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EO for Agriculture Under Pressure
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EO4AGRI 2024 – SESSION SUMMARIES AND RECOMMENDATIONS

This document contains summaries and recommendations of the EO4AGRI 2024 Workshop, "*EO for Agriculture Under Pressure*", which was organised 13-16 May 2024 in ESRIN, Rome, Italy.

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Introduction

The **EO for Agriculture under pressure 2024 Workshop,** co-organised by the European Space Agency, the European Commission (EC), the World Food Programme (WFP), the Food and Agriculture Organization (FAO) and GEOGLAM, took place in ESRIN 13-16 May 2024. The event gathered close to 300 attendees in person from 40 different countries, with more than 500 additional attendees joining online.

A comprehensive overview and discussion of the current state of the art of Earth Observation (EO) applications in agriculture were ensured through 10 technical sessions featuring 60 presentations selected from 175 abstracts by a scientific committee of 43 experts. Session themes covered new satellite missions, soil and crop monitoring, smallholder farming, climate impact, crop yield forecasting, community support tools, water resource intelligence, drought and pest stressors, climate adaptation, data integration, and policy uptake. Session summaries are provided in this document.

Two poster sessions complemented the technical sessions, presenting over 100 posters and offering young scientists an opportunity to network.

Six panels with scientists, policy makers, policy owners and user organizations addressed specific issues, e.g. transition from R&D to operations and integrating in-situ and EO data. Summaries are provided in this document.

A dedicated session highlighted 20 EC and ESA projects and served as a kick-start of the launch meeting of ESA's Agriculture Science Cluster which took place in ESRIN the day after the workshop (session summary at the end of the document).

Participants proposed recommendations to ESA & EC regarding future R&D activities, which are summarised under the respective session or panel in this document.

Video recordings of the sessions and panels are available on the workshop website: https://eo4agri2024.esa.int/

Session 1: New Missions to Agri-Space

Chair: Michel Massart, EC
Chair: Benjamin Koetz, European Space Agency

The session provided an overview on a variety of missions, including Sentinel Expansion Missions, Sentinel Next Generation, ConstellR HiVE, PRISMA, NISAR and HydroSAT. They are listed below along with a description of their main features and scope:

- Sentinel Expansion Missions and Sentinel Next Generation relevant for Agriculture:
  - CHIME: hyperspectral measurements for plant traits
  - ROSE-L: L-band SAR for soil moisture and crop type mapping
  - LSTM: thermal high-resolution EO for evapotranspiration (ET) retrieval and optimising water productivity
  - Sentinel-1 & 2 Next Generation: these missions allow to increase resolution for crop monitoring

- ConstellR HiVE constellation (thermal mission):
  - High-resolution 30m thermal EO with 5 satellites for up to daily revisit
  - The first mission of the constellation is to be launched in October 2024, and foresees synergy with Copernicus LSTM; the constellation is part of the Copernicus Contributing Missions

- PRISMA: hyperspectral mission from the Italian Space Agency (ASI)
  - 30m resolution hyperspectral EO, every 10 days
  - Enables spectroscopy-based products – e.g. for crop residue coverage, monitor crop development stages

- NISAR: L-band SAR mission from NASA/ISRO
  - L-band and S-band SAR EO at 10 m resolution, with a revisit of 12 days
  - Use of SAR time series for agricultural monitoring
  - To be launched in Sept 2024

- HydroSAT: thermal mission
  - High resolution 50 m thermal EO for up to daily revisit
  - The first prototype instruments are planned for 2024
  - Aims to enable an ET and irrigation service developed based on sharpened thermal EO

<u>Recommendations:</u>

- It is important to verify the quality of the EO data provided by new missions.
- Develop a comprehensive data policy to ensure data availability, reach a wider audience, support data uptake, and facilitate effective use of the data.
- Provide the broader context when retrieving necessary agricultural information.
- It is recommended to create a synergy between institutional missions and commercial missions. This is important when it comes to mission's temporal revisit.
- Furthermore, and based on the point above, it is important to develop applications making use of complementarities between institutions missions and new space.

Session 2: Soil and Crop monitoring

Chair: Kristof Van Tricht, VITO
Chair: Martin Claverie, EC, JRC

This session discussed a wide range of monitoring applications, from early R&D activities pushing scientific boundaries by using new sensors, to operational dashboards that bridge the gap between consolidated data products and end-users. An overarching theme remains the need for harmonized and open reference data to train and validate methods, and the long-term continuity and expansion of the Copernicus programme.

Some specific highlights from the session:

- The community discussed the importance and benefits of using experimental hyperspectral data (PRISMA and EnMap) for new applications, such as plant water monitoring and for estimating and predicting crop nutrients.
- Farmer parcel declarations (from the GeoSpatial Application (GSA) datasets) covering multiple years and harmonized into the Common Harmonized European Agricultural Parcels (CHEAP) database hold unprecedented reference data, and this enables the development of innovative methods, in particular:
    - Regarding the addition of crop rotation to improve crop mapping accuracy
    - Regarding the development of new in-season crop mapping approaches
- WaPOR Accounter, a web app to monitor water productivity at field scale, is discussed as an example dashboard that bridges the gap between data products and end-users
- Near-real time harvest monitoring in Ukraine using Planet data and unsupervised clustering methods reached high accuracy levels.

<u>Recommendations:</u>

- OPEN in situ as a priority
    - GSA (GeoSpatial Application, parcel declarations) extremely useful; we need more countries to open this up: push politically
    - Define larger test areas (commercial farms) where we can have open data, going beyond just crop types (incl. farm management). Build partnerships outside Europe, play a leading role.
    - Push for a larger budget share going to in situ data collection and sharing, the single largest bottleneck for major progress
- RS data processing and sensors design
    - We need more focused efforts on standardized preprocessing workflows resulting from sensitivity analyses (benchmarking the preprocessing)
    - Standardized data access (STAC + COG)
    - Focus on upcoming SWIR bands
    - Fusion of multispectral and hyperspectral data
- Need for consolidated guidance on methods that work (incl. crop type, irrigation and ETa mapping) and continued efforts to improve and operationalize them

Session 3: Small-holder farming

Chair: Mark Noort, HCP
Chair: Ruud Grim, NSO

During this session, several satellite-based services for small holders were discussed, based on a variety of studies that are summarized below:

- "Satellite-based services for smallholder food producers in support of food security, A dream or a reality?":
  - Since 2013, the Geodata for Agriculture and Water (G4AW) programme has reached more than 4 million smallholders, about 1.2 million users, and has largely influenced decreased use of inputs, an increased production, and higher incomes for farmers
  - Several successes have been achieved: insurance, pastoralist routing advice, high value crop advice and pest management advice regarding potato late blight
- "Satellite-based germination insurance for smallholder farmers in Africa":
  - Germination insurance was set up in Ghana thanks to the development of the necessary parameters
  - Farmers were consulted and seed companies were onboarded
  - Germination insurance was considered relevant, and the combination with yield insurance was also considered interesting
- "Development of a farm-scale water accounting model incorporating farmers behaviour and remote sensed data":
  - Overextraction was successfully estimated in the model
  - The study is developed in compliance with the European Water Framework Directive (WFD) and with the National Decree of the Italian Ministry of Agricultural, Food and Forestry Policies
  - A tool for groundwater management and farm-scale water balance was developed
  - Remote sensing allows for a better estimation of the crop coefficient (Kc)
- "Near-real time monitoring of irrigation water use per farm by combining satellite and in-situ data with hydrological models":
  - This presentation detailed the successful development of irrigated area mapping and irrigation water use estimates services in Australia making use of hydrologically similar pixels and incremental evapotranspiration (ET)
  - The study detailed a context where users are paying clients, and identified opportunities for scaling up
- "Retrieving crop phenology at field scale in the Nile Delta using Sen2Like processor and PlanetScope imagery":

    - Regarding the detection of crop seasons, using Sen2Like did not provide a substantial improvement when compared to using Sentinel-2 alone, but tests in other areas and with more cloud cover would be needed
    - There was a good agreement between Sen2Like and PlanetScope when it comes to retrieving phenology metrics
    - Several opportunities exist to study the effect of climate shifts on crop phenology, and to support the agricultural practices of smallholder farmers
- "Mitigating food security challenges in Afghanistan: A geospatial and remote sensing approach":
    - This presentation detailed the use of both remote sensing data and field data for wheat monitoring (using NDVI) and for water management interventions
    - The approach included the use of optical and radar remote sensing data as well as of the Global Food Awareness System (GloFAS), with the goal of analysing floods
    - Regarding water harvesting, the study included an analysis of trenches and dam behaviour
    - It was discussed to improve the process and results in the future by using the FAO Water Productivity Open-access portal (WaPOR)

