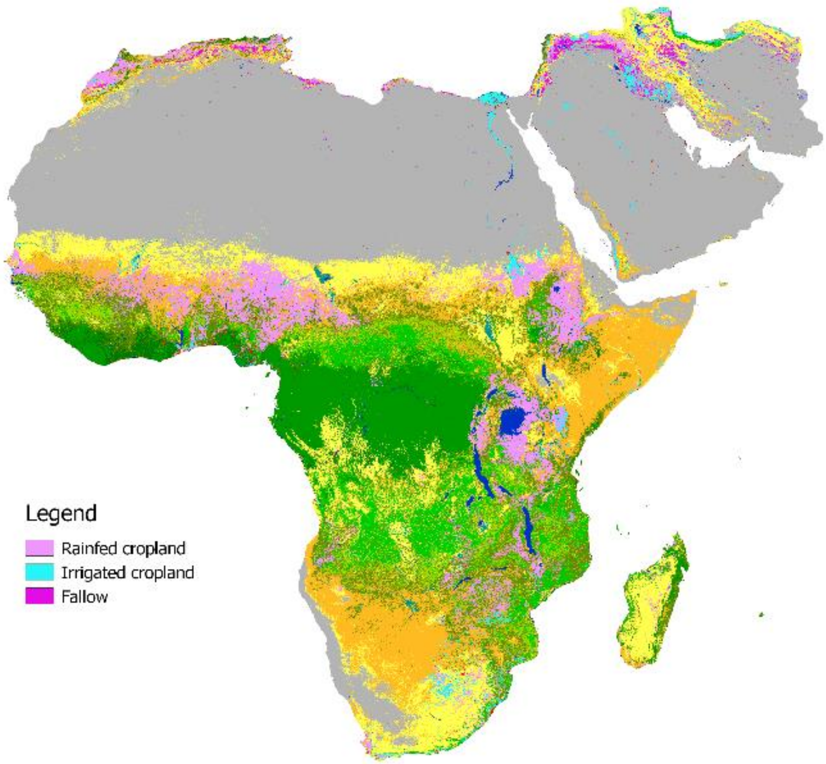
Underwriting:

- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Identification of farmer's production practice (technology, infrastructure, property, machinery, etc.)

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value))
- Quality control assessment of claims before pay-out
- Fraud detection

IRRIGATION MAPPING



Land cover map over Africa and Near-East for 2015 at 250 m resolution, including distinction between irrigated and rainfed cropland (Source: VITO)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☐ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Sustainable water management in agriculture is increasingly important to safeguard global food security, given the growing pressure on water resources worldwide exerted by climate change. In this respect, global and timely monitoring of water use and water productivity is urgently required. In particular, frequent and reliable information on the location and extent of irrigated areas could assist local governance to optimize water resource management. To date, this information is either produced at a limited, local scale in separate case studies, or derived from national statistics and hence characterized by high uncertainty. One exception is the global land cover map produced by ESA's Climate Change Initiative[1] from 1992 up to 2015, which includes information on irrigated versus rainfed cropland at 300 m resolution.

As the methodology was not being designed for irrigation monitoring, accuracies are rather low. In response to this, FAO launched the WaPOR data portal[2], specifically designed for large-scale crop water productivity assessment. Here, spatially explicit data on water availability and use are brought together, currently covering Africa and the Near-East.

Ongoing research in this topic mainly focuses on improving accuracy in semi-arid regions (see below) and detection of irrigation events on individual fields using high-resolution data.

[1] https://maps.elie.ucl.ac.be/CCI/viewer/

[2] https://wapor.apps.fao.org/home/WAPOR_2/1

PRODUCT SPECIFICATIONS

Main processing steps	Irrigation mapping is accomplished by first detecting cropland and identifying growing seasons based on optical satellite observations. Next, using a water balance approach, in which observed rainfall quantities (input) are compared to modelled crop evapotranspiration (output), a distinction is made between irrigated and rainfed cropland. Cropland is classified as irrigated in case the crop water output cannot have been provided solely based on the available water from precipitation. The evapotranspiration is modelled using a combination of optical and thermal infrared satellite observations and weather data. All WaPOR products are available at 3 levels of spatial detail, i.e. 250 m (covering entire study area), 100 m (covering principal watersheds) and 30 m (for dedicated target areas).
Input data sources	Optical: MODIS (250 m), Proba-V (100 m) or Landsat (30 m), depending on desired spatial resolution Radar: n.a. Supporting data: CHIRPS rainfall data, Copernicus Global Land Cover dataset, weather data including, Land surface temperature data derived from thermal infrared imagery (MODIS or Landsat)
Spatial resolution and coverage	Spatial resolution: 250 m (also 100 m and 30 m products available for dedicated areas) Coverage: Africa and Near-East (see extent displayed in Figure above) Availability: Available on demand with service providers for regions with limited rainfall.
Accuracy / constraints	Thematic accuracy: The WaPOR methodology described above has shown particularly good performance of detecting irrigated areas in arid climatic conditions. In semi-arid regions however, where irrigation is only applied supplementary to overcome occasional periods of drought, distinction between rainfed and irrigated agriculture is less straightforward and requires a more dedicated methodology based on high-resolution input data and machine learning. At present, this is still an active field of research. Spatial accuracy: depending on resolution of input data and desired product
Limitations	Current methodologies are mainly focused on regions with limited rainfall.
Frequency / timeliness	Frequency: updated yearly (available for 2009 – present) Timeliness: each year released after final growing season
Delivery / output format	Data type: Numerical land cover classification (integers) File format: GeoTIFF
Accessibility	Large-scale irrigation mapping (area based) in semi-arid and arid regions (WaPOR) The mapping of agricultural practices at field level is being tested in project such as SEN4CAP Available on demand with service providers for regions with limited rainfall.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analysis
- Elaboration of crop profile: field crops, vegetables, horticulture, greenhouses
- Information on crop rotation

