Workshop on Earth Observation and Water-Energy-Food Nexus
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The Need for an Integrated EO Strategy and Requirements to address the WEF - Nexus

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NEXUS Background

- There is **interconnection** amongst and between global food, energy, water security and environmental sustainability
- Addressing **only one part** may not lead to desirable and sustainable outcomes
- Cooperation among scientists and policy makers to **mediate tradeoffs and explore synergies**, helping reduce costs and increase benefits for humans and nature by integrated approach to the management of water, energy, food and the environment.
- Natural ecosystems and their related services are **degrading fast** because of human activities, threatening the well-being of current and future generations
- Water-Energy-Food (WEF) Nexus implements an **ecosystem integrated approach** to better understand and to systematically analyze the complex interdependences of water, energy and food systems
Workshop Goals

- To identify specific examples of where Earth Observations (EO) can add to Water-Energy-Food (WEF) Nexus assessments and to inform EO users on how to address issues related to water, energy and food security.

- To review the information needs of resource-managers and policy-makers dealing with WEF issues.

- To assess gaps in monitoring information and services that could be addressed by satellite and in-situ data products.

- To develop a synthesis report on the state of EO applications to WEF issues, based on the outcomes of the workshop.

EO related

- How Integrated Earth Observations (EO) can support WEF Nexus assessments;

- Information needs;

- How satellite and in-situ data products can fill gaps in monitoring information and services.
WEF and Earth Observations

The Nexus is about understanding how we can achieve different economic, social and environmental goals with the same and limited resources.

- There is a need for readily available sound and up-to-date information on:
  - the state of the ecosystems and the processes that sustain them,
  - the pressures that are affecting them and responses to those pressures.
- EOs, monitoring and information sharing are critical and essential tools for the sustainable implementation of the Nexus approach.
WEF and Earth Observations

The Nexus is about understanding how we can achieve different economic, social and environmental goals with the same and limited resources.

Data and Analysis

- There is a need for adequate, robust and reliable data and evidence-based analysis to identify and assess water, energy and food systems and the impact that any change in the system can have on the environment and livelihoods.
- This work area includes anything from Earth Observation data to rapid assessment tools.
- **Earth Observations** include
  - satellite observations,
  - in situ measurements and
  - Survey ??
Integrated EO Strategy: needs and requirements

availability, quality, and timeliness of satellite and in situ data

- Data are not integrated and presented in ways that support monitoring and analysis by decision-makers and the public.
  - Enhance the collection and use of data, moving from supply to demand-driven systems that are product orientated and harmonized regardless of scale of observation.
  - Improve data discovery, data access and technical capabilities for information processing and promote construction of easy-to-use online interfaces.
  - Integrate multi-source EO data and services - into hybrid products?
Integrated EO Strategy: needs and requirements

availability, quality, and timeliness of satellite and in situ data

- **Lack of access and harmonized products**
  - Neutral, and expert-based applications that cater to the interests of all
  - Access to open data, standards, and models to address real-world problems
  - Recommendations on the appropriate use of standards and protocols for EO data access and visualization

- **Timeliness**
  - As real-time as possible. Stimulate the development of interactive applications with models or alert interfaces.
Challenges

- Integrated observations
- Trade-offs - spatial, temporal spectral
- Status and monitoring gaps / use of proxies for essential products
- Validation and Calibration
- Indicator Development
- Essential inputs to models (process-based models), historical trends analysis (data driven models)
Integrated EO Strategy: needs and requirements

- Effective national and regional capacity to use Earth Observation data for agriculture and other sectors related to the Nexus
- Strong, effective groups to secure support for operational terrestrial monitoring (satellite and in situ) systems
- Joint definition of hybrid observational requirements with the user community
- Periodic large-scale integrated assessments of land and water resources at a high resolution with comprehensive and validated global products:
  - Land cover and use, land degradation, crop production, physical and chemical soil characteristics, forestry assessment, fire
  - Freshwater resources, e.g. total irrigated area, fluxes in small water bodies, and groundwater resources, aquaculture
  - Ocean and coastal resources, e.g. aquaculture, shellfish, fish
  - Socio-economic conditions, e.g. population distribution, production intensity, food provision, and the location of cultural heritage sites
- Timely monitoring and information systems for events such as fire, forest management, crop yield, land degradation and desertification, etc..
EO and Water-Energy-Food Nexus

- **Nexus priority areas** related to EOs and data needs and uses:
  - Land
  - Water
  - Energy

The Water-Energy-Food Nexus at FAO
Diagram illustrates the scope of EO inputs to the WEF- Nexus.