<u>Recommendations:</u>

- Allow for the fact that innovation and scaling take time, especially in developing countries
- Implement a user-centred approach & digital inclusion using active monitoring and evaluation mechanisms
- Bundling of services to smallholder farmers provides benefits
- Smallholder farmers are not likely to pay for services, links should be established with other actors in the value chain, e.g. input providers, off-takers, financial institutions
- Education and trust remain crucial success factors, when working with (smallholder) farmers
- Better soil data needed for good fertiliser advice
- Develop services and service delivery in a flexible way that allows for adaption and makes scaling up feasible: end users may have different requirements and local conditions, laws & regulations and ways of doing business may vary
- Find ways to establish and maintain in situ data infrastructures for weather, water, environment and climate and mechanisms to promote and facilitate open and free data sharing
- Satellite-based service implementation should take into account collaboration between research and industry, clearly communicate with end-users, considering their internal decision-making processes and be ready to integrate future EO missions

Session 4: Impact on Climate and Environment

Chair: Heike Bach, Vista GmbH
Chair: Magdalena Fitrzyk, RSAC c/o European Space Agency

In this session, the impact of agriculture on climate and environment was explored from different aspects through six presentations. These focused on a diversity of topics, among which the improvement of nitrogen use efficiency, the role of blockchain and EO in making the food system more sustainable, supporting CAP monitoring, the effects of landscape features, the management of soil organic carbon through crops, and the monitoring of oil palm plantations.

The main topics discussed during the session were:

- Innovation and scaling take time, especially in developing countries
- Pointing towards an implementation with a user-centred approach and ensuring digital inclusion using active monitoring and evaluation mechanisms
- Regarding smallholder farmers, bundling services for them provides more benefits
- Smallholder farmers are not likely to pay for services, so it is better to establish links with other actors in the value chain, e.g. input providers, off-takers, financial institutions
- Additionally, keep in consideration that education and trust remain crucial success factors when working with farmers, especially with smallholders.
- Better soil data is needed for adequate fertiliser advice
- The fact that developing in a flexible way both the services and the service delivery allows for adaption and makes scaling up feasible. In fact, the requirements of end users and their local conditions can be very varied from one end user to another, as can be the laws, regulations and ways of doing business.
- One important aspect discussed was the necessity to find ways to establish and maintain in situ data infrastructures for weather, water, environment and climate, as well as mechanisms to promote and facilitate sharing data in an open and free manner
- Different aspects were discussed regarding satellite-based service implementation: possible collaborations between research and industry, communication with end-users should be clear, the internal decision-making processes of end-users should be considered and, as a last aspect, it is important to be ready to integrate future EO missions

<u>Recommendations:</u>

- Providing farmers with information to support decision making should be the final goal of EO based services.
- Integrating EO data and physical models is essential
- Causal Machine Learning is used to uplift green metrics in an efficient way, and to personalise sustainable agriculture
- However, it is important to differentiate between correlations and causal effects, because overfitting of Machine Learning is a further risk.
- Machine Learning has no predictive capabilities, and therefore it is required to have process models

- Hybrid approaches combining the benefits of physical and Artificial Intelligence models should be further researched
- It is a necessity to have open-source farm reference datasets with good quality
- Improved algorithms for CAP monitoring are still required, and this includes Machine Learning and marker approaches.
- Regarding landscape features, high resolution remote sensed products equivalent to European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL) should be used
- An important recommendation is to join efforts related to biodiversity and landscape features monitoring, with the goal of having a more complete and harmonized survey and a better assessment of landscape features and biodiversity assessment
- In the framework of the European Union Regulation on Deforestation Free Products (EUDR), the monitoring of industrial plantations should be considered too

Session 5: Crop Yield estimation and Forecasting

Chair: Belen Franch, Universitat de Valencia
Chair: Michele Meroni, EC, JRC

In this session, several key aspects were discussed in depth concerning the role in crop yield estimation and forecasting of the combination of Sentinel-1 and Sentinel-2, the further combination with machine learning, the results obtained at field scale, the combination of EO with digital tools and fields assessments, predictions in-season within fields using Sentinel-2, and estimations under extreme circumstances. The main points of the discussion are found below:

- Yield forecasting activities are performed at sub-national level but also at field level
- Regarding the accuracy of yield forecasting, the positive role of Sentinel-1 when used in combination with Sentinel-2 was discussed
- The short-wave infrared (SWIR) range was also found useful, besides traditional vegetation indices (Vis) and bio-physical variables
- Growing Degree Days (GDD) normalization shows better performance metrics in yield modelling than Day-of-Year (DOY)
- Gridded meteorologic data are used routinely in sub-national yield forecasting, but not so much for field-level yield forecasting
- General difficulties arise regarding data driven approaches at field level in full prediction (LOYO validation)
- Beyond/besides data driven models, the power of using Crop Growth Model in conjunction with EO to provide yield forecasting in the absence of in situ data (i.e. full prediction) were shown using the example of yield estimation in Ukraine

<u>Recommendations:</u>

- In situ data are of crucial importance (their quantity, quality and the presence of long-term time series). It is needed to expand current data collection activities, to use harmonised collection methods and to make data public
- For smallholder farmers, the spatial resolution of Sentinel-2 poses limitations
- The importance of mission continuity cannot be overstated, as was seen when Sentinel-1B failed. A warning is issued that the sector would be in crisis if Sentinel-2 has a failure too
- It is crucial to have improvements in the Sentinel-2 cloud masking methods
- Potential improvements could be developed thanks to the Copernicus Land Surface Temperature Monitoring (LSTM) data
- It is a necessity to have accepted metrics for the inter-comparison of model results , and in that sense, attendees were encouraged to join the AgML initiative that was presented earlier

during the workshop by Ioannis Athanasiadis (on Monday 13th May, during the opening session, in particular during the keynote called "Machine Learning and EO for Agriculture")

- The Food and Agriculture Organization of the United Nations (FAO) shared the value of understanding user needs, of co-designing and co-developing in operational settings (with examples of Malawi / Namibia) and of guaranteeing long-term sustainability

Session 6: Community Support Tools

Chair: Sophie Bontemps, UCLouvain
Chair: Inbal Becker-Reshef, NASA Harvest

This session, dedicated to community support tools, listed a variety of projects related to agricultural water stress monitoring, to supporting agricultural statistics, policy and food security, to global-scale seasonal and reproducible crop mapping, and to business applications. Furthermore, the role of the Copernicus Data Space Ecosystem as a key provider of data was discussed. The characteristics and advantages of all these projects were discussed, and a summary can be found below.

- The Ecostress Hub was discussed with regards to its support to the Copernicus LSTM: it supports testing land surface temperature (LST) and assessing LST impact on evapotranspiration (ET)
- The Sen4Stat tool is a mature tool for acreage estimates (clear impact of EO on uncertainty, spatial disaggregation and sampling design), and it is progressing with regards to yield. Sen4Stat is currently being demonstrated in more and more countries, with the support of the United Nations Food and Agriculture Organisation, the World Bank, and the Asian Development Bank (ADB)
- The Agriculture Virtual Lab (AVL) aims to facilitate research in the EO agriculture community and to foster collaboration between scientists
- NASA Harvest is developing the Rapid Agricultural Assessments for Policy Support (RAAPS) initiative, which aims to provide EO-driven agricultural assessments in the context of increasing extreme weather, conflicts, decreasing market transparency. It was discussed that this constitutes an opportunity to meet the growing need for information in the GEOGLAM community
- The WorldCereal project has been extended, and the goal is to discriminate between a larger number of crop types, as well as to improve crop calendars and agro-ecological zones (AEZs), all while making the processing system “easy and friendly” to use and building capacity for wider uptake from users
- The EO4EU platform has the objective of bringing technologies to users (data and algorithms). A set of use cases (among which three are related to agriculture) are already demonstrated. The platform will be available soon
- The Copernicus Data Space Ecosystem (CDSE) is discussed as a very relevant tool for agriculture: it allows easy access to the archives of Sentinel-1, Sentinel-2 and Sentinel-3, allows working on areas of interest (it is not tile-based), and is very competitive in terms of price

<u>Recommendations:</u>

- The new upcoming high resolution thermal missions will be a game changer for agricultural water stress mapping
- Regarding R&D, the advice is to focus on yield modelling and on in-season crop type mapping

- Ensuring users adopt tools requires a significant effort in capacity building, so an important recommendation is to ensure funding after the end of the projects, so as to keep sustaining the tools and to keep the support for users, if not from ESA and EC, facilitate the link with relevant institutions
- It is important to be more transparent about the long-term vision of the developed tools, and to do so from the start of the project
- There has been a tremendous increase in the demand for rapid response services (extreme weather, regional conflicts, market uncertainty). This has increased the recognition of the value EO data can bring, and it constitutes an important moment to build on, in the context of our longstanding effort to advance the science and applications
- There is a need for long-term continuity of harmonized and curated reference data repositories, as well as a need for more standardization when it comes to metadata and to accessing and retrieving EO data (currently each service has different means to access data)
- There is also a need to bridge the disconnection between “state of the art” and “state of practice”, so the recommendation is to place the emphasis on co-development and user-led procedures
- Focus R&D activities on the generalization (in space & time) methods exposed in community support tools
- An important recommendation is to ensure that R&D projects include requirements for computational upscaling.

