Prospects and Challenges in the Field of Geospatial Data and its Applications to Overcome Data Deficiency for Evidence-Based Decision-Making in the Water and Agriculture sectors

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Presented by: Zoltán Vekerdy\textsuperscript{1},
\textsuperscript{1}ESA EO AFRICA R&D Facility
\textsuperscript{2}ESA - ESRIN

Fourth Meeting of the High-Level Joint Water-Agriculture Technical Committee of the League of Arab States, Cairo, Egypt

18. October 2022.
ESA’s numbers

**EUROPE’S GATEWAY TO SPACE**

<table>
<thead>
<tr>
<th>WHAT</th>
<th>22 Member States, 4 associate members, 5000 employees</th>
</tr>
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<tbody>
<tr>
<td>WHY</td>
<td>Exploration and use of space for exclusively peaceful purposes</td>
</tr>
<tr>
<td>WHERE</td>
<td>HQ in Paris, 7 sites across Europe and a spaceport in French Guiana</td>
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<tr>
<td>HOW MUCH</td>
<td>€6.68 billion = €12 per European per year</td>
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FAO-ESA Partnership development

- **Building on a long-term cooperation**
  - Project based – e.g. GlobCover 2005, TropForest 2010, Sen2Agri 2013, Sen4Stat 2018
  - FAO engaged as key user driving requirements
  - FAO ESRIN visit 2020
    - Identification of priority thematic areas
- **Setup of FAO-ESA MoU**
  - Design of common Activity Plan (MoU Annex)
  - Formalization of the MoU – signature in April 2021

**FAO & ESA MoU**

**COOPERATION ON THE USE OF EARTH OBSERVATION FOR FOOD AND AGRICULTURE**
Objective: “to improve the exchange of expertise between the Parties, to facilitate the development of Earth Observation applications and exchange of relevant data, to enhance the understanding of agricultural processes and food systems [...].”

- **Main benefits (Article 2):**
  - Identification and understanding of the requirements;
  - Facilitation of sharing of field data sets
  - Support of access to open Earth Observation data sets
  - Development of innovative Earth Observation algorithms, products and applications using cloud computing;
  - Demonstration and validation of Earth Observation capabilities
  - Support of capacity development of Earth Observation skills for FAO

- **6 thematic priorities (MoU Annex):**
  - Agriculture, water productivity, forestry, land cover, early warning, SDG reporting

- **Activity plan** for the next 3 years by thematic, progress to be reviewed annually
Develop world-class Earth Observation systems with European and global partners to address scientific & societal challenges

ESA’s Earth Observation Mission

Satellites
12 in heritage
15 in operation
41 in development
22 in preparation
(90 in total)

Science
Copernicus
Meteorology

*Pending final mission selection

THE EUROPEAN SPACE AGENCY
Copernicus Sentinels (First Generation)

300 TB of EO data disseminated daily to society
Copernicus services

Monitoring the State of the Earth System Environment ...

... Six cross-cutting Thematic Services
Land service

Global Systematic Monitoring

Global Hot Spot

Pan-European land cover mapping

EU Local component
Land Service: Global portfolio
Land services: variables

Products (vegetation - energy - water) providing a picture of the world:
- Ten daily frequency / Delivery timeliness 3 days
- Resolution from 1km to 300m and 100m
- Current Portfolio of 27 products

<table>
<thead>
<tr>
<th>Product Family</th>
<th>Product (Variable)</th>
<th>Acronym</th>
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<tbody>
<tr>
<td>Vegetation</td>
<td>Leaf Area Index</td>
<td>LAI</td>
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<tr>
<td></td>
<td>Fraction of absorbed photosynthetically active radiation</td>
<td>FAPAR</td>
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<tr>
<td></td>
<td>Fraction of vegetation cover</td>
<td>Fcover</td>
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<tr>
<td></td>
<td>Normalized Difference Vegetation Index</td>
<td>NDVI</td>
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<td></td>
<td>Vegetation Condition Index</td>
<td>VCI</td>
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<td></td>
<td>Vegetation Productivity Index</td>
<td>VPI</td>
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<td>Greenness Evolution Index</td>
<td>GEI</td>
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<td></td>
<td>Dry Matter Productivity</td>
<td>DMP</td>
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<td>Phenology metrics</td>
<td>PHENO</td>
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<td>Evapotranspiration</td>
<td>ET</td>
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<td>Radiation fluxes</td>
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<td>Global Land Cover</td>
<td>GLC</td>
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<td>Active Fires</td>
<td>AF</td>
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<td>Burnt Areas</td>
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<td>Energy Budget</td>
<td>Top Of Canopy Reflectance</td>
<td>Toc-R</td>
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<td>Surface Albedo</td>
<td>SA</td>
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<td>Land Surface Temperature</td>
<td>LST</td>
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<tr>
<td>Water</td>
<td>Surface Soil Moisture</td>
<td>SSM</td>
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<td></td>
<td>Soil Water Index</td>
<td>SWI</td>
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<td></td>
<td>Water Bodies</td>
<td>WB</td>
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<td></td>
<td>Snow water extend</td>
<td>SE</td>
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<td>Snow water equivalent</td>
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<td>Snow water equivalent</td>
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<tr>
<td>Lake</td>
<td>Lake ice coverage</td>
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<td></td>
<td>Lake surface water temperature</td>
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<td>Lake and river water level</td>
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<td>Lake surface reflectance</td>
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<td>Lake turbidity</td>
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<td>Lake trophic state</td>
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<tr>
<td>Coastal</td>
<td>Erosion</td>
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</tbody>
</table>
Activities and results
Water Resources Management
Surface Waters examples
Advanced Surface Water Dynamics  https://www.worldwater.earth

30 m  10 m

**WorldWater**
SURFACE WATER DYNAMICS FROM SPACE

New advanced algorithms. Methods intercomparisons.