There are essential and acceptable overlaps between systems, variables and indicators.

Now need to identify the active services, future options for EO inputs to characterisations, change analysis and forecasting and modelling systems.

Some elements (Ecosystem services) are not directly monitored - monitor the elements (agriculture, food security, S-E vulnerability and Water etc) to infer the service.
EO and Water-Energy-Food Nexus

- Nexus priority areas related to EOs and data needs and uses:
  - Land
  - Water
  - Energy
Variables and indicators

- **Climate change**
  - **Variables:** Essential Climate Variables (ECV’s) GTOS - ocean, atmospheric and terrestrial inputs, Met variables
  - **Indicators /Metrics:** Met forecast

- **Power Production / potential**
  - **Variables:** seasonality, regime, downstream impacts, terrain
  - **Indicators /Metrics:** discharge, erosion, deposition

- **Socio-economic/ Vulnerability**
  - **Variables:** proxy measures via road networks land use, infrastructure, settlement typologies
  - **Indicators /Metrics:** Assets, access to resources/services and population distribution

- **Socio-economic/ Vulnerability**
  - **Variables:** Agri-systems (rain/irrigated/pasture etc), crop production, yield, land degradation, infestation, infrastructure,
  - **Indicators /Metrics:** land use, change, phenology, monitoring
Variables and indicators

- **Built environment and infrastructure**
  - **Variables:** Consistent global maps of human settlements on an annual basis using multiple data sources/ Infrastructure / industry / road networks / settlement / Model spatial distribution of fossil fuel emission
  - **Indicators / Metrics:** Typology, extent, rate of change

- **Hazard and Exposure**
  - **Variables:** Flood, erosion, land degradation, drought, landslide, fire
  - **Indicators / Metrics:** extent, distribution, rate of change
Variables and indicators

- **Water Quantity & Quality**
  - **Variables:** Meteo variables, hydrology, catchment characteristics, morphology/dynamics, ecosystems, groundwater, proximity to pollutants; High to medium land cover, change and degradation mapping (incl. vegetation indices); Water body mapping (small/large, shoreline changes, wetlands); Water quality monitoring (lake surface temperature, chlorophyll and sediment load); Hydrological monitoring (precipitation, evapotranspiration, soil moisture, water level); Hydrological modeling (scenario analysis and operational forecasting); Flood monitoring, historical and vulnerability assessment; Erosion potential mapping; Urban sanitation planning support.

  - **Indicators /Metrics:** change over space and time, soil moisture, land cover, deposition and erosion, planforms, discharge, extent (river/glacier/lake), turbidity
Standards and Guidelines for Terrestrial ECVs

ECVs: What are they and why are they needed for?

- ECVs are the core set of observations required to contribute to the achievement of UNFCCC, IPCC and other end users objectives and mandates, by improving the understanding of climate system and predicting its change. ECVs enable:

  a. the analysis of climate change impacts
  b. the assessment of vulnerability and risk to it, and
  c. the development of the related adaption and mitigation strategies
Terrestrial Essential Climatic Variables

- Albedo
- Land cover
- fAPAR
- LAI
- Biomass
- Fire disturbance
- Framework
- ECV standards
- CEOS LSI
- River discharge
- Water use
- Ground water
- Lake levels
- Snow cover
- Glaciers
- Permafrost

www.fao.org/gtos/
EOs and Water

TIGER-NET project

- ESA launched TIGER-NET as part of the TIGER initiative to develop and demonstrate a African, user-driven Water Observation Information System (WOIS) to exploit the observations of current and future EO satellite systems.

- Specifications and development in direct collaboration with African Water authorities corresponding to information needs for Integrated Water Resource Management (IWRM).

- Enable more comprehensive observational capacity through generation of multi-source integration platform.

Funded by the European Space Agency’s (ESA) Strategic Initiative and run within the Data User Element programme.

- Nile Basin Initiative
- Lake Chad Basin Commission
- Volta Basin Authority
- Department of Water Affairs, South Africa
- Department of Water Affairs, Namibia
User Application Requirements

- High to medium land cover, change and degradation mapping (incl. vegetation indices)
- Water bodies mapping (small/large, shoreline changes, wetlands)
- Water quality monitoring (lake surface temperature, chlorophyll and sediment load)
- Hydrological monitoring (precipitation, evapotranspiration, soil moisture, water level)
- Hydrological modelling (scenario analysis and operational forecasting)
- Flood monitoring, historical and vulnerability assessment
- Erosion potential mapping
- Urban sanitation planning support
- GIS Mapping base data collection with read-to-map templates
Recommendations

Water availability and use

- Ensure continuity of high-resolution (10-30 m) remotely sensed data
- Water clarity measurement through hyperspectral imaging
- Water use and demand modeling at the catchment scale
- Map irrigated land area using high- and moderate-resolution remotely sensed data
- Wetland areas
Eos for Food Security

- "Food Security" is the condition in which a population has physical, social, and economic access to sufficient safe and nutritious food over a given period, to meet dietary needs and preferences for an active life.