Session 7: Water Resources Intelligence

Chair: Jacopo Dari, University of Perugia
Chair: Livia Peiser, FAO

The main topics discussed during this session on water resources intelligence included a variety of techniques aimed for monitoring irrigation dynamics, mapping and forecasting water use, assessing the effects of agriculture on groundwater levels, monitoring water stress and assessment of drought. The authors presented various methods including integration of soil moisture and land surface temperature into an energy-water balance model, as well as using Sentinel-2 time series and deep learning methods, among others. The usefulness of hyperspectral when compared to thermal infrared was discussed in detail. The main take-away messages are summarized below:

- Monitoring irrigation dynamics (mapping and quantification) through multi-source satellite data is feasible, but room for improvement is large; the lack of-situ reference data is one of the major challenges to be faced
- There exists a variety of methods that rely on several EO products, and attendees discussed if they should be standardized or at least made more comparable among each other
- Satellite data offer the possibility of monitoring irrigation impacts on freshwater availability, which is crucial especially over regions already facing water scarcity
- Satellite data was discussed with regards to their utility as a tool for assessing benefits of modernising irrigation
- Several presentations focused over northern Africa: satellite data are an essential tool for environmental studies over scarcely monitored areas

<u>Recommendations:</u>

- An important aspect is to obtain data on land surface temperature and on soil moisture at higher resolution
- It is recommended to integrate information on agricultural practices in in-situ data sets
- Future missions should aim to reduce the spatiotemporal mismatch between satellite data and irrigation dynamics
- An important recommendation is that projects should foster the collection of high-quality in-situ data
- The community recognized that a long time is needed for water authorities to adopt digital services
- It is also recommended to integrate WaPOR data into the Copernicus Data Space Ecosystem
- Regarding machine learning approaches and process-based approaches, the community discussed the importance for the relative communities be connected
- A recommendation addresses the pending need to tackle the comparison of the many methods currently available for irrigation monitoring

- The operational aspects of evapotranspiration algorithms need to be considered (PT-JPL)
- A final recommendation is for irrigation monitoring to be carried out not only in terms of extent, but also estimate timing and quantification of the irrigation

Session 8: Droughts, Pests and other Stressors

Chair: Thuy Le Toan, CESBIO/GlobEO
Chair: Jose Moreno, University of Valencia

The session concerned the most recent advances in the field of crop stressors and their monitoring, especially concerning droughts and pests. The first presentation focused on multisource data for multi stressors, whereas presentations 2, 3 and 4 focused on drought and presentations 5 and 6 focused on pests. Multiple stress is addressed separately for different sites/crops and conditions.

Regarding droughts, advances in the integration of EO data and modelling approaches were detailed, as well as the use of drought indices derived from a variety of sources and their sensitivity to soil moisture changes. The impact of drought and the assessment of drought risk using time series from Sentinel-2 and Sentinel-3 were also topics of discussion in this session, along with the benefits of the combination of drought indices based on EO data with climate data and with decision tree ensemble technique, with regards to improving forecasting. Regarding pests, the role of EO in pest surveillance and pest management was discussed. The main points discussed by the community can be found below:

- Some applications presented are very local, and when global scale is addressed, the approaches still remain qualitative
- There is a need for additional consolidation (statistical sampling) to tackle the mismatches between the scale of EO products and the reporting outcome in spatial maps
- Most contributions use statistical regression approaches, although there are some attempts to establish physical-based models (e.g. for soil moisture in Africa)
- Quantification of stressors remains a challenge
- Most of the projects are still in an R&D phase, and the involvement of stakeholders is needed to move them to an operative phase

<u>Recommendations:</u>

- It is recommended to guarantee the access to contextual data; in other words, to facilitate the access to ancillary data in the public domain
- An important point is to make available the link between EO and sensitive data, such as socio-economic data or vulnerability data, concerning Europe but also globally (in particular in developing countries) since spatially explicit data on vulnerability remain a challenge (in most cases vulnerability indicators are aggregated to e.g. national scale)
- It would also be desirable to involve stakeholders in the whole process, from the definition of the objective until the validation of the results, and in the follow-on exploitation of the results
- It is important to establish a precise definition of quantitative indicators (for example, a precise definition of crop failure, or of pest impacts)
- Uncertainties need to be properly evaluated
- For each stressor, it is important to include the type of EO data that constitutes the best proxy for the specific stressor

- It is recommended to further exploit the integration of EO data from various sources
- It is also important to carry out an exploration of the cascading effects of multiple stressors

Session 9: Climate Adaption

Chair: Lara Congiu, EC
Chair: Pierre Defourny, UCLouvain

This session focused on state-of-the-art methodologies and tools that tackle adapting agricultural systems to a variety of stressors derived from a changing climate, as well as to human pressures. The main topics presented include:

- Analysis of agriculture productivity of crops using machine learning and process-based models to create soil and farm management maps, as well as to predict future climatic scenarios
- Crop seasonality assessments of maize. Linked to this, calculations were carried out including variables such as rainfall/sun related to the growing season to perform better crop yield estimation and identification of optimal planting
- Winter wheat production and migration cropland to analyze the impact of climate change to better plan and manage production
- In Senegal, rice represents a major nutritional crop, and the goals of the project were to increase crop fields and their intensity while maintaining an effective irrigation network
- The VietSCO project aimed at improving food security in the Mekong delta. There, the stressors on rice farming, which are due to climate change and to human pressures, were analysed using both in-situ data and satellite data for model-based observations. The outcomes have been the adaptation of the crop calendar, reduction of cropping density, conversion to other land use types and decrease in methane emissions.

Recommendations:

- There is a need to improve the temporal resolution of EO missions
- Analysing the impact of climate change on agriculture requires high-resolution climatic data with large area coverage
- The recommendation is for geospatial products (crop maps and points) to separate the winter and summer crop varieties of the same crop
- It is needed to continuously integrate EO data and machine learning, when it comes to intervention and aid strategy
- There is also a need for an enhanced integration of EU with regional data and data from agriculture organisations, along with coordinated reporting of yield data
- Satellite data should be adapted to tropical regions
- More investment is needed on ground data and Internet of Things
- There is a need for integrated observations of the impact caused by multiple stressors
- Inclusion of socio-economic data in climate change analysis is also relevant
- It is important to invest in better user uptake of EO applications, services and products, by co-developing solutions in partnership with relevant (local) stakeholders also in testing phases

Session 10: Data Integration

Chair: Marijn van der Velde, EC, JRC
Chair: Linda See, IIASA

This session provided an overview of various types of data (e.g. from drones, in-situ data via LUCAS photographs, various types of crop maps and administrative data as well as data from Wikipedia) which can be integrated with EO and allow each to tackle specific challenges. There were four presentations in the session, and the main points are detailed below for each of them:

- Drone Sampling - increased efficiency of drone surveys for agricultural applications:
    - Demonstrated the use of small low-cost drones in combination with a mapping system and sampling strategy (instead of the need to fly over the whole field with overlaps), resulting in lower costs, lower flight times and lower data volumes compared to a more expensive drone that maps the whole field
    - Use cases include damage assessment for insurance and invasive weed detection, among others
    - It is a very promising use case for the future when it comes to the calibration and validation of EO data

- Bridging the Gap: Enhancing Land Cover Classification Through In-Situ Photo Analysis and Remote Sensing Integration:
    - This presentation tackled the integration of in situ data via LUCAS photographs and remote sensing for land cover mapping
    - Authors used computer vision and semantic segmentation of LUCAS photographs and machine learning to predict land cover
    - The accuracy assessment of LUCAS land cover and recent high resolution land cover maps (ESRI, WorldCover and ESRI's dynamic land cover) yielded overall accuracies of 52 to 59%
    - The study undertook a semantic gap evaluation by comparing the semantic labels from the photographs where there were errors in the land cover map to provide context and information about the reasons for these errors occurring
    - The community identified a promising use for this topic, related to the detection of areas/biomes where more commission errors are happening
- A new high quality global hybrid herbaceous annual cropland map for the year 2020:
    - This presentation focused on integrating existing state-of-the-art high-resolution cropland maps to produce a hybrid cropland map
    - Two cropland maps (UMD Cropland, which includes fallow and WorldCereal 2021, which excludes fallow) were compared for disagreement areas despite some differences in their definitions