WATER EXTENT AND VOLUME.

Monthly water masks: (S1+S2)

Involved stakeholders
National Water Management Agencies, River Basin Authorities
Changes in surface water extent

Lake Kariba, Zimbabwe

Southern shore of Lake Kariba, Zimbabwe, 12-month water occurrence frequency map synergistic use of Sentinel –1 and -2
Changes in Lake volume

*Lake Cuitzeo, Mexico*

**Multi-annual surface water frequency**
From Sentinel-1 and -2.

**Monthly water surface elevation (WSE) timeseries from Sentinel-3**
Monthly surface water extent (SWE) timeseries
From Sentinel-1 and Sentinel-2

**Water level variations** and Lake storage changes
Changes in river discharge
From river water level to river discharge

Satellite altimetry missions monitor river level changes globally
Fleet of satellites carrying altimeters growing

Syn
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a) Sentinel-3A/B observations

b) Relative surface water elevation (m)

Water Occurrence Frequency (%)

Discharge [m³/s]

Daily GPM Precipitation [mm]
Wetlands, Soil Moisture and Evapotranspiration examples
Sentinels for wetland inventory, assessment and monitoring

- **Multi-sensor information (S1+S2+S3)** allow to overcome limitations of single sensor approaches.
- **10m spatial resolution** allow to have more spatial details for capturing the variety of small habitats in wetlands and for detecting small water bodies.
- **Short repeat cycle** allow to capture the flooding regimes of wetlands (permanent and seasonal waters) that are important indicators of wetland healthy conditions, and to detect decreases in water availability (due to misuse, abstraction & climate change).
- **Systematic global acquisitions** allow to improve wetland inventories globally, which are still largely lacking.
GlobWetland Africa Wetland Pre-inventories: Tunisia
Climate Change Initiative: Soil Moisture

- Annually algorithmically updated global climate data record of soil moisture spanning > 40-yr
- 3 separate soil moisture products derived from active, passive and combined (active + passive) sensors
- 12 public releases to date

ESA CCI soil moisture v06.1 products utilize 4 active and 10 passive microwave sensors
High resolution Evapotranspiration

- Use of Machine Learning for EO sharpening (1km to 20 m)
- Combination of Sentinel-2 & -3
- ET Modelling based on open-source algorithms

**ET4FAO** – demonstration for SDG 6.3


![Fine resolution ET (20 m - S2 & S3)](image1)

![Coarse resolution ET (1 km - S3)](image2)
Water use, pollution and the Blue Economy examples
HOW MUCH WATER IS USED FOR IRRIGATION?

Irrigation is the major water consumer of our planet (70%), and it has a tremendous impact on the water cycle in our times.

IRRIGATION+ aims to explore, develop and validate advanced EO-based algorithms and techniques for irrigation mapping, quantification and detection of seasonal timing of irrigation from field to regional/global scale.

Irrigation water use at 1km/15 day resolution (2011-2017) exploiting @ESA SMOS and Sentinel-1 soil moisture.
Optimization of irrigation water distribution in Morocco
Past TIGER Initiative: Water in Africa

90+ research projects

150 African institutions
EO AFRICA

https://eo4society.esa.int/eo-africa/

EO African Framework for Research, Innovation, Communities & Applications

- Fostering Partnership
- Facilitating R&D
- Leveraging Digital Tools
- Reinforcing Capacity
- Enhancing Data Accessibility
African-European EO Partnership: ESA’s contribution

**FutureEO**
Earth Science for Society

**EO AFRICA**
EO African Framework for Research, Innovation, Communities & Applications

**GDA**
Global Development Assistance

**CCI**
Climate Change Initiative

from EO R&D activities to EO mainstreaming in partnership with AUC, EC, African stakeholders
EO AFRICA: Partners and Contributors