- The potential contributions of Earth Observation to food security are related to:
  - direct and timely monitoring of agricultural production,
  - global or regional climate modeling and prediction (e.g. drought),
  - environmental modeling and prediction such as tracking of ocean currents and sea surface temperatures, forest fires, dust storms, etc.

- Effective use of Earth observation information, in combination with data gathered in the field, provide tools that enhance the collection, storage, analysis and dissemination of food security information.
EOs for Food Security

- Earth observation tools and techniques can help monitor short-term food security by increasing the spatial coverage, uniformity, frequency and reliability of all agro-meteorological data, and by providing improvements on the techniques used to extrapolate conclusions drawn from the combination of satellite-based and ground based data sources.

- This typically involves a combination of low-resolution satellite data, ground based agro-meteorological information, and ancillary data such as crop use intensity, or more precise land cover or cropland maps.

- Current crop estimates regarding area cultivated, which often does not change drastically from year to year, and yields.

- Earth observation tools and techniques can help crop production assessment by helping calibrate estimates based on a combination of large-scale data and ground observations.

- The use of satellites to monitor and forecast weather is of vital importance to farmers for crop irrigation planning purposes.
EoSs for Food Security

Monitoring Crop Production

- EoSs provide direct information on, or indicators of, production (area), agricultural parameters such as soil moisture, soil type, crop stage, crop vigor, crop type, which are vital for effective global agricultural monitoring.

- The factors influencing food availability and prices are linked to a number of elements with a strong global dimension:
  - population growth and dietary changes in fast-income-growing countries
  - competition from the increased demand for crop-based biofuel.
  - climate variability
EoSs for Food Security

Monitoring Crop Production

- In this context a global system to monitor and assess production is seen as an important decision making tool to:
  - provide timely information on crop production and yield in a standardized and regular fashion at the regional to global level.
  - provide estimates as early as possible during the growing season(s) and update the estimates periodically through the season until harvest.

- Examples of current global crop estimation systems are GEOGLAM, the FAS-USDA and EC-MARS combining in-situ information, weather and satellite data in a convergence of evidence approach to estimate production and yield.
E0s for Food Security

Early warning, prevention/ mitigation and preparedness: GIEWS example

- It adopts an approach to food security monitoring in sub-Saharan Africa based on producing a very general (low resolution) view of major climatic and agricultural events through rainfall estimates, ground-observed agro-meteorological data and satellite-derived normalized difference vegetation index data.

- The monitoring of growing conditions at large scale is then refined with models such as start-and-duration of growing season, water satisfaction index for various crops, and general productivity of rangelands.

- Drought is one of the main causes of food insecurity on the world. As part of GIEWS, an “Agricultural Stress Index System” (ASIS) was developed for detecting agricultural areas with a high likelihood of water stress (drought) on a global scale. METOP-AVHRR imagery 10-day step and 1km resolution is used.
# Observational requirements

<table>
<thead>
<tr>
<th>Land</th>
<th>Crop production (yield, by crop type)</th>
<th>Livestock number, type and offtake</th>
<th>Land cover and change: cultivated area, forest area, rangeland area</th>
<th>Within-season crop condition: greeness and water stress</th>
<th>Topography (Digital elevation model)</th>
<th>Fuelwood supply</th>
<th>Drought risk</th>
<th>Active fire, burned area and fire risk</th>
<th>Soil type (depth, texture, stoniness, fertility, acidity)</th>
<th>Land quality and land quality change (degradation)</th>
<th>Nutrient status and balance</th>
<th>Area affected by salinisation, water erosion, wind erosion</th>
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Agriculture Monitoring remains a challenge for EO

- EO are expected to deliver timely reliable information at various scales which can be used to derive the information above
- Coordination amongst EO provides is needed to ensure operational acquisitions (governance)
- Timeliness and programming of EO acquisition is critical (coordination)
- EO data availability is an issue in terms of (coordination):
  - processing time to deliver the final product
  - frequency of useable observations
  - due to cloud coverage during the growing season
- Spatial structure of the agricultural landscape (product specification)
  - EO compatible to field size for crop specific approach
- Spectral bands for efficient cloud/shadow masking and atmospheric correction (product specification)
GEOGLAM Baseline Datasets Requirements