Product Sales:

- Client outreach
- Pre-contractual consulting (show-case risk exposure)
- Farm structure / management practice (linking to cadastre)

- Regular market penetration review

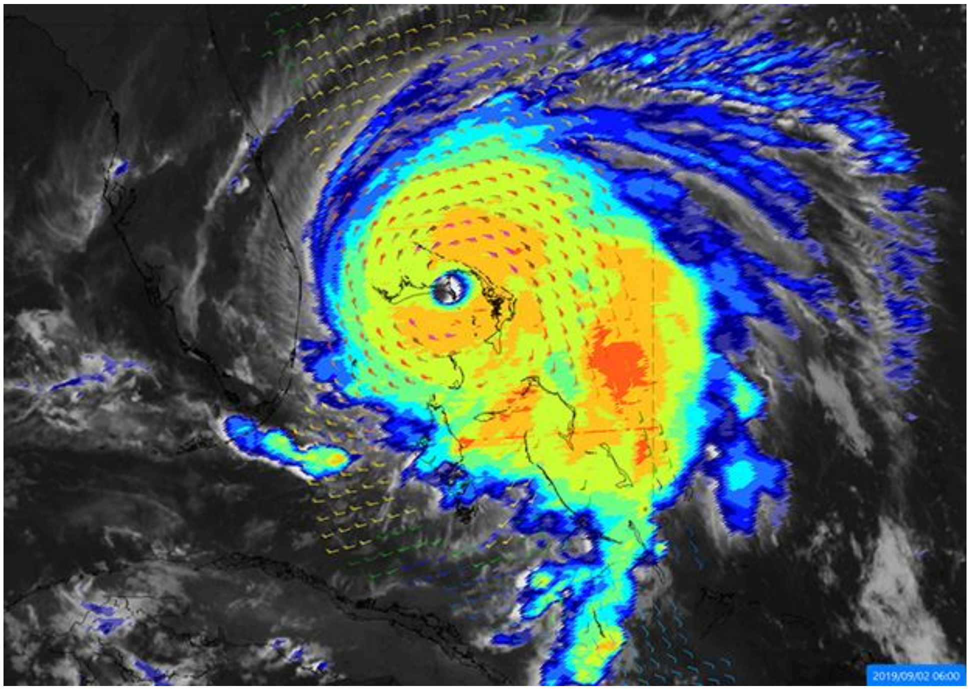
Underwriting:

- Seasonal portfolio monitoring
- Identification of farmer's production practice (technology, infrastructure, property, machinery, etc.)
- Identification of productive units
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

Claims Handling:

- Quality control assessment of claims before pay-out
- Fraud detection

MONITOR AND FORECAST WEATHER EVENTS



Hurricane Dorian, September 2019 (Source: EUMETSAT 2020)

CATEGORY

☒ Policy pricing ☒ Underwriting ☒ Loss assessment ☐ Claims management

DESCRIPTION

The monitoring and forecasting of weather events is important for agricultural business processes to take appropriate measures already in advance and for agro-insurance to correlate damages to certain risk events. Weather observations and forecasts are based on a continuous, global EO data on the weather events in Earth's atmosphere and on surface. Observations made by special weather satellites are an important source for this application in agricultural insurance and crop monitoring.

Two types of weather satellites are currently in operation, the geostationary and the polar orbiting satellites. To get the best results, a combination of both sources is ideal. Satellites with a geostationary orbit appear stationary when viewed from the earth, meaning they have the same rotation period as the Earth. They are located further away from the surface; therefore, the spatial resolution is lower; however, they provide a higher temporal resolution than polar orbiting satellites. The Meteosat Second Generation for example provides a baseline repeat cycle of 15 minutes. On the other hand, with each revolution polar / sun-synchronous / Lower Earth orbit satellites pass both poles while they pass the equator at a different longitude each time.

Forecasts usually range from a few hours until 10 days ahead being a good tool for insurance portfolio monitoring and application of non-insurance measures by farmers to decrease the potential negative effects of the forecasted event on their crop yields.