Strategic Partners

R&D Facility – Advisory Board
Selected Proposals

Title | Countries | Co-PIs
--- | --- | ---
A workflow for forecasting primary productivity and its determining climatic factors using remote sensing in the eastern Sahel region | South Africa-Hungary | Adam-Toth
Applying innovative cloud computing technology for the effective management of Groundwater resources to promote SUSTainable food security within the Sokoto Basin, Nigeria | Nigeria-U.K. | Oladeji-Novellino
Crop Stress Monitoring in the semi-arid context of Doukkala, Morocco | Morocco-Italy | El Ghandour-Corbari
Drought impACt on the vegetation of South African semiarid mosaIC landscapes: Implications on grass-crop-lands primary production | South Africa-Spain | Dube-Andreu
Fusion of EO data for crop yield forecast in Benin and Morocco | Morocco-Germany | Brouzyne-Lehnert
Improvement of Agricultural Statistics in the cotton zone of Mali thanks to the synergy of the Sentinel-1 and 2 time series | Mali-Belgium | Traore-Defourny
Integration of open-source solutions with deep learning for estimating crop production in data-scarce smallholder farming areas | Ethiopia-Austria | Mengistu-Lang
Mapping and Monitoring Artisanal Mining from Space | Ghana-Germany | Forkuur-Ullmann
Monitoring by optical and radar satellite imagery of the level and volume of water in the lakes Buyo and Kossou dams in Côte d'Ivoire | Côte d'Ivoire-France | Kouame-Lang
Quantifying Soil Moisture from Space-based Synthetic Aperture Radar (SAR) and Ground-based Geophysical and Hydrological Measurements | Senegal-Spain | Djanni-Gao
Rising with temperature! Reconstructing the hydroclimatic record of Lake Naivasha with Earth Observation | Kenya-Netherlands | Ongo-Salama
Sentinel-1 and -2 data fusion for mapping smallholder cropping areas in southern Africa to support crop monitoring and yield forecasting | Namibia-Germany | Hamunyela-Herold
SENTINELs for Cape Verde Water & Food Security Monitoring | Cabo Verde-Netherlands | Tavares-Mannaerts
Towards daily maps of water hyacinth cover: exploiting synergies between Sentinel-2 and 3 | South Africa-Netherlands | Shoko-de Vries
West Africa Lake Monitoring System | Benin-Netherlands | Belfrid-van der Kwast

In alphabetical order
EO AFRICA – 2nd call for R&D Research Projects

Theme: EO for managing water scarcity and safeguarding food security in Africa in collaboration with African Union Commission

Who can apply: African-European research tandems
- call for 12-month projects
- EUR 25,000 research budget + ICT infrastructure + technical/scientific support

Deadline for proposal submission 15 November 2022.
With the research period starting from March 2023.

Establishing a **digital capacity development platform** to provide domain-specific training **(SPACE ACADEMY)**

Moodle: Open-source learning management system

Provide:

- **8 Training modules**
- MOOC
- Webinars
- Online and face to face courses
- Support for hackathons
  - The next one: AARSE2022
**EO AFRICA – Accessibility and Data Services**

**Brief description:** This procurement focuses on complementary data services provision and cloud resources collocated with the Copernicus Sentinels data over Africa. An environment to share additional value-adding resources and services tailored for Africa with protocols adapted to low bandwidth and fast data exploitation. Resources provision will also be included.

**Status:** ITT launch in the second half of 2022. **Budget:** 3.6MEuros
Destination Earth (digital twin of the Earth precursors)

- Encourage and support open science practices (open software, open data, open papers, and open methods) to accelerate development and facilitate broader adoption of remote sensing methods into the operational practices and systems of institutional stakeholders.

Water management: New 1Km Datasets and model results are used together for water resources management at basin scales, drought risk and agriculture.

Flood Risk: Modelled river discharge is used as input for flood modelling and hence for flood risk. Satellite river discharge (and flooded areas) are used for calibration and testing flood modelling.

Landslide risk: Modelled soil moisture together with satellite soil moisture and precipitation are used for landslide modelling and hence landslide risk.
EO AFRICA R&D Facility Contact

http://www.eoafrica-rd.org

@EOAfricaRD1

info@eoafrica-rd.org

Prof. Dr. Zoltán Vekerdy (Project Leader, ITC)
z.vekerdy@utwente.nl
**FAO-ESA PoC for Priority Themes**

- **Land cover statistics**
  - FAO: Francesco N. Tubiello and Lorenzo De Simone (FAO ESS/OCS)
  - ESA: Olivier Arino and Marc Paganini

- **Agricultural statistics**
  - FAO: Carola Fabi, Yakob Seid, Lorenzo De Simone (FAO ESS/OCS)
  - ESA: Benjamin Koetz, Zoltan Szantoi

- **Agricultural water productivity**
  - FAO: Jippe Hoogeveen and Livia Peiser (FAO NSL)
  - ESA: Benjamin Koetz

- **SDG Statistics**
  - FAO: Lorenzo De Simone, Yakob Seid, and Aida Khalil (FAO OCS)
  - ESA: Marc Paganini

- **Forestry Statistics**
  - FAO: Anssi Pekkarinen (FAO NFO)
  - ESA: Frank Martin Seifert

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**Agricultural Stress Index system**
- FAO: Monika Tothova (FAO EST)
- ESA: Benjamin Koetz, Zoltan Szantoi

**Coordination activities of the program and with other programs**
- FAO: Yakob Seid (FAO OCS)
- ESA: Benjamin Koetz, Patrick Griffith
An Earth system approach

Source: ESTELLUS (FR)
WACMOS-MED, In close collaboration with HYMEX

Glaciers and snow cover also part of the system (Cryosat altimetry data, U of Edinburgh)