A good starting point:

- **What?** → requirements table
- **Where?** → cropland mask (Fritz et al., 2013); field size (Fritz et al., unpublished)
- **When?** → agricultural growing season calendars (Whitcraft et al., in press)
- **How frequently?** → requirements table considering cloud cover constraints (Whitcraft et al., unpublished)
<table>
<thead>
<tr>
<th>Spatial Resolution</th>
<th>Spectral Range</th>
<th>Effective observ. frequency (cloud free)*</th>
<th>Sample Type</th>
<th>Field Size</th>
<th>Crop Mask</th>
<th>Crop Type Area and Growing Calendar</th>
<th>Crop Condition Indicators</th>
<th>Crop Yield</th>
<th>Crop Biophysical Variables</th>
<th>Environ. Variables</th>
<th>Ag Practices / Cropping Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-70m</td>
<td>VISNIR + SWIR + TIR</td>
<td>Monthly (min 2 out of season + 3 in season). Required every 1-3 years.</td>
<td>Cropland Extent</td>
<td>All</td>
<td>X</td>
<td>L/M</td>
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<tr>
<td>10-70m</td>
<td>VISNIR + SWIR + TIR</td>
<td>Weekly (min. 1 per 16 days)</td>
<td>Sample</td>
<td>All</td>
<td>X</td>
<td>X</td>
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<tr>
<td>10-100m</td>
<td>SAR</td>
<td>Weekly (min. 1 per 2 weeks)</td>
<td>Cropland Extent of persistant cloudy areas/Rice</td>
<td>All</td>
<td>X</td>
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**Fine (5-10 m)**

- 7: 5-10 m VISNIR + SWIR Monthly (min. 3 in season) Cropland Extent M/S M/S M/S
- 8: 5-10 m VISNIR + SWIR Weekly (min. 5 per season) Sample All M/S X X X X X
- 9: 5-10 m SAR Monthly Cropland Extent of persistant cloudy areas/Rice M/S M/S M/S M/S

**Very Fine (<5 m)**

- 10: < 5 m VISNIR Mosaic 3 per year (2 in season 1 out of season). Required every 2 years. Cropland extent of small fields S S S
- 11: < 5 m VISNIR 1 to 2 per month Refined Sample All (Demo) X X X X
Where to Image?

Best Available Cropland Distribution

Source: Fritz et al., (2013)
Version 1
Where to Image?

Field Size Layer (beta version)

Source: Fritz et al., (IIASA)
Based on interpolation of 50,000 GEOWIKI validation points
Standards and Classification System  
**LCCS / LCML / ISO 19144-2:2012**

- **LCCS**: Comprehensive methodology for description, characterization, classification and comparison of most land cover features identified anywhere in the world, at any scale or level of detail: basis for comparative classification. (6 UN official languages)

- Created in response to a need for a harmonized and standardized collection and reporting on the status and trends of land cover
EoSs for Energy and Climate

Monitoring variations in GPP, nPP and eT is significant in tracking degradation in ecosystem services:

- **Gross primary production (GPP)** is the amount of carbon fixed by photosynthesis, and net primary production (nPP) is the amount of carbon converted into biomass after subtracting the cost of plant respiration.

- **Terrestrial primary production** provides the energy to maintain the structure and functions of ecosystems, and supplies goods (e.g. food, fuel, wood and fibre) for human society.

- **Evapo-transpiration (eT)** is the water loss through exchange of trace gas CO2 by leaf stomata during photosynthesis plus evaporation from soil and plants.
E Os for Energy and Climate

- Measurable terrestrial properties that control physical, biological and chemical processes affecting climate, are themselves affected by climate change, or serve as indicators of climate change.
- Climate determines the distribution of natural vegetation, so changes in vegetation can provide a way to monitor climate change.
- Changes in land cover force climate by modifying water and energy exchanges with the atmosphere, and by changing greenhouse gas and aerosol sources and sinks.
- Global land observations are used in climate, carbon and ecosystem models that provide predictions and scenarios.
EoSs for Energy and Climate

- Bio-energy from fuelwood, crop residues, biofuel crops, etc., has long been crucial and is increasingly being relied upon as a renewable energy resource. Land observations are necessary for assessment of biofuel production and production expansion, and for environmentally sustainable production of biofuels.