PRODUCT SPECIFICATIONS

Main processing steps	Information are derived from geostationary and polar orbiting satellites.
Input data sources	Geostationary satellites: Meteosat-8/-9/-10/-11, GOES Polar orbiting satellites: Metop-A/-B/-C Other satellites: Sentinel-3A/-3B, Jason-3

	Supporting data: n.a.
Spatial resolution and coverage	Spatial resolution: > 1 km Coverage: global Availability: globally available
Accuracy / constraints	Thematic accuracy: > 85 % Spatial accuracy: Different data sources are combined to reach the highest accuracy possible. Higher resolution does NOT mean higher accuracy necessarily. It mainly means more spatial detail. This is especially true for precipitation accuracy, which might decline at higher resolution (below 5 km), see e.g. https://content.meteoblue.com/nl/specifications/data-sources. For a detailed analysis of weather forecasts, please refer e.g. to the evaluation of ECMWF forecasts: https://www.ecmwf.int/node/19277.
Limitations	Weather predictions limited to 10 days in future; severe weather event warnings available 48 hours to 15 minutes prior to a weather event.
Frequency / timeliness	Frequency: depending on satellite Timeliness: near real-time
Delivery / output format	Data type: NetCDF File format: NetCDF; typically available also in web interfaces
Accessibility	Data is available through portals after registration, some products are subject to licence agreements., e.g. through the Copernicus Atmosphere Monitoring Service (https://atmosphere.copernicus.eu/). Available on demand from commercial service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Index insurance: Platform for crop health products

Product Sales:

- Client Outreach
- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Risk alerts

Underwriting:

- Weather forecast tool

Loss Adjustment:

- Increase credibility of loss adjustment (e.g. show pictures to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)

NEAR REAL TIME (NRT) SERVICE

CATEGORY

☐ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

With the increase of weather extremes and the pressure on agricultural production it is necessary to have near real time (NRT) monitoring and mapping of agricultural production, vegetation change and environmental conditions within the risk portfolio of the agricultural underwriter.

The availability of NRT data in high to very high resolution allows to respond quickly and accurately to vegetation change with field-level detail and allows agronomists to identify possible issues at early stages to decide on further treatment of the crop with required inputs, and track further crop's vegetation health. By providing an API access, an integration of field imagery into customer's apps, analytics, and workflows is ensured.

NRT data services include high to very high spatial resolution satellite data and derived products. Sentinel mission data can be provided within 2 to 5 days while data from various commercial third-party service providers (e.g. Planet, DigitalGlobe, Airbus, etc.) are available daily. Derived products and services are provided by commercial EO service providers in NRT to date when the satellite image is acquired. NRT information enables detailed insights across regional and local level daily.

The NRT Service is a baseline for all offered services and products in this portfolio providing accurate and timely information, especially for underwriting, loss assessment and claim management.

PRODUCT SPECIFICATIONS

Main processing steps	Depending on requested service
Input data sources	Optical: HHR and VHR data providers (e.g. Planet, DigitalGlobe, Airbus, etc.) Radar: n.a. Supporting data: n.a.
Spatial resolution and coverage	Spatial resolution: 0.3 – 5 m Coverage: Farm level to Regional level Availability: globally available
Accuracy / constraints	Thematic accuracy: depending on provided NRT information Spatial accuracy: depending on satellite input data
Limitations	Optical satellite data is prone to cloud coverage. Through high temporal resolution and the use of various sensors this impact can be limited.
Frequency / timeliness	Frequency: daily Timeliness: near real-time
Delivery / output format	Data type: API solution File format: depends on provider
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Underwriting:

- Seasonal portfolio monitoring

- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Actual crop health (vegetation)
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Procure more reinsurance from better insurance practice
- Information on growing stages is useful to indicate sensitive stages (e.g. flowering) to estimate the impact on the actual yield when a crop is affected by a damage
- Forecasting tool needed to have flexible pricing for the next time frame
- Crop calendar and crop practices
- Regular assessment of risk pricing and product rating

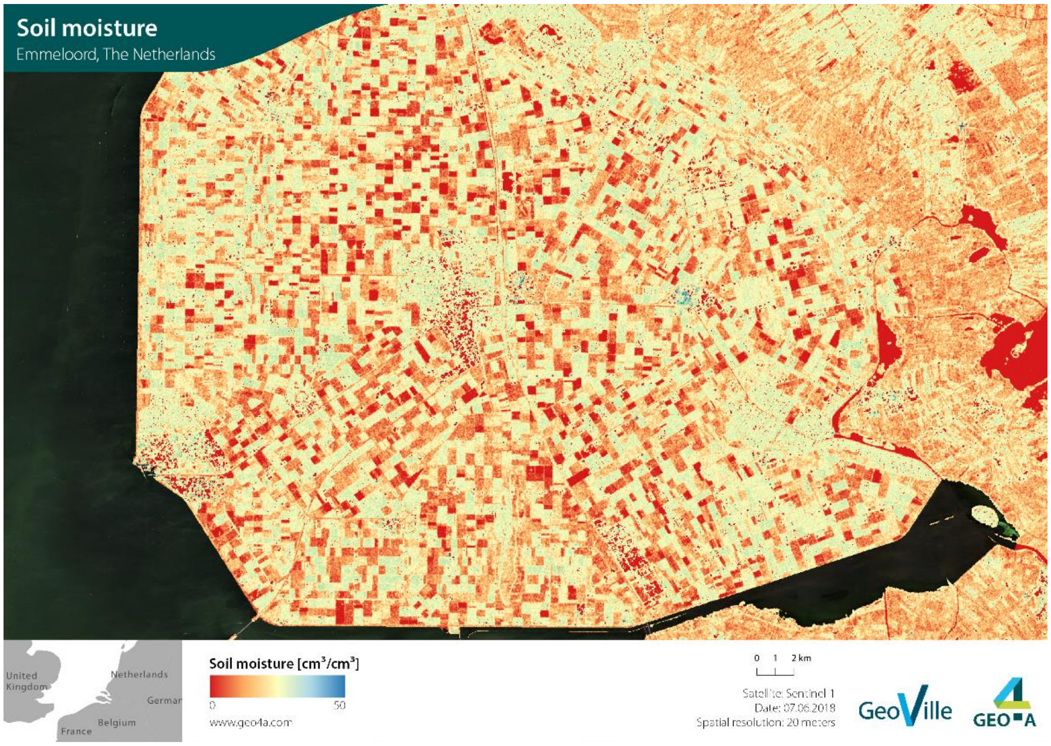
Loss Adjustment:

- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect yield damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

SOIL MOISTURE



High resolution soil moisture based on Sentinel-1 (Emmeloord, The Netherlands) (Source: GeoVille/Geo4A)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Soil moisture plays an important role for the environment and the climate system. Affected by precipitation, temperature, soil characteristics and more factors, soil moisture refers to water stored in the soil. It influences hydrological and agricultural processes as well as runoff generation and many other processes. Earth observation provides global, seamless surface soil moisture information, measuring the moisture content of the top five centimetres of soil. Based on this, root zone soil moisture can be modelled. This seamless observation is a clear advantage compared to point based in-situ measurements, and recent developments allow to obtain also high-resolution satellite soil moisture observations.

The ESA Climate Change Initiative (CCI) Soil Moisture provides a +40-year dataset of daily soil moisture [m^3/m^3] at 25 km, updated yearly. Based on active and passive sensors this consistent global dataset provides valuable information at larger scales but does not meet the need for real time soil moisture information at field level. The Copernicus Global Land Service provides Surface Soil Moisture (SSM) and the Soil Water Index (SWI) with a resolution of 1 km for the layer over Europe and 12,5 km at global scale, every day. Recently, also higher resolution (e.g. 100 m as well as 10 m) near real time soil moisture products are being made available using the Copernicus Sentinel Constellation and offered by commercial Earth observation companies.

The data may be used as an indicator for insurance portfolio's drought/flood monitoring and loss adjustment procedures to benchmark the areas affected/unaffected by risk event. A more accurate and robust underwriting with additional rating instruments to be applied based on the soil moisture data.

PRODUCT SPECIFICATIONS

Main processing steps	High resolution soil moisture is estimated by a multi-sensor, time-series data-based approach. Data from various satellites with different spatial resolutions is combined.

	Additionally, the NDVI is used as a proxy because of its sensitivity to surface soil moisture patterns. Statistical downscaling procedures using Deep Learning methods are applied to combine data with different spatial resolutions and transfer them to higher resolutions. By using this method, data can be generated also on a local, regional or national level and at a higher spatial resolution than the European and global layers.
Input data sources	Optical: n.a. Radar: Sentinel-1, SMAP, MetOp ASCAT Supporting data: in-situ data
Spatial resolution and coverage	Spatial resolution: 10m – 25km Coverage: Local/regional/national/global level Availability: globally available
Accuracy / constraints	5-10% RMSE / not applicable in densely forest areas
Limitations	Currently available products indicate the surface soil moisture of the top few centimetres soil from coarse to high spatial resolution. However, it is not possible to directly observe root zone soil moisture.
Frequency / timeliness	Frequency: various time steps and long historic archives Timeliness: near-real time
Delivery / output format	Data type: GIS-ready data formats; Raster; API (depending on customer needs) File format: NetCDF, GeoTIFF, CSV
Accessibility	Freely available products are provided e.g. through the Copernicus Land Monitoring Service (https://land.copernicus.eu/global/themes/vegetation). Products from ESA's CCI Soil Moisture initiative with global coverage are open and freely available for registered users (https://www.esa-soilmoisture-cci.org/). Products with higher resolution are commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analysis
- Index insurance: Toolbox for indices
- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather events and impact on crop productivity
- Index insurance: Parcel/Field and regional yield statistics
- Index insurance: Platform for crop health products
- Identification of specific stresses and vegetation problems and their underlying causes
- Radar data (eliminated cloud cover effects)
- Risk exposure (product design and customer communication)

Product Sales:

- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring

- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Actual crop health (vegetation)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

