Space for Food Security

Pierre-Philippe Mathieu, ESA/ESRIN, Frascati, Italy.
pierre.philippe.mathieu@esa.int

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Many thanks to F. Cecinati & colleagues
Scope of the Talk

Planetary Challenges

Earth Observation Satellite data

Global Issues

Global Data, Information & Knowledge
A new era for global open data from space

Source: Taitus Software, SAVOIR
A family of Sentinel missions

COPERNICUS AND ITS 5 SENTINELS

Observing our planet for a safer world. The European Earth Observation Programme Copernicus provides geo-information products and services based on satellite imagery.

 Sentinel-1A/1B
- Medium InSAR optical satellite for observation of land and ocean services
- 13 spectral bands with 10, 20 or 60m resolution and 210km swath width
- Global coverage of the Earth’s land surface every 5 days
- Airbus Defence and Space prime contractor for satellites and missions

 Sentinel-2A/2B
- Medium resolution optical satellite for observation of land, vegetation and water
- 13 spectral bands with 10, 20 or 60m resolution and 210km swath width
- Global coverage of the Earth’s land surface every 5 days
- Airbus Defence and Space prime contractor for satellites and missions

 Sentinel-3A/3B
- Global observation of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide and other environmental pollutants
- Improves climate models and weather forecasts
- Provides data continuously during repeated passes between the feet of Envisat’s Sea and Land Monitor (SLV)
- Airbus Defence and Space prime contractor for satellites

 Sentinel-4
- Provides hourly updates on air quality with data on atmospheric aerosol and traced pollutants
- Spot scanning is thin and spectral resolution between 0.52m and 0.55m
- Airbus Defence and Space prime contractor for spacecraft

 Sentinel-5
- Measures air quality and solar radiation, monitors atmospheric pollutants and climate
- Global imaging of Earth’s atmosphere with unprecedented spectral resolution
- Airbus Defence and Space prime contractor for spacecraft

 Sentinel-5P
- Launched aboard ESA’s MetOp Second Generation (MSG) satellite

 Sentinel-6
- Measures sea surface topography with a resolution of 300m sea and land surface temperatures and other with a resolution of 16km
- Measures water vapor, cloud water content, and thermal radiation emitted by the Earth
- Determines global sea surface temperature with an accuracy greater than 0.3 K
- Airbus Defence and Space supplies Microwave Radiometer
Sentinel-1

- C-Band Synthetic Aperture Radar Payload (at 5.405 GHz)
- Life time: 7 years design life time with consumables for 12 years
- Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km.
- Repeat Cycle 12 days repeat cycle (1 satellite)
A wide range of applications

- Larsen ice shelf loss between 2002 and 2009 (Credit: Polar View)
- Oil spill detection and Surveillance (Credit: EMSA)
- Ship detection (Credit: ESA)
- Crop Monitoring (Credit: AgriSAR)
- Land use (Credit: ESA)
- Forest monitoring (Credit: Gamma)
- Subsidence map 1992-2006 (Credit: Terrafirma)
- Emergency management: flooding (Credit: SAFER, DLR)
- Mean wind speed from 2005 to 2009 (Credit: CLS)
- Earthquake analysis (Credit: INGV)
- Arctic ice extent August 2009 (Credit: MyOcean)
- Acceleration of Greenland glaciers flow (Credit: Rignot et Al)

C-band SAR observations to support a wide range of applications

…and more

Source: Potin et al. (ESA), 2013
S-2 workhorse for agriculture

S-2 (13 spectral bands, 10-60m, 5d revisit 2sat)
Routine crop monitoring to better manage agriculture and manage food security risks

Source: ESA, Benjamin Koetz,
THE CHALLENGE
SUSTAINABLE DEVELOPMENT
“Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. “

Rome Declaration of The World Food Summit of 1996
Top 5 Global Risks in Terms of Impact

<table>
<thead>
<tr>
<th>Year</th>
<th>1st Risk</th>
<th>2nd Risk</th>
<th>3rd Risk</th>
<th>4th Risk</th>
<th>5th Risk</th>
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<td>2007</td>
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<td>Retrenchment from globalization</td>
<td>Interstate and civil wars</td>
<td>Pandemics</td>
<td>Oil price shock</td>
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<td>Oil and gas price spike</td>
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<td>Geopolitical conflict</td>
<td>Asset price collapse</td>
<td>Climate change</td>
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<td>Water supply crises</td>
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Interconnected Risks – from Nexus to a Risk Web

More crowded …
More Pressure ..
Planet under Pressure

Source: adapted from Johan Rockstrom, by PPM
More Food, More Meat, More Feed needed ...

Changing Lifestyle & Consumption. Towards Western World Diet.