    - Hotspots were then identified, and expert-based local corrections were made to the map using very high-resolution satellite imagery and other data sources, e.g., street level imagery

    - This approach is promising as it constitutes a simple way to create a hybrid map from existing products and ancillary data, in order to produce a more accurate product for global agricultural monitoring. It is noted that it could be used in many other applications

- Knowledge distillation from Big Administrative Data:
    - The presentation detailed an approach to integrate administrative data and content from Wikipedia on crop types via a large language model: Eurocrops harmonized product using GeoSpatial Application (GSA) data and Hierarchical Crop and Agriculture Taxonomy (HCAT), created through manual labelling, translation and matching

    - The study used a Retrieval Augmented Generation (RAG) approach with a Large Language Model, providing the model with Wikipedia pages in different languages to help do the translation and mapping of crop types to HCAT

    - Results were promising and improvements between versions of ChatGPT were observed in the mapping of categories but not in the translation, which still contained errors

    - This approach is promising and there is a potential extension of methods presented in this study to many other tasks that would otherwise require a large amount of (manual) resources

<u>Recommendations:</u>

- In relation to the drones for mapping:

    - It is recommended to consider the complementarity of small drones for high resolution mapping and for flexible data acquisition

    - To exploit the benefits of drone sampling and to explore drone products for the validation of existing EO products

    - Future research should support new EO satellite missions

    - Sharing platforms are needed to tackle the risk of fragmentation of different drone products and infrastructures

- In relation to the integration of in situ photographs and remote sensing:

    - It is important to maintain the temporal stability of in situ products like LUCAS

    - It is recommended to consider streetview as a source of information for land cover mapping, because it has incredible potential that has yet to be exploited

- In relation to hybrid cropland mapping integrating existing products:

  - To gain a better understanding of the influence of the quality of the in situ data on the final classification cost, compared to the processing costs, to understand if more resources should be invested in good quality situ data
  - Data integration can be best done if data are FAIR and free, ideally cloud-optimized and catalogued on the OpenEO platform to facilitate seamless workflows
  - Data comparison, data integration and in situ data should get the necessary attention since crop type mapping can only be done with sufficient, high-quality ground data
  - More research is needed in optimizing training and validation collection, to better understand how costs can be reduced (e.g. can costs be reduced while maintaining a minimum level of statistical robustness?)
  - There is a need for an operational service for crop type mapping (especially for major global crops), beyond the mandate of ESA

- In relation to the integration of administrative data and Large Language Models (LLMs) for matching and translation:
  - It is recommended to provide better access to administrative data (in this case GSA) as gated-access is prevalent
  - To provide more computing resources for using LLMs for tasks like automated matching and translation

    To provide more funding for this type of automated matching and translation so data can be compared

- Other recommendations/comments
  - Standardize data such as the GSA and ask member states to publish them according to an international standard like the international species register or automate this process afterwards
  - While we require data from farmers, it is not mandatory for member states to provide these data in a harmonized way. The community wonders the reasons behind this and recommends that it be improved
  - Funders should put much less stress on the need to reach a minimum level of accuracy and instead stress common terminology (i.e., common classes) that are comparable across products even if this means that some individual classes may have higher commission and omission errors

Panel 1: FAO

Organiser(s): Lorenzo De Simone, FAO

Moderator(s): Jose Rosero Moncayo, FAO

The FAO Panel consisted of 10 min talks which highlighted the use of Earth Observation (EO) by different teams working in FAO to solve real-world agricultural problems, emphasizing the user perspective and various applications. This Panel brought FAO's experts who explore how the Earth Observation can support sustainable practices, multi environmental climate and socio-political pressure mitigation. During the panel discussion following topics were presented:

1. Monitoring pressure on agriculture resources: EO for land and water information systems

- Due to significant population growth the agriculture productivity is compromised by pressures on land and water, exemplified by drought and flood cycles in Pakistan.
- EO projects like WaPOR provide real-time open access data on e.g. water productivity, evapotranspiration. Other datasets include information on roots and soil moisture (beta product).
- FAO offers also detailed land cover and crop type mapping at 10m resolution and databases like global agroecological zones used for sustainability assessments.
- "Status of Food and Water for Food and Agriculture" - FAO's publication, provides more insights into the topic of monitoring pressures on land and water resources that affects agriculture. Next version of this book is due next year.

2. Crop mapping and crop yield process-based models for adaptive agriculture in the face of climate change

- Main challenge in accurate crop assessment is the difficulty with timely locating, quantifying and estimating crop production.
- EO data plays critical role in modernizing official crop statistics which can help to tackle the challenges. In line with the recommendation from the Agenda 2030 and the SDG Framework FAO provides support in this matter by collaborating with National Statistical Offices.
- One of the key FAO's initiatives is EOSTAT: launched in 2019, supports capacity building in crop mapping, yield forecasting, and survey design optimization. Some activities support understanding of the current data collection protocols, discussing their expectations for the EO data, understanding the gaps in the field data collection, co-designing and co-implementing pilots and co-validation of solutions.
- For crop mapping and validation FAO uses Sen4Stat supervised approach developed with collaboration between FAO, ESA and UCLouvain.
- The advantages of using process-based crop growth model developed in collaboration with Michigan State University for crop type mapping and yield mapping were highlighted. The model allows to evaluate the response of crop to the daily input such us the solar radiation, precipitation, temperature. It also allows to simulate the soil-plant-atmosphere systems which enables to obtain prediction at pixel level. The crop yield can be model in spatially explicit manner, in different seasons.
- It is very important to use such models because we can easily implement there the climate anomalies data to understand what the crop response in 5 or 10 years in a given country under specific conditions will be. Importantly, in some countries by the average minimal temperature

rise, the yields are seen to be lower, so the countries could be warned to start thinking about more adaptive cultivars in their area.

- Adaptive agriculture can benefit from EO by its contribution to decision-making, risk mitigation and planning (water and fertilizers use), supply chain management, and support for the policy and insurance programme.

3. Assessing and tackling drivers of deforestation

- Despite its enormous role in terms of livelihoods, biodiversity, water cycle (closely linked to agriculture), climate change mitigations, in the last 20 years 100 million hectares of forest has been lost.
- How can EO data support hunting the deforestation? To study forest changes FAO introduces FAO FRA Remote Sensing Survey (RSS). Based on 400 thousand samples all over the world, including Sentinel and Landsat data but more importantly local experts were involved (~800 National Experts) to integrate the field information with the RS results and allow their interpretation.
- Agricultural expansion, especially small-scale farming, is a significant driver of deforestation, including the loss of mangroves.
- FAO's FRA 2025 RSS aims to monitor forest changes with updated data (e.g. EO Planet data) and new variables (incl. specific crops, pastoral systems, mangroves etc.)
- FAO works in three main workflows: enhancing synergy between forest and agriculture, mobilizing climate finance, and promoting sustainable forest management.

4. EO for the assessment of the impacts of war on agriculture in Ukraine

- An assessment of the impacts of war on agriculture in Ukraine, using as an example the Kakhovka dam breach has been presented. Explanation on FAO contribution to understand the impact of that dam breach on agriculture was discussed.
- The importance of the dam and its irrigation network has been emphasized (800 thousand ha of irrigated lands, that fed 8-10 million people/year, 4 oblasts affected)
- Assessing impact of that destruction of the dam was very difficult taking into account that field campaigns were not possible to be performed in active conflict zone.
- Other challenges in the assessment included: very short time for the anayses: data from 2022 and 2023 had to be compared; lack of baseline information in particular for 2022; outdated irrigation network map.
- Geospatial analysis was an essential tool the main tool to fill data gaps. With high-resolution imagery the impact could be seen, even within 2 weeks after the dam breach (example of North Crimean canal).
- FAO's collaboration with DIEM (Data in Emergencies) and Agrifood Economies Division enabled loss estimation and highlighted the need for substantial resources to rebuild the dam and irrigation network.

Discussion and Q&A with the audience:

1. Forest disturbances – their definition:
    - Disturbances include deforestation, degradation, fires, logging, wood energy and charcoal consumption, storms, and pest diseases.
    - FAO aims to capture reasons behind forest unstocking by adding relevant variables to measure that.