- Efficient siting and impact assessments for wind-power and hydropower generation also rely upon land observations.
EoSs for Energy and Climate

BEFS areas of analysis:

- **Diagnostic**
  - Agricultural outlook
- **Natural Resources**
  - Land assessment (land suitability assessment and the availability of suitable land)
  - Water resource management
  - Woody biomass and residues (an application of WISDOM)
- **Techno-economic and Environmental**
  - Biofuel production costs
  - Greenhouse gas emissions
- **Socio-economic Analysis**
  - Economy-wide impacts
  - Household food security and vulnerability

Outputs:

- **Reports**
  - The BEFS Analytical Framework
  - The BEFS analysis for Peru
  - The BEFS analysis for Tanzania
  - The BEFS analysis for Thailand
- **Crop specific maps** showing where the crop can be grown and which maximum yields can potentially be attained under different levels of input
EoSs for Energy and Climate

Biomass Potential Assessment Tools from NRL (FAO)

- Global Agro-Ecological Zoning (GAEZ v.3)
  - Developed in collaboration with IIASA
  - Web portal with global, regional and location information on actual and potential crop production.
  - The database covers five thematic areas at 5 arc-minute resolution with global coverage:
    - Land resources, agro-climatic resources, suitability and potential yields for some 280 crops, global patterns of actual yields and production statistics and yield gaps.
**EOs for Energy and Climate**

Biomass Potential Assessment Tools from NRL (FAO)

- Biomass assessment methodologies potential based on land cover mapping (land cover and land cover change) created using the interpretation of remote sensing and the Land Cover Classification System (LCCS), standard
- Global to sub-national scale applicable

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**Land Cover Classification System**

Classification concepts and user manual

**Software version 2**

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**Above ground woody biomass**

**Carbon stock**

**Land Cover**
E Os for Energy and Climate

Biomass Potential Assessment Tools from NRL (FAO)

- Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology
- Provides the basis for strategic wood energy planning to secure subsistence energy supply to vulnerable populations whilst reducing at the same time the unsustainable pressure on natural resources
- Global to sub-national scale applicable
Scoping EO requirements for NEXUS - next steps

- Literature review of important relevant product specification
- Design the product specification for nexus needs
- Aim at increase precision of estimates of area and productivity of specific crops at national scale
- Consolidate main requirements for NEXUS EO products pertinent and most relevant to the applications
- Identification of additional application requirements that can be used in the product specification based on activity
- Identify and test selection criteria to be used to screen and evaluate the inclusion and prioritization of the core requirements
- Specify requirements for dynamic crop masks, crop area extent and type, and other vegetation status indicators of main interest that need to be included as a minimum in the product specification
Scoping EO requirements for NEXUS - next steps

- Harmonization of the core requirements and preparation of preliminary requirements to be evaluated for inclusion based on the predefined criteria
- Prepare the preliminary requirements report
- Assess preliminary product specification for its relevancy, completeness and coherence through the workshops and consultations with the user groups
- Develop an exploitation scenario of the EO data for national to global monitoring based on the consolidated user requirements
- The scenario will consider the required data volume, data access, processing facilities, performance and specific types of service delivery to different types of users
- Develop and update product specification through use cases scenarios and testing underpinned by standards and indicators
Integrated EO Strategy: recommendations

- Achieve **sustained operation, continuity and interoperability** of existing and new systems that provide essential environmental observations and information, including common infrastructure initiatives facilitating access to, and use of, these observations and information.

- Provide a **shared, easily accessible**, timely, sustained stream of comprehensive data of documented quality, as well as metadata and information products, for informed decision-making.

- Enhance the coordination of efforts to strengthen individual, institutional and infrastructure capacities, particularly in developing countries, to produce and **use Earth Observations** and derived information products.

- Ensure full interaction and engagement of relevant science and technology communities to **share benefits** from innovations in Earth observation science and technology.

- Ensure that critical user information **needs** for decision making are recognized and met through Earth Observations.
Integrated EO Strategy: what are we aiming for?

- **Improved management** of agricultural resources, helping to reduce malnutrition and contribute towards the achievement of the Millennium Development Goals.

- Improved **observing capacity** and deliver observations in a cost-effective and timely fashion

- **Best met user** community needs in terms of observational resources

- Developed **comprehensive framework** to harmonize the common interests of the major space-based and in-situ systems for global observation of the land

- Established and used **coordination mechanisms** for streamlining the use of space-derived geospatial data

- Promoted partnerships with the private sector, academia and Government agencies.
Thank you

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FAO

Links:

www.fao.org

www.fao.org/geonetwork

www.glcn.org