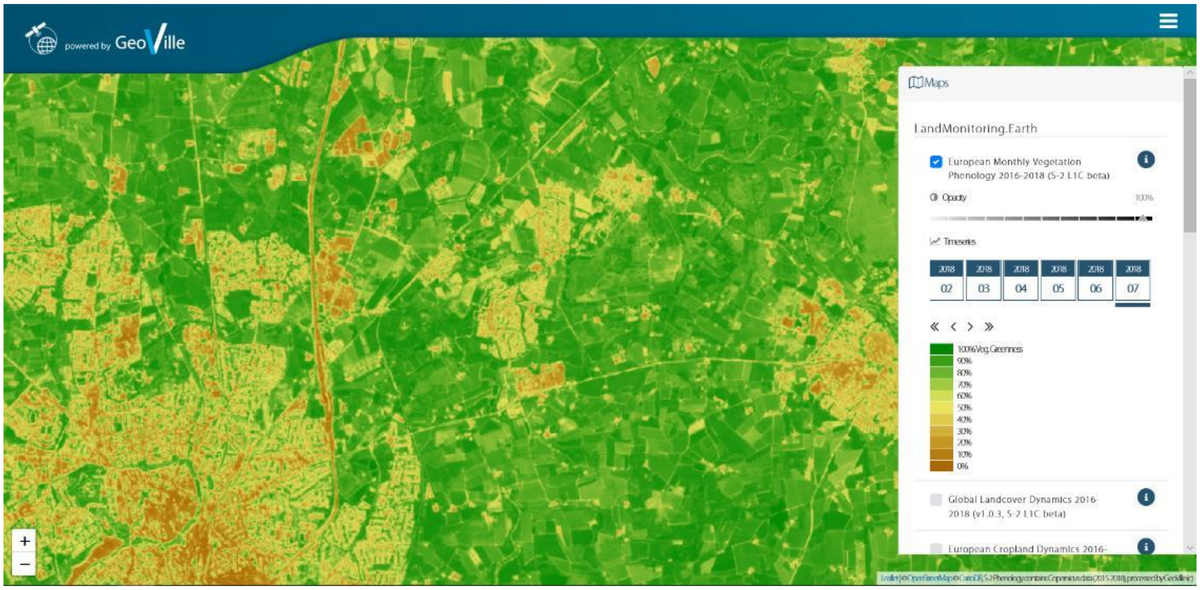
Loss Adjustment:

- Regularly updated consistent long-time series of reliable data for index insurance
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage
- Soil type data

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value)
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

VEGETATION GROWTH MONITORING



Monthly vegetation phenology (Source: landmonitoring.earth by GeoVille)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Monitoring the vegetation provides an important information on crop's development and performance of fields. Information on the vegetation status and possible deviations at certain fields is important to identify the problem areas throughout the entire insurance season so that the farmer can react with application of necessary agricultural production technology and inputs to ensure the lesser effects of possible vegetation change in time, to ensure crop's optimal growth and yielding capacity.

Vegetation growth monitoring service allows better precision in underwriting and loss adjustment.

PRODUCT SPECIFICATIONS

Main processing steps	EO methods to monitor the growth status is based on optical satellite imagery. With the analysis of vegetation indices such as the Leaf Area Index (LAI). The LAI is an indicator of the canopy structure. It therefore provides a measurement for the biomass on a field and the crop growth.
Input data sources	Optical: Sentinel-2 Radar: n.a. Supporting data: n.a.
Spatial resolution and coverage	Spatial resolution: 10m Coverage: Regional/national level Availability: globally available
Accuracy / constraints	Thematic accuracy: > 85 % Spatial accuracy: 1,5 – 2 pixels of input data resolution
Limitations	Times series of optical data are prone to cloud coverage and thus have limited observational capacity in some regions.

Frequency / timeliness	Frequency: various time steps, starting from daily Timeliness: Near real-time
Delivery / output format	Data type: GIS-ready data formats; Raster; API (depending on customer needs) File format: GeoTIFF
Accessibility	Commercially available on demand from EO service providers. In the future such information will also be made available by Copernicus: https://land.copernicus.eu/user-corner/technical-library/phenology

CHALLENGES ADDRESSED

Product Development:

- Market analysis
- Index insurance: Toolbox for indices
- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather events and impact on crop productivity
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Parcel/Field and regional yield statistics
- Index insurance: platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Information on forest health and production at different temporal scales (realtime monitoring, historical development)
- Identification of specific stresses and vegetation problems and their underlying causes
- Risk exposure (product design and customer communication)

Product Sales:

- Client outreach
- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers
- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Actual crop health (vegetation)
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

Loss Adjustment:

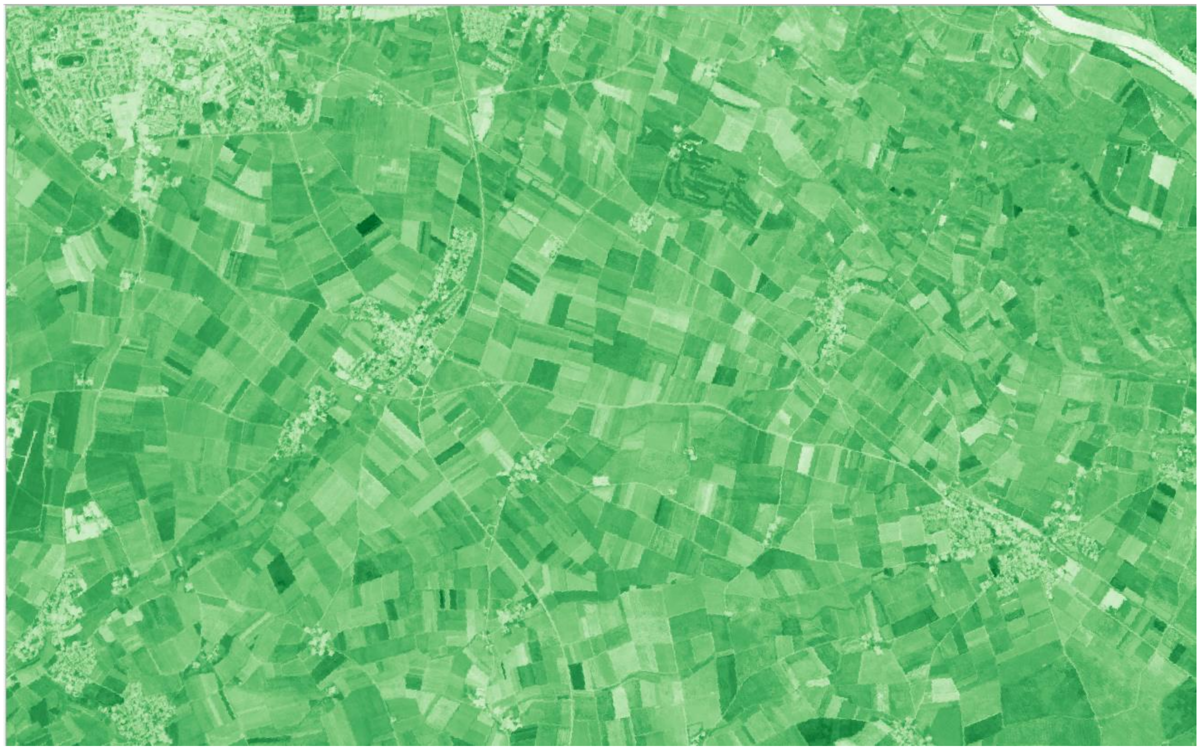
- Workforce allocation and planning
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)

- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value))
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

VEGETATION INDICES: LAI, NDVI



NDVI (Source: Sentinel-2)

CATEGORY

☒ Product Development ☒ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

Different vegetation indices serve as input for various applications and services of remote sensing-based analysis and products/services, such as the Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Enhanced Vegetation Index (EVI) or Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). They are derived from satellite images using different bands. Consistent long time series are available on various spatial levels.

The Normalized Difference Vegetation Index (NDVI) is an indicator of the greenness of the biomass. It is widely used for ecosystem as well as vegetation monitoring. Depending on how the plant reflects light at certain frequencies the NDVI indicates the state of plant health.

The Leaf Area Index (LAI) characterized the plant canopies. It is defined as half the total area of green elements of the canopy per unit ground area. The LAI quantifies the thickness of the vegetation cover.

Vegetation indices are widely applied in insurance industry for product development, underwriting and loss adjustment purposes.

PRODUCT SPECIFICATIONS

Main processing steps	The NDVI is calculated by normalizing the spectral reflectance that are measured in the near infrared (green leaf scattering) and red (chlorophyll absorption) wavebands of satellite imagery.
Input data sources	Optical: Sentinel-2, MODIS, PROBA-V Radar: n.a. Supporting data: n.a.

Spatial resolution and coverage	Spatial resolution: >10m Coverage: global Availability: globally available
Accuracy / constraints	Thematic accuracy: n.a. as indices are calculated directly on the basis of raw measurements Spatial accuracy: Absolute geolocation is constantly monitored for S2A and S2B; the long-term performance is close to 11 m at 95% for both satellites. For the geolocation accuracy for PROBA-V satellites please refer to http://proba-v.vgt.vito.be/en/quality/platform-status-information/geolocation-accuracy.
Limitations	Atmospheric effects and clouds can affect the calculations and may lead to misinterpretation.
Frequency / timeliness	Frequency: various time steps and historic archive Timeliness: near real-time
Delivery / output format	Data type: GIS-ready data formats; Raster File format: GeoTIFF
Accessibility	Products with higher resolution are commercially available on demand from EO service providers. 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/

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Market analysis
- Index insurance: Toolbox for indices
- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather events and impact on crop productivity
- Index insurance: Functionalities of plants, chemical reactions, early stress detection
- Index insurance: Parcel/Field and regional yield statistics
- Index insurance: Platform for crop health products
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Information on crop rotation
- Information on crop (seasonal) calendar
- Information on forest health and production at different temporal scales (realtime monitoring, historical development)
- Identification of specific stresses and vegetation problems and their underlying causes
- Forestry: Infrastructure & management
- High accuracy of crop-specific yield for smaller crop parcels
- Risk exposure (product design and customer communication)

Product Sales:

- Client outreach
- High accuracy of crop-specific yield for smaller crop parcels (penetration)
- Pre-contractual consulting (show-case risk exposure)
- Greater acceptance of index covers by farmers

- Regular market penetration review
- Risk alerts

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Actual crop health (vegetation)
- Global/Regional production trends (e.g. monitoring specific crop acreages of surrounding regions/countries)
- Procure better reinsurance terms/capacity from enhanced insurance practice
- Trustful historical data agro-insurance indemnity pay-outs
- Identification of farmer's production practice (technology, infrastructure, property, machinery, etc.)
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stage)
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