Source: Worldwatch, FAO, USDA, Earth Policy Institute (EPI)
More Energy Demanding

50% The annual global energy demand has increased over the past 25 years
80% Energy demand met through fossil fuels today
40% The amount annual global energy demand could increase over the next 20 years

Source: ISS Space Station, Nicholas Stern, DLR Irradiance
Less Arable Land …

1.4B ha
0.47 ha/person

1.5B ha
0.23 ha/person

Majority of our food coming from 37% of our land

Image: Francesca Cecinatii, 2013
Source: Information Please® Database, 2007 Pearson Education, Inc.; FAO, 2011, The state of the world’s land and water resources for food and agriculture (SOLAW)
More stress on Water resources …

Water: 97% saline, 2% freshwater (ice), 1% drinkable

70% of water used for Irrigation (agriculture), 20% industrial production

Image: Francesca Cecinatii, 2013
Source: Information Please® Database, 2007 Pearson Education, Inc.; FAO, 2011, The state of the world’s land and water resources for food and agriculture (SOLAW)
More stress on Water resources …

But we need much more water for food!

And we need water for energy!

Food security issues are water issues

kg of ...?  maize: 900 l  beef: 16 000 l

1200 liters vegetarian  2300 liters meat
More Heat, More Extremes …

Food insecurity and climate change

- More frequent heatwaves have been observed over the past two decades.
- In 2015, the Russian drought resulted in wheat yield reductions of 49% in key production areas, and the Pakhtuns foods resulted in losses of half a million tons of wheat. Together with market speculations, these events led to price increases.
- Climate-related hazards affected over 320 million people on average every year in the period 2000–2009.
- Water for irrigation is often extracted from rivers which depend on climatic conditions in distant areas along the rivers' path.

Source: MetOffice and WFP, 2010
Climate Environmental Refugees

Source Study: http://www.bis.gov.uk/assets/foresight/docs/migration/11-1116-migration-and-global-environmental-change
Source Data: International Immigration Organisation
Disasters affecting everyone ....

If improved EO-based information and warnings could lead to a few % reduction in insured losses, this would be worth $B to the global insurance industry.


but they impact mostly the poor and vulnerable ...
More Pressure on limited natural resources …
Human Footprint of Agriculture ...

Tropical Forest

Agriculture

1984

Mato Grosso, Brasilia

Landsat data © USGS, animation © Vista
“Already, we have cleared or converted more than **35 percent of the earth’s ice-free land surface for agriculture**, whether for croplands, pastures or rangelands…. Since the last ice age, nothing has been more disruptive to the planet’s ecosystems than agriculture.” Jonathan Foley, Uni Minessota
Human Footprint in desert areas

Source: ALOS, Jan 2011
Decline of Biodiversity, Forests & Ecosystems

60% decline in species, large-scale deforestation (e.g. rate of deforestation of 13 Mha/yr. one stadium every 3 sec). Reasons: Timber, Agriculture, Energy. Issue of illegal logging, REDD.

Source: FAO, Global Forest Resources Assessment 2010

Certification of Sustainable Forest Management Practices

Reducing Emissions from Deforestation & Forest Degradation (UN-REDD+)
Over-plowing & Over-grazing in parts of Africa, Asia, and the Middle East, transform productive cropland is turning into wasteland, and topsoil into dust. Emergence of new Dust Bowls (e.g. China, Sahel) and transboundary storms.
Melting Glaciers: key water reservoirs

Himalayan glaciers alone store water used by more than a billion people. Scientists measure the volume of glaciers in "mm SLE" - the amount that sea levels would rise if the ice melted. ESA CCI Glacier Inventory in support of IPCC, also important to understand available water resources in Asia.

ESA GSE service on "Glacial Lake Outburst" delivered to "International Centre for Integrated Mountain Development" (ICIMOD).

Source: ARTE, Le Dessous des Cartes, Conflicts 2030

Estimated decrease of Water Availability in 2030
Rivers are the **arteries** of the water cycle, and significantly affected by man made activities, such as **dams** and **irrigation**.

Source: ERS River & Lake Products, Source Global Reservoir and Dam (GReaD) Database [www.gwsp.org](http://www.gwsp.org)
Aquifers depletion as seen from space

Gravity measurements from GRACE highlighting that, water tables have fallen in various countries, including China, India, and the United States, which together produce nearly half of the world’s grain.
More urban ...
Cities will hold most of projected increased in humanity over the next decades. Migration from Rural to Urban, with about 3M people moving to cities every week in developing countries (UN-Habitat).
Mega-Cities, Mega-Pollution

Source: Global Urban Footprint, DLR, based on TerraSAR-X; ESA / DLR, 2013

Source: ESA Dragon, NASCC.

NO$_2$ reductions detected from space during the 2008 Beijing Olympic Games


European Space Agency
EO based $\text{NO}_2$ emissions South Africa

OMI, 2009

Mijling and van der A KNMI, 2012

Matimba power plant

vanadium mine

Sasol company

oil from coal

Majuba power plant
From local to regional and global impact

Source: Envisat/SCHIAMACHY NO2 concentration, courtesy IUP.
More volatile ...
Global food prices are increasingly volatile due to climate extremes, which alter global production patterns and exacerbate hunger in poorer countries. About 44M people driven into poverty by rising food prices in the second half of 2010 (World Bank).