2. Standardized survey design for National Crop Statistics: Is the standardized survey design applied uniformly across different countries or contexts, and what metrics are used in national crop statistics surveys? (Lorenzo de Simone)
    - Initial step: Assess existing annual agricultural surveys and their suitability for geospatial analysis (e.g. sample plots distribution).
    - If no survey exists, design from scratch using EO data, geospatial data, and coherence formulas for sample collection.
    - Use standardized approaches: random sampling, stratified sampling, and coherence formulas.
3. Match and mismatch between national statistics and models. Is the statistics helpful to calibrate the models? (Lorenzo de Simone)
    - EO-based crop assessments often align well with official statistics.
    - Regression-based models (e.g., LAI, NDVI) are weaker compared to process-based models.
    - Pre-trained process-based models, validated through backcasting, align well with official statistics and understand anomalies.
    - Integration of EO data with field surveys enhances accuracy.
4. Which type of the insights or collaboration do you see coming from the community?

- The partnership with the scientific community is crucial, especially in the areas of conflicts like Ukraine, Gaza or areas in Africa impacted by El Nino, to be more specific particularly in the crop type monitoring and to always get improved information.

<u>Recommendations:</u>

- Strengthen partnerships and ensure the availability of open data, methodologies, and tools to support agricultural monitoring and decision-making. More partners are needed to find new resources and ways to engage the private sector.
- In terms of data: FAO looks forward to using the Copernicus LSTM data and the precursors data, Global evapotranspiration (through WAPOR this is available at 300 m resolution in the real-time), but resources are needed; crop type mapping, irrigation mapping, phenology but at the operational level (not project's level).
- FAO recommends using supervised approaches (like Sen4Stat) for crop mapping that leads to validation.
- Involve local experts and national statistics offices in the design and implementation of EO projects to ensure relevance and accuracy. FAO can play a role in stronger countries engagement which is very much needed.
- Foster climate engagement among different stakeholders to support sustainable forest management practices. Develop and utilize comprehensive forest monitoring systems to provide detailed and actionable information.

Panel 2: High Level Policy Panel

Organiser(s): Espen Volden, European Space Agency
Raphael D'Andrimont, EC, JRC

Moderator(s): Sophie Bontemps, UCLouvain
Raphael D'Andrimont, EC, JRC

This panel discussed the transition of agricultural monitoring from research and development (R&D) to operational applications useful for policies, but with plenty of challenges, particularly emphasizing the roles of various organizations in this process. The panel consisted of three rounds of the same questions posed to each panellist and was followed by the discussion and questions from the audience.

Q1: What is your organization's role in ensuring transition from R&D into operations?

- ESA has a very strong role in R&D activities providing input for operational services by supporting mission operations, data quality improvements, veracity of data. Lots of efforts is placed on stakeholder and policy owners' engagement to develop long-term strategies like 'Earth Action,' while seeking operational partners for scaling solutions.
- JRC, is providing scientific input and research to policymakers. It is renowned for the achievements in land use mapping, crop monitoring, and yield forecasting, contributing to ESA missions (e.g. by providing user requirements) and agendas of EC research in collaboration with DEFIS and RTD to translate scientific data into actionable information.
- GEOGLAM focuses on transitioning R&D into operations, addressing policy needs through products like Essential Climate Variables and gap analyses, while performing capacity building and training to advance operational crop monitoring, particularly in African countries, and facilitating agricultural research through the JECAM network.
- WFP emphasized the critical need for investment in field data collection, noting that AI efforts are ineffective without ground-truth data, and highlighted the importance of collaborating with local institutions in developing countries to translate research into practical solutions that address real-life problems.
- FAO focuses on policy-relevant information and data. Data collection, harmonization, and republishing data is one of the key tasks to enhance agricultural information. FAO improves data collection in various countries through cost-effective technologies, improved crop mapping, and detecting land use and extreme events, supported by programs like 50x2030 to elevate data collection standards in 21 member countries.

Q2: What are the major challenges & limitations to succeeding in moving from R&D to operations?

- ESA: One major challenge is that policy-making is not within ESA's mandate. While ESA excels in delivering products and translating data into usable information, there are still hurdles due to a lack of awareness among policymakers about the potential of EO data. This awareness gap can hinder appropriate technology investment. ESA's systematic approach involves identifying needs through collaboration with policy owners and the user community (pathfinding), funding promising initiatives (seeding), and expanding successful projects (scaling). However, bridging the gap between R&D and operational use requires aligning these efforts with policymakers' understanding and needs.
- JRC: DG AGRI and JRC is investing now in making the data interoperable and reusable, which is crucial for future development. The challenge lies in setting up data collection mechanisms

for validating or training remote sensing data, highlighting the need for data reusability (circular economy). Creative integration of different datasets is essential, along with ensuring the stability of services and long-term missions to support operational applications. Innovation in methodology is necessary to address real-life questions and needs effectively.

- GEOGLAM: Sustainability and long-term vision are essential. Bridging the gap between R&D projects and operational services, such as Copernicus, presents a significant challenge. Mechanisms are needed to finance semi-operational activities, while capacity building must be integrated into project proposals to enhance operations effectively.
- WFP: Addressing ongoing agricultural crises globally requires access to relevant information, which often proves challenging despite the wealth of recent research results. Continuous support is needed to fill that gap, in the technologies and methodologies (from the research) and the financing to transfer the knowledge and to go to operations. Targeting national partners could facilitate this transition effectively.
- FAO: Two primary challenges include financial and human resources. A sustainable approach to capacity development and technical assistance involves decentralized offices empowering local communities. While resources for data are limited, there's a growing willingness among donors to finance initiatives. Collaboration among multiple institutions can create larger programs to make data generation more appealing to donors.

Q3: FAO, WFP and GEOGLAM recommendations to EC and ESA to help the transitions.

- FAO suggests ESA's assistance with shaping science and providing more frequent, high-resolution imagery, particularly for intercropping initiatives. Collaboration with EC is crucial for community connection and financial support.
- WFP proposes transitioning some research champions to operational roles and evaluating their effectiveness in the field.
- GEOGLAM highlights Copernicus's global leadership and emphasizes the need to implement semi-operational research into operational strategies. Joint efforts between EC and ESA in capacity building and in technological advancement.

<u>Discussion and Q&A with the audience:</u>

Q1: Regarding capacity building (particularly in developing countries): it is sometimes very difficult to tell people what they should do, when we are bringing our own methodologies for data collection or models. How the organization deal with that?

- WFP: as the WF organization is not providing solutions but helping to solve problems identified by the local community. The research information is useful in understanding the gap, and what are the expected numbers for the upcoming crisis for instance. Identification of problems and implementation of possible solution is done together with the community.

Q2: Deep Learning (DL) and new innovations are emerging every day. What would be a strategy in finding a way that the community would be satisfied with the existing methods and become operational instead of continuously searching and advancing new methods in the R&D projects.

- FAO: we should think of upscaling of our activities. It is therefore recommended in the FAO projects to scale them up with some solid methods.
- GEOGLAM: We have to always start the project from the user needs. State-of-the-art answers are not always necessary. Nothing is wrong with the service that is based on the outdated technology unless is answers the user needs.

- JRC: A right balance what you can find, what can be improved and what is to be delivered must be adopted. Products should be showed and advertised to the community.

Q3: As an early-career scientist which are the metrics of success in terms of publications and citations? Is there a way to train scientists to produce something that works and helps also people at the same time?

- GEOGLAM: The metrics of the success that we should look at is the impact of the projects. It does not have impact on scientist career, but it gives a visibility, builds a network. Getting visibility on the projects it's the right direction.

General recommendations from the discussion:

- Emphasize sustainability in project outputs, utilizing public-private partnerships and business models to scale R&D project outcomes effectively.
- Adopt business models conducive to scaling products for operational use.
- Connect existing innovations with emerging technologies to bridge skill gaps and support the research and design of new initiatives.
- It is crucial to provide visibility on products. Possible recommendation: peer-review of the product (by the independent community): define the community that could peer review the product, not only the research papers, to assess if that can go to community.

Panel 3: EUDR

Organiser(s): Felix Remboldt, EC, JRC
Zoltan Szantoi, European Space Agency

Moderator(s): Zoltan Szantoi, European Space Agency

The panel discussed the topic of regulation and deforestation free products. Short presentation was provided by each panel member which was followed by the discussion on several emerging points.