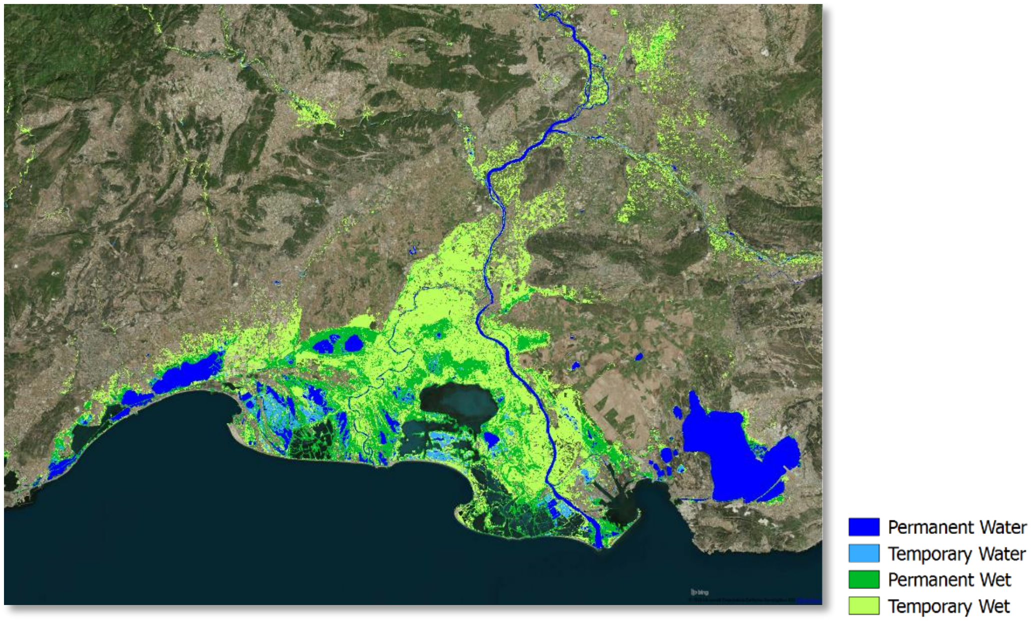
Loss Adjustment:

- High accuracy of crop-specific yield for smaller crop / land parcels
- Regularly updated consistent long-time series of reliable data for index insurance
- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Detect crop damage at field level
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage
- Obtain information on pasture biomass

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area) / price (yield value))
- Quality control assessment of claims before pay-out
- Fraud detection
- Obtaining timely, reliable and consistent data to speed-up the indemnity pay-outs

WATER BODIES DETECTION



Detailed water and wetness classification (Source: GeoVille)

CATEGORY

☒ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☐ Claims Handling

DESCRIPTION

This product identifies open water bodies, including natural lakes as well as man-made reservoirs such as ponds or lakes and wide rivers showing their extent. Furthermore, changes in water body outline can be monitored over a period of time to detect seasonal changes.

Analysing the frequency in periodical water masks based on time series allows to monitor any changes of water body extents over time as well as the frequency of water occurrence. High accuracy is reached due to the contrast in radar backscatter from open water surfaces and land.

This service may be used for product development, underwriting and loss adjustment purposes.

PRODUCT SPECIFICATIONS

Main processing steps	The product is derived by applying a suite of dynamic water detection processing chains optimized for various target areas. The production workflows mainly operate on Sentinel-2 time-series imagery (optical) and Sentinel-1 Synthetic Aperture Radar (SAR) data but can also applied to many other optical and SAR data for historical analysis. Individual processing chains are applied to these data inputs and their results are combined using a rule-based fusion algorithm that ensures the detection strengths of each sensor are incorporated into the final product.
Input data sources	Optical: Landsat-8, Sentinel-2, VHR imagery Radar: Sentinel-1 Supporting data:
Spatial resolution and coverage	Spatial resolution: 10 – 500 m Coverage: global Availability: globally available

Accuracy / constraints	Thematic accuracy: > 95% accuracy / limitations for densely forested areas Spatial accuracy: Absolute geolocation is constantly monitored for S2A and S2B. The long-term performance is close to 11 m at 95% for both satellites.
Limitations	Topography is a major issue in mountainous regions due to geometric and radiometric effects causing radar shadow and thus false detections.
Frequency / timeliness	Frequency: monthly to multi-annual; observation may be required over a specified period Timeliness: within 3 days after last satellite pass
Delivery / output format	Data type: raster and vector formats File format: GeoTIFF, Shapefile
Accessibility	Near real time water and wetness information is commercially available on demand from EO service providers. A water and wetness layer for Europe showing the occurrence of water and wet surfaces over the period from 2009 to 2015 for the status year 2015 is publicly available through the Copernicus Land Monitoring Service (https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness), an updated layer for the status year 2018 will be available soon.