Source: IMF (index of Mundi) on Wheat Monthly Crop Prices
Global Framework for monitoring of agriculture and limit volatility. EO from space has a key role to play. ESA is developing EO products to quantify food insecurity risks.

Source: G-20, GEO-GLAM
Improved Soil Moisture monitoring from space enables identification of dry conditions to support appropriate actions to avoid food insecurity.
Warmer world,
Oceans rising high,
Turning sour ...
The Great Geophysical Experiment

Source: Michael Buchwitz, IUP, University of Bremen, Schneising et al., 2011
Monitoring Ice Thickness with ESA Cryosat
Global Sea Level Rise from altimetry
Sinking cities: combination of subsidence (e.g. water pumping) monitored by InSAR and sea-level rise SSH help quantify flood risk in coastal mega-cities. Mega-deltas in Asia are the “rice bowls” to the world, their subsidence is a threat to food security.
Flood damage in the world's major coastal cities may top $1 trillion a year by 2050 due to rising seas and subsiding land, according to a new World Bank study in Nature Climate Change. More than 40% of these prodigious costs could fall upon just four cities – New Orleans, Miami and New York in the US and Guangzhou in China.

Impacts on Marine Ecosystems

- Health indicators: reef extent, reef roughness, coral and macro-algal cover, coral population structure, coral mortality, coral bleaching, coral diseases, herbivorous.

- Stress indicators: sedimentation, pollution, coastal development, over-fishing, ocean acidification, thermal stress

Characterization of Thermal stress regime

Improved SST, SSH, OC, sea state, monitoring to identify suitable sites for safely breeding coral reefs

Wave exposure map (from shape of basin, wind-speed & direction (ERS Scatt)

Source: Peter Mumby, Uni Exeter
An ecosystem service is defined as the benefit that people derive, either directly or indirectly, from a natural reserve. Earth observation can provide input to the valuations of ecosystem services by establishing baselines, monitoring the compliance of standards, spot checks of sustainable management practices and support environmental reporting (MetroVancouver)
More Digital,
More Connected ...
More Mobile, More Digital

Election of the Pope ....

& the emergence of Mobile Phones
(now 6B cell phones, dramatic increase in Africa / Asia)
THE OPPORTUNITY
EO FUELING A DATA REVOLUTION
Global Partnership for Sustainable Development

Moving from Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs)

A NEW GLOBAL PARTNERSHIP:
ERADICATE POVERTY AND TRANSFORM ECONOMIES THROUGH SUSTAINABLE DEVELOPMENT


May 2013

“We also call for a **data revolution** for sustainable development, with a new international initiative to improve the quality of statistics and information available to citizens. We should actively take advantage of new technology, crowd sourcing, and improved connectivity to empower people with information on the progress towards the targets.”

July 2014

READ ‘A WORLD THAT COUNTS: MOBILISING THE DATA REVOLUTION FOR SUSTAINABLE DEVELOPMENT’
Vision:
Each farmer on the Globe will be part of an open cyber-environmental system which supports him in ensuring food security and sustainable agriculture.
Monitoring Rice with Sentinel-1

GEOGLAM Asia-RICE Site: An Giang (Mekong River Delta, Vietnam)

10 Jan 2015 - VH

Crop calendar

<table>
<thead>
<tr>
<th>Crop season</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
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<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
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<tr>
<td>Winter-Spring crop</td>
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<td>Summer-Autumn crop</td>
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<td>Autumn-Winter crop</td>
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November-December: end of Autumn-Winter crop and beginning of Winter-Spring crop
Thematic Exploitation Platform (TEPs)

Moving the Calculations to the data

Data Gravity, and web services, Geohazard Exploitation Platform
Driving R&D - New algo / products

Development / Testing / Validation new Algos / Products

sentinel-2

AGRICULTURE

Project

UCL
Université catholique de Louvain

CESBIO

ES
România

Key Users

UCL

FAO

WFP

IFAD

EJRC

cirad

FEWS NET

RCMBD
Crowdsourcing ground truth and classification (EO Science 2.0)

Driving R&D - New validation techniques
Opportunity to develop a **Innovation Pulse Lab** @ ESRIN bringing together academia, private sector and regional actors to address Big Data issues for society and develop new applications.
Conclusions
What does all this mean for EO?

**Ingredients:**

- Agriculture is the largest employer on the Globe,
- Agriculture is a major sector of national economies (from >60% to 3% of GDP),
- Agriculture shows large productivity potentials,
- Agriculture is the economic sector with the largest environmental impact on the Globe,
- Productivity gains and environmental impacts are closely related to information science and technology used in farm management,
- Agriculture is and will remain the largest outdoor economic activity.

What is it that the Global Food System wants to know from EO?
Towards a Planetary Management System

- Early Warning
- Monitoring
- Attribution
- Prediction
- Citizen Observatory
- Planetary Boundaries

http://augureye.blogspot.it/ (?)
We are the tip of an Iceberg ... of an information revolution
Thanks!

Current World Population:

7,127,758,356

Source: Cassini’s view of the Earth from Saturn. NASA/JPL Caltech
Source Population: www.worldometers.info