<u>The role of geospatial information for mapping and monitoring deforestation free commodities</u> (Felix REMBOLDT, EC, JRC)

- Geospatial information (GPS and VHR) is crucial in the EUDR Regulation for proving commodity origins and ensuring due diligence, aiding operators, traders, producers, smallholders, and state members in demonstrating sustainable production and conducting risk assessments and controls.
- Additional data for risk assessment includes land use change maps, deforestation risk maps, and a forest disturbance alarm system.
- Existing global forest maps are insufficient at the parcel level;
- National maps with transparent methodologies allowing for direct mapping of commodities offer added value, compared to existing global forest maps – less useful at the parcel level.
- World AgroCommodities, an ESA initiative, provides technical support to member states for verifying due diligence declarations.

Short presentation of each organization represented at the panel:

- Francesca Ronca, Unipalma:
  - Promotes science-based palm oil information and sustainability, collaborates with trade associations to raise awareness among Italian stakeholders
  - Supports the EUDR regulation, which mandates deforestation-free and legal products by 2025, necessitating thorough supply chain tracking and risk assessment.
- Steffen FRITZ, IIASA:
  - IIASAT known from many activities related to global modelling, IPCC work on land use and competition, training data collection with initiatives like Copernicus Land Products, WorldCover and WorldCereal as well as crowdsourcing campaigns and geowiki tools.
  - Regarding EUDR, IIASA collaborates with Guidehouse that will categorize countries into different risk levels, determining the proportion of due diligence polygons to be inspected: 9% for high-risk, 3% for standard risk, and 1% for low-risk countries.
  - A centralized European database will collect and check due diligence polygons for commodity tracking as they are submitted.
- Remi D'ANNUNZIO, FAO:
  - FAO's Forestry Division develops free and open-source EO solutions with a focus on forest monitoring, particularly under the Open Forest initiative.
  - The EUDR regulation is an opportunity to promote transparency and open-source processes and datasets.

    - Collaborates with the SAFE (Sustainable Agriculture for Forest Ecosystems) project as a part of Team Europe Hub on deforestation-free value chains initiated at COP28, to develop digital public infrastructure to produce geolocation information and create open-source databases.
- Felix REMBOLDT, EC, JRC:
    - Three teams are working on EUDR implementation at EC-JRC.
    - 1st team: capacity building for countries to map and monitor commodities under the EUDR regulation, particularly focusing on agriculture.
    - 2nd team: Contributes to the EUDR through the EU Forest Observatory, providing global forest maps.
    - 3rd team: Investigating the socio-economic impact of the EUDR, particularly on small-scale farmers and transitions toward more sustainable practices.

<u>Questions from the audience:</u>

Q1: Do you assess cases of over logged forests resulting from selective logging or illegal logging, specifically focusing on wood and wood-based products?

- The EUDR addresses deforestation for six commodities and degradation for wood, which must be degradation-free and legal, with selective logging not considered degradation if sustainably managed.

Q2: Do multiple stakeholders, including producers, the EC, and national competent authorities, use the same data but apply different algorithms for compliance? How do we determine which algorithms are correct and how to judge their validity?

- All parties are involved, but due diligence is the operators' responsibility to prove products are deforestation-free; member states verify these statements, potentially using different data, and the regulation remains open on which data to use, with no definitive answer yet on validation methods.
- We need to differentiate between EU member countries' risk assessments, utilizing available maps for optimization, supplemented by high-resolution images in high-risk areas, while recognizing that not all collected data (polygons) may be disclosed for EUDR regulation compliance.
- Multiple stakeholders, including producers, the European Commission (EC), and national competent authorities, use data from the EU Forest Observatory, however this is not legally binding. Additional information such as ground observations, traceability, and geolocation data used by many producers may not be directly shareable due to privacy concerns.
- Harmonization and alignment among member countries is essential for evaluating products, determining which algorithms are correct and judging their validity.
- Guidelines for data treatment will be issued in June/July 2024, accommodating diverse resources and understanding levels among competent authorities, with the regulation assuming best practices from each EU member state; efforts are underway to ensure minimum data availability through digital public infrastructure, leveraging existing country data and JRC products for a good basis.
- Definition of forests based on land cover is challenging, including the classification into forest of temporary non-stocked areas and the absence of accurate tree height information (<5m). We must not be concerned only about tree cover but looking at forest management to understand the agro-forestry systems.

- National authorities may supplement Sentinel data, with its 10m resolution, by exploring additional options like Planet data, ensuring GPS accuracy and potentially acquiring Very High-Resolution (VHR) data, especially for legal proceedings.

Q3: How is the definition of forest including a minimum potential height of 5 meters for future tree growth addressed?

- This is presenting a challenge that requires examination of past data to determine if the area historically exceeded this threshold.

<u>Other discussion points and recommendations:</u>

- <u>Recommendation to the EO community with respect to EUDR:</u>
    - Contribute to provide evidence of Forest Cover 2020
    - Be at the forefront of supporting countries and farmers and provide elements of feasibility, best practices and standards
    - Promote open data, transparent methods validated results
    - Be open to new partnership
    - Scale up
- The innovation that EUDR brings is the necessity of providing geolocation data at the plot level. This is the area where the immediate support is required and initial focus on addressing concerns regarding data quality.
- Harmonize data treatment methods among stakeholders to ensure consistency and validity.
- Ensure transparency and privacy considerations in sharing additional information such as ground observations and geolocation data.
- Very often small-holder plantations are not visible on crop maps, which are available to EO community. A baseline for both sides producers and national authorities should be provided to make better decisions.
- Numerous challenges persist, particularly in the countries like Ivory Coast where there are many parcels to control under the EUDR regulation. In such cases there is the possibility for some smallholders to bear the cost; however, the regulation may deter illegal activities and promote sustainable production. Complete every single plot control remains difficult to achieve. But if the regulation discourages some activities which are illegal, and cannot prove the sustainable production, it will be a great achievement.
- Companies must adhere to due diligence requirements outlined in various directives, including the EUDR. It's a part of commitments that companies are taking upon to align with sustainable practices.

Panel 4: In-situ: the last hurdle?

Organiser(s): Raphael D'Andrimont, EC, JRC

Moderator(s): Sven Gilliams, GEOGLAM
Raphael D'Andrimont, EC, JRC

In this panel, invited panelists were asked to summarize in 5 minutes their roles along with current and future challenges with respect to in-situ data.

- Jose Miguel Rubio Iglesias (EEA) emphasized the critical role of in-situ component data in enhancing the accuracy and validation of Copernicus services, highlighting the challenge related to coordination of myriad of data providers that provide in-situ data. CORDA platform has also been demonstrated as a key tool for accessing geospatial data (including LPIS/GSAA data) to Copernicus services providers.
- Inbal Reshef (NASA HARVEST, Univ. Strasbourg, GEOGLAM) advocated that it was not the last hurdle, but one of the key hurdles that we have. Agriculture needed a holistic approach, and the applications must start from end users to make sure that the work we do is driven by their needs. In-situ data is critical to all diverse application areas, to meet their requirements. She also highlighted the potential of connecting with private companies, especially considering the amount of data that private sector possess.
- Gregoire Tombez (Green Triangle) shared insights on digital crop insurance applications and how in-situ data supports damage assessment and yield estimation. The collection of the yield data is done at two levels: one is field level and another administrative level done with the use of stratified random sampling – that allows to create representative datasets. through mobile apps, data being available in real-time to perform quality checks.
- Sophie Bontemps (UCLouvain) outlined contributions to EO for agriculture, emphasizing collaborative projects that integrate EO and in-situ data for enhanced agricultural monitoring (e.g. Sent4Stat, Sen4CAP and Sen4Agri). She also underlined the importance of enhancing the existing protocols while working with different stakeholders to make data EO compatible.
- Luca Kleinewillinghöfer (EFTAS) discussed the integration of in-situ data in environmental monitoring and how EFTAS incorporates ground data collections into their EO services (e.g. IACS, LUCAS, CAP control, EMBAL).
- Steffen Fritz (IIASA) focused on the challenges of obtaining high-quality in-situ data and the opportunities for improving reference data collection methodologies and activities to support agricultural monitoring and making data EO-compatible ie:
    - WorldCereal – most of the data are open and share. EO data will be placed in the STAC Catalogue to make data cloud-optimized.
    - CropObserve app – released in LPS2022, all data is open, involves non-experts data collection about the crop type but also phenological stage and damages.
    - Mapillary – interface to perform AI crop detection with a possiblity to delineate the fields making them EO-compatible.

  He underlined the efforts which are made to make data FAIR – highlighting the difference between fair and open and publicly accessible data vs exchanging data between the scientists.