CHALLENGES ADDRESSED

Product Development:

- Market analysis
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses
- Elaboration of livestock profile: Cows, sheep, pigs, poultry
- Radar data (eliminated cloud cover effects)

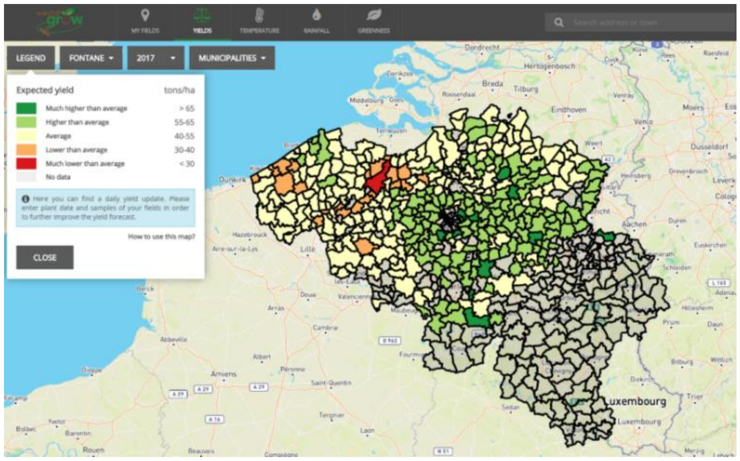
Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Crop calendar and practices
- Regular assessment of risk pricing and product rating

Loss Adjustment:

- Regularly updated consistent long-time series of reliable data for index insurance
- Benchmark physical field observations against yield loss detection (e.g. product calibration)

YIELD ESTIMATION



Example Image (watchitgrow.be)

CATEGORY

☒ Product Development ☐ Product Sales ☒ Underwriting ☒ Loss Adjustment ☒ Claims Handling

DESCRIPTION

EO based yield models are integrators of various data sources, for example vegetation indices to estimate the crops' phenology and meteo data derived from weather satellites. Several methods exist to estimate yield from EO data. Operational initiatives exist such as the EU Joint Research Centre (JRC) Mars Crop Yield Forecasting System (MCYFS), using agro-meteorological modelling (Crop Growth Monitoring System, CGMS) and statistical analysis tools. At local level, operational yield estimates at the farm level are available from commercial service providers. Besides the operational applications, a wide spectra of crop models is available which use EO data as inputs. A commonly used is the SAFY model of CESBIO (Duchemin et al., 2008).

Yield estimation models (for a wide variety of crops) are among the key priorities of the global agricultural insurance sector, as insuring yield may be referred as all-peril crop insurance. Existing pilot models continue their development while service providers are calibrating yield estimation models with in-situ data applying machine-learning and other technologies (e.g.: rice (Philippines, Indonesia, China)).

Combination of other EO services (e.g. field delineation, crop identification, NDVI, etc.) with yield estimation models provides a broad range of applications in all agricultural insurance business processes and product cycle activities. Being important at all product cycle stages, it is highly important for a more robust underwriting and loss adjustment processes.

PRODUCT SPECIFICATIONS

Main processing steps	Yield estimation is generally based on either machine learning (e.g. deep learning) and/or process-based (i.e. crop growth models) modelling approaches. Both can make use of a range of input data sources including satellite imagery time-series (e.g. of vegetation indices and derived parameters e.g. emergence date) and meteorological data along with environmental parameters such as soil and crop type. Process based models also allow different scenarios to be simulated, e.g. with or without water- or nutrient stress.
Input data sources	<u>Optical</u>: Sentinel-2 <u>Radar</u>: Sentinel-1

	Supporting data: in-situ calibration data (yield statistics, crop cutting experiments…)
Spatial resolution and coverage	Spatial resolution: 10m Coverage: Farm level till Watershed scale Availability: globally available
Accuracy / constraints	Thematic accuracy: depending on region and availability of in situ data Spatial accuracy: field level
Limitations	There are still no globally applicable yield forecasting models, mainly local pilots.
Frequency / timeliness	Frequency: daily Timeliness: near real-time
Delivery / output format	Data type: yield estimates (ton/ha). GIS-ready data formats; regional summaries, statistics, report sheets; API (depending on customer needs) File format: parcel level aggregated values (e.g. CSV)
Accessibility	Commercially available on demand from EO service providers.

CHALLENGES ADDRESSED – USE CASE(S)

Product Development:

- Index insurance: Risk / crop modelling (Correlation of EO data with in-situ data)
- Index insurance: Relation between weather events and impact on crop productivity
- Index insurance: Parcel/Field and regional yield statistics
- Elaboration of crop profile: Field crops, vegetables, horticulture, greenhouses

Underwriting:

- Seasonal portfolio monitoring
- Online platforms or easy-to-use interfaces integrating various data sources (e.g. vegetation stress, field boundary changes, comparison, etc.)
- Risk / crop zoning
- Identification of vegetation stages (identify most sensitive stages when crop is the most vulnerable to a risk, e.g. flowering stages)

Loss Adjustment:

- Benchmark physical field observations against yield loss detection (e.g. product calibration)
- Risk-mapping against crop's vegetation stages
- Increase credibility of loss adjustment (e.g. show EO data/visualization to support loss adjustment communication to farmer)
- Enhance field survey (better precision with EO data support)
- Assess crop damage at field level
- Distinct field heterogeneity with crop damage

Claims Handling:

- Identification of actual damage size (tons (volume) / ha (area)
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