Recommendations:

- Making the best use of in-situ data (making data EO-compatible): quality assessment – part of data collection process.
- Co-development and equitable engagement with communities where data is collected
- The application matters – depending on the application the requirements for in-situ data changes!
- Public-private partnerships and articulation of mutually beneficial propositions
- Innovation in data collection: crowdsourcing opportunities, street2sat, partnerships, multi-disciplinary teams; scientific progress (active learning, model transfer, etc.)
- Reliable yield data are even more challenging than information on crop types and area) still the guidelines are needed
- Involving national stakeholders is crucial for sustainability and EO endorsement
- Short term survey projects often entail high logistical challenges.
- Legal framework for data collection on the ground is often unclear, with access to existing data which is limited
- Push more for the open data, transparency and interoperability.
- Data collection not yet adequately integrated into project planning and calls for tender
- All the ESA projects must have a clear cause to make the in-situ data available. This will be a game changer. All the reference data must become available and the validation as well.
- With ML data available, more data we have on crops the better the model will become.
- Unclear legal framework for collecting field data and access to existing agricultural data is limited.

Panel 5: PRISMA, EnMAP and ECOSTRESS experiences

Organiser(s): Zoltan Szantoi, European Space Agency

Moderator(s): Zoltan Szantoi, European Space Agency

Panel members presented shortly themselves giving an overview of their experiences in exploitation of hyperspectral imagery provided by PRISMA, EnMAP and ECOSTRESS missions and their instruments. Each of the panellist presented the main characteristics of the mission they work with, providing examples of their capacities and applications in agriculture:

EnMAP:

- Launched in 2022, operational from 1 year and a half.
- 246 spectral bands, in a range from 400-2500 nm
- Registering light from visible to shortwave infrared - with very good signal to noise ratio
- Data are freely available: by access to archive or by submitting special targeted request
- Acquisition length is 1000 km/orbit as a maximum
- For agriculture is a very powerful tool
- HyperEdu is an educational program designed to learn how to work with hyperspectral data.
- The EnMAP Toolbox offers free tools for processing L3 and L4 hyperspectral data, providing a starting point for working with such data. Chlorophyll content and LAI products are already included in EnMAP Toolbox.
- At the moment more than 2000 users are registered.
- Commercial use not restricted, but no task acquisition is supported for commercial users. Scientific users are given priority.
- No global coverage is achieved yet – limiting factor regarding the applications. Gap hopefully can be filled by upcoming CHIME mission.

PRISMA:

- Similar parameters to EnMAP, but PRISMA was a precursor of this type of satellites
- 270 bands, but by eliminating the overlapping bands, it has about 230 bands
- Covers visible to SWIR spectral bands from 400 – 2500 nm
- Swath width of 30 km
- Revisit time 29 days with possibility of another acquisition to improve the revisiting time
- strip acquisition up to 240 km
- Experimental mission
- We are in the phase of understanding the opportunities and challenges related to processing, calibration and amount of data available.
- Around 20 % of PRISMA users use the images for agriculture purposes.
- In last 5 years around 90 research papers have been published related to agriculture.

ECOSTRESS:

- Highest spatial resolution thermal infrared sensor in space at the moment
- 5 spectral bands between about 8-12 micrometre
- Swath width about 400 km
- Because of wider swath width it has higher revisits of about 3-5 days globally

- It produces a set of standard products – producing data for agriculture application (e.g. evaporative stress index, evapotranspiration
- With the use of different equations for instance Priestly Tailor Approach the evapotranspiration is calculated to derive Level-3 ET-PT-JPL product.
- Another product to list is Level-3 DisALEXI-JPL which uses disaggregation approach
- Standard products are usually available 3-5 days after the acquisition, free to use.
- Data for Europe can be also downloaded through European Hub
- Mission launched in 2018 initially planned for 1 year has been extended to be in space until 2029.
- **Placed in precessing orbit** - **acquiring data at different times of day**. Advantage: allows measuring surface temperature at different times a day (e.g. to assess the changes in evapotranspiration), disadvantage: due to existing algorithms that rely on measurements at specific times of day, assuming particular crop behaviours.

Use of the three abovementioned satellite missions in agriculture:

- PRISMA – news is that the data is now free also for commercial applications.
- Hyperspectral and thermal data is very essential for agricultural applications.
- The importance of PRISMA, EnMAP and ECOSTRESS in agriculture applications was clearly stated - data provided by these missions can serve to enhance currently existing products such as LAI or explore new products in applications such as fertilization, irrigation, soil organic content estimation etc.

Recommendations:

- Use more PRISMA, EnMAP and ECOSTRESS data in the research in order to develop new algorithms, find synergies and address lessons learnt – important in the view of new operational missions (CHIME, LSTM)
- Large volumes of data require very demanding computation, new solutions in IT needed
- Relation between physical models and AI models have to be better understood
- Operational satellites are needed and are expected by the community – improved temporal resolution.
- New solutions to deal with clouds shall be studied - solutions from multispectral don't work well.
- Staggering missions (upcoming SBG, LSTM, Trishna) and existing ones allows for daily images and day-night data, unlocking diverse new application potentials.
- Panellists emphasized the importance of PRISMA, EnMAP and ECOSTRESS, which are experimental missions in the preparation of operational missions e.g. CHIME, LSTM and the necessity to work in finding the synergies to make jointly use of these data and learn from the experiences.

Panel 6: Experiment preparing for the use of new Sentinels

Organiser(s): Espen Volden, European Space Agency

Joshua Gray, European Space Agency

Moderator(s): Espen Volden, European Space Agency
Joshua Gray, European Space Agency

This session had a form of open discussion with the audience on demonstrated ideas proposed by ESA in preparation to the recently announced FutureEO programme initiative – The Sentinel Users Preparation (SUP). The goal of this session was to investigate which developments should be made to ensure optimal exploitation of the application and opportunities which will be provided to community with the future Copernicus Sentinel Expansion and next Generation missions.

Espen Volden started a session with an overview of potential, generic requirements, trade-offs, needed data and research questions that could be addressed.

Joshua Gray provided presentation on the importance of phenology information from sensors in agriculture, using it as an example for new Sentinel experiments. He emphasized Phenocams technology, which can create a link between coarse spatial resolution satellite imagery with ground-level crop phenology observations. Combining Phenocams measurements with direct observation protocols tailored to specific needs can enhance understanding of land surface phenology products (LSP) from Sentinel.

Key characteristics of Phenocam instruments include:
- Very low cost
- Oblique view angle
- RGB imagery of agricultural fields, grasslands, and forest sites
- Image capture every 5 minutes, centrally processed into time series

<u>Recommendations:</u>

- Depending on the crop there is variety of parameters that might be of interest. First step would be to identify which type of crop we would look at.
- For crop processed based modelling prioritize the phenology as the key input in calibrations.
- Consider multi-angle cameras mounted on towers to overcome the shadow issues that oblique angle of that camera produces sometimes.
- Among potential data that are missing to derive crop phenology are: crop type we look at (e.g., wheat, maize), information about crop management, agricultural practices, basic agronomy information, fertilizing management etc. Also, information on air and soil temperature, plant-available water, soil microbiology data should be included.
- Establish synergy between various observations e.g. tower observations, collocated meteorological data, observations from missions like PRISMA, EnMAP, exploit ESA campaign data.
- Observations should cover at least one full season and at least two different sites (to avoid situation that one site is influenced by for example periodic lack of water) however this exercise might require to be performed in the controlled, experimental facility since its difficult to obtain reliable results with the presence of e.g. diseases

- Collected data should be made available for future research projects
- Consider that characterizing the phenological stage at experiment site requires data over a wider time span, which may limit some applications. For yield forecasting, recording the BBCH-stage is crucial and should be prioritized.
- Focus on specific types of crops and explore various factors like seeding dates, fertilization, and soil conditions, ideally across at least two fields, representing diverse rainfall patterns, or other affecting factors and geographical locations.
- Incorporate crop emergence dates as a critical parameter in crop modelling.
- Initiate communication with other communities (for example modeling community) to explore opportunities in data reusability for upscaling.
- Increasing significance of frost events on perennial crops (e.g. grapes, apples), particularly with earlier blooms due to warmer weather, important for governmental and insurance purposes.
- Adopt a crop-agnostic approach to address farmer concerns such as fertilization costs and compliance with the new CAP. Replicate findings across different crops and regions, integrating with carbon market dynamics and carbon credits to provide high-impact information.

Panel 7: Copernicus uptake for EU Agricultural policies

Organiser(s): Raphael D'Andrimont, EC, JRC
Marijn van der Velde, EC, JRC

Moderator(s): Marijn van der Velde, EC, JRC
Usue Donezar Hoyos, EEA

The JRC and the EEA moderated the Copernicus Uptake for Agricultural Policies Panel that featured inputs from DEFIS, DG-AGRI, DG-ENV and Eurostat on their current and future use of Copernicus products for their respective domains.

Usue Donezar Hoyos (EEA) provided a comprehensive overview of Copernicus Land Monitoring Service (CLMS) products, highlighting two main ones utilized in agriculture: land use mapping and biogeophysical parameters. Specifically, discussed HR Vegetation Phenology and Productivity, initiated in 2017, with potential expansions to cover tree cover disturbances and biomass productivity. Land use mapping encompasses high-resolution layers categorizing areas into vegetated, non-vegetated, and water bodies, with vegetated layers detailing forest, grasslands, and crop type maps. Additionally, another product based on VHR coverages that is being developed includes small woody/landscape features.
Marijn van der Velde (DG JRC) highlighted the JRC team's work in benchmarking Copernicus products, creating an accessible database harmonizing multi-annual public GSA data (covering 48 million ha for 2021). This work led to a hierarchical crop taxonomy published recently (Schneider, 2023) crucial for reporting country crop statistics. Also showcased methodological developments in European crop mapping for 2018 and 2022 using LUCAS database and Sentinel data. Discussed the impact of agricultural policy on landscape, such as crop diversity, and the use of VHR and HR observations to monitor small woody features (SWF) loss by combining with Sentinel observations.

Topics discussed at the panel included:

- **DG DEFIS' ambitions engaging policy users for Copernicus uptake beyond the current multiannual framework (beyond 2028)**

Tim Lemmens (DG DEFIS): Copernicus will continue operating and providing free products to all users. Future evolution is necessary to address technological advancements, user needs, and scientific developments. Efforts have begun with a focus on user uptake, national collaboration programs, and integrating new technologies like LSTM, CHIME, and the next generation of Sentinels, aiming for 12 satellites in orbit by 2028.

- **What are the current uses of EO in your policy areas, and what opportunities and significant gaps remain that could enhance policy uptake?**
    - Koen Mondelaers (DG AGRI): EO significantly enhances evidence-driven and results-driven policymaking, notably through the CAP's area monitoring system, which integrates administration and control to verify farmers' claims for area-based payments, with Sentinel Copernicus program (e.g. **Sen4CAP project**) playing a vital role in its effective implementation and ensuring continuous data provision. Other applications of EO in policy mentioned included: **The Farm Sustainability Tool** (FaST) aiming among others to optimize use of fertilizers by farmers to reduce costs and environmental impact maintaining the nutrient balance which is achieved with use of EO data. The need of using EO data in grasslands and landscape features was

underlined as well as its potential to replace at least to some extent costly ground data collection
    - Bruno Combal (DG ENV): EO supports sharing information on protected areas and degradation sites. The Habitat Directive requires member states to report on the conservation status of species and habitats, currently done mostly through costly in-situ visits with many unknowns remaining. EO could significantly contribute to this effort. The EU Grassland Watch initiative focuses on natural and semi-natural grasslands, aiming to exceed current CLMS capabilities.
- **What are the challenges in integrating process of EO with geospatial data, and what could be improved to better serve the needs of applications:**
    - Carla Martins (Eurostat) presented how EO data is utilized for crop official statistics and addressed the major challenge of accessing all available data through LPIS and aid applications. Key challenges mentioned:
        - **Data anonymization –** ensuring confidentiality of farmers data.
        - **Harmonization -** establishing common ontologies, definitions, and harmonizing standards.
        - **Data flow and continuity -** maintaining sustainable time series for consistent and transparent reporting.
- **Can EO support policy coherence?**
    - Tim Lemmens (DG DEFIS): Legislative initiatives and needs of DGs must be communicated. The **Knowledge Centre for EO** used to gather these needs and determine how to provide support within specific topics, such as biodiversity policies.
    - Koen Mondelaers (DG AGRI): Cooperation across various institutions is crucial, focusing on common datasets and interoperability, including legal aspects of data sharing. Investing in projects such as the **Agricultural Information System** in collaboration with JRC database that couples information from IACS and LUCAS should be prioritized and scaled up.
    - Bruno Combal, DG ENVI: listed three opportunities where EO data support the policy:
        - 'last-mile' strategy involving all stakeholders, including member state experts, DG ENV, JRC, CMES, and EEA, to enable collaborative tool development.
        - DeepDive from Knowledge Centre of EO in gathering information with special focus on wetlands, relevant to all the policy sectors.
        - Establish a **geospatial natural habitat register** to identify habitats, attribute information, and facilitate sharing across different policy files.
    - Carla Martins (Eurostat): EO products must exhibit clarity, quality, and credibility, supported by robust in-situ data and transparent methodologies. It's crucial to provide comprehensive metadata and demonstrate accuracy for official statistics, ensuring accessibility and comprehension for policymakers.

<u>Recommendations:</u>

- In order to achieve EU-wide integration of EO and other data sources the continued importance of interoperability across Member States, including LPIS/GSA systems and investments in projects like Agricultural Information System to scale up data integration efforts.
- Utilize EO to partially replace costly data collection methods for increased efficiency and cost-effectiveness.
- Explore EO's potential in grasslands and landscape features monitoring.

- Improving intra-annual variability and timeliness of Copernicus products is crucial.
- Improve EO integration by addressing the challenges on data anonymization, harmonization, and data flow continuity. Ensure confidentiality, establish common standards, and maintain sustainable time series for transparent reporting (including official statistics).
- Communicate legislative initiatives and DGs' needs. Utilize the EO Knowledge Centre to support specific topics like biodiversity policies.
- Address technological advancements, user needs, and scientific developments. Focus on user uptake and integrate new technologies like LSTM, CHIME, and next-gen Sentinels.

Summaries and Closing

During the closing session, brief summaries and recommendations have been provided by chairs of each scientific session. Sessions and panels summaries with recommendation are provided in this Workshop Report. Next steps after the workshop have been mentioned by the Workshop Organizer including:

- EC and ESA Lightning Talks 17:00-18:30 – as the last session of the EO4AGRI 2024 event
- ESA Agriculture Science Cluster launch (Friday 17 May 2024)
- Workshop report June (after review by co-chairs)
- Work Programme 2025
- ESA Living Planet Symposium 23-27 June 2025 in Vienna

Lightning talks: Lightning Presentations of EC and ESA agriculture projects

The last session of the workshop focused on short presentations of invited ESA and EC Agriculture Projects to be included in the ESA's new initiative: Agriculture Science Cluster. The idea behind the Lightning Presentations was to promote networking, collaborative research, and international collaboration in the domain of Earth Observation and Agriculture. By taking the opportunity to bring together several EC and ESA-funded projects to exchange their expertise, data, resources and address common challenges. During the last session following projects were presented by their representatives:

European Commission projects:

- TEMBO Africa: Transformative Environmental Monitoring to Boost Observations in Africa
- SYLVA: A SYstem for reaL-time obserVation of Aeroallergens
- EO4EU: AI-augmented ecosystem for Earth Observation data accessibility with Extended reality User Interfaces for Service and data exploitation
- ScaleAgData: Upscaling agricultural sensor data for improved monitoring of agri-environmental conditions
- AgriDataValue: Growing innovative platform for smart farming
- CERBERUS: Multiplatform Field Surveillance For Integral Crop Health, Early Detection And Actuation
- STELLA: Digital technologies for plant health, early detection, territory surveillance and phytosanitary measures
- EIFFEL: GEOSS Applications for climate change
- THEROS - Transparency and trust in organic food supply chain & GI products
- WaterSense: Making SENSE of the Water value chain with Copernicus Earth Observation, models and in-situ data
- DINOSAR - Diagnostic tool that integrates optical, infrared and SAR data

European Space Agency projects:

- AFRI4CAST: EO AFRICA Food Security and Safety in Africa
- EOAfrica WRM: EO AFRICA – Water Resources Management (WRM)
- HyRELIEF: Enhancing ECOSTRESS drought monitoring with hyperspectral narrow bands
- CRISP: Consistent Rice Information for Sustainable Policy
- WorldCereal: Global crop monitoring at field scale
- European Ecostress Hub
- YIPEEO: Yield Prediction and Estimation from Earth Observation
- EO4NUTRI: Earth Observation for estimating and predicting crop nutrients
- EO4Cereal Stress: Theme 3: Crop response to multiple stressors

More information about each project and the ESA Agriculture Science Cluster initiative can be found on the dedicated website: https://eo4society.esa.int/communities/scientists/esa-agriculture-science-cluster/