Agriculture monitoring by multi-sensors observations and crop growth modelling in Europe, China and Ethiopia - the GLOBAM project


based on an international partnerships combining research labs, EO production entities and (pre-)operational systems (currently MARS-FOOD, GMFS)
Background

Operational Community in Ag. Monitoring

also in UN FAO, Australia, Brazil, Argentina,…
Catastrophic Fall in 2009 Global Food Production Foreseen!

Droughts in N. China, Argentina, Australia, Uruguay, Paraguay, Brazil

Need for RELIABLE, TIMELY, OBJECTIVE assessments of crop condition

*(slide from GEOSS conf. - C. Justice)*
Background
Geoss working group on ag. monitoring

Towards a Global Agricultural Monitoring System of Systems (GEOSS Ag 0703 Task)

Global Agricultural Monitoring System

The Group on Earth Observations (GEO) / Integrated Global Observing Strategy (IGOS) Agricultural Monitoring Community of Practice was established in July of 2007 at the second IGOS/GEO workshop convened at the headquarters of the UN Food and Agriculture Organization (FAO) in Rome. This community of practice represents twenty-five national and international organizations concerned with agricultural monitoring. Its purpose is to develop and implement a strategy for global agricultural monitoring in the framework of GEO.

A number of global trends suggest an urgent need for a comprehensive, systematic and accurate global agricultural monitoring system. More frequent extreme climate events such as floods, droughts and floods are adversely affecting agricultural production worldwide. The risk of food supply disruptions continues to grow as the earth continues to respond to pressures such as climate change, increasing energy needs, and population growth, on the land that sustains us. Understanding and monitoring global agriculture production is essential to combat both short-term and long-term threats to stable and reliable access to food for all.

Strategic investments over the next 10 years in earth observations, involving satellite observations, in-situ (ground-based) measurements and survey could revolutionize global agricultural production monitoring, leading to improved management of our agricultural resources, helping to reduce malnutrition and contribute towards the achievement of the Millennium Development Goals.

The IGOS and the GEOS Agriculture Societal Benefit Area

Agriculture is an essential component of societal well-being. Agricultural production influences, and is influenced by, health, water quality and quantity, ecosystems, biodiversity, the economy, and energy use and supply. The seasonality and ubiquity of agriculture make agricultural practices and production amenable to efficient dynamic monitoring.

Assessing the need for enhanced agricultural observations (satellite and in-situ) is a responsibility of the Integrated Global Observations of Land (IGOL) program. IGOL advises the Group on Earth Observations (GEO) on the requirements for improved observation of the land surface. The Third Earth Observation Summit, February 2005, established the GEO with the mandate to lead a worldwide effort to build a Global Earth Observation System of Systems (GEOSS) over the next ten years. The GEOSS is working with, and building upon, existing national, regional and international systems to provide comprehensive, coordinated Earth observations to provide useful information for society. GEO is addressing a broad range of societal benefit areas, one of which is supporting sustainable agriculture. Developing a ten year strategy to obtain these observations and generate and distribute the necessary information is a
**Overall GLOBAM objectives**

- to couple EO and crop growth model for crop production estimate by **filling the gap** between state of the art research and ‘global’ operational systems
  
  ➡️

- scientific research to tune and to assess methods potentially operational **over large areas and in different agro-ecological contexts**
  
  ➡️

- ‘globally distributed’ ag monitoring experiment: phase 1 for development (3 sites of 300 x 300 km) and phases 2 & 3 for performance and robustness assessment
GLOBAM — a Globally Distributed Agricultural Monitoring Experiment

3 study sites of 300 x 300 km in Northern Europe, China and Ethiopia
joint field and EO data collection during the 2007(08) growing season
for cereals and maize to look for robust and generic methods
**GLOBAM Key Ideas**

- **crop type mapping for crop specific monitoring** (mask for each main crop)
- **crop specific retrieval of LAI/biomass from optical and SAR data**
- **evapo-transpiration estimation from MSG for croplands area**
- **select/adjust crop models sensitive to EO retrieved variables**
- **assimilation of EO retrieved variables including ET from MSG into crop growth models**

=> Target scale for information production : NUTS 3
**EO Sensors for GLOBAM**

- the Wide Swath High Resolution data (AWIFS, DMC) (50 m) covering 2 or 3 times the site for crop type mapping,
- the daily 250 m MODIS data processed in 10-day composite to estimate the crop fraction and to retrieve the crop LAI
- the High Resolution imagery (SPOT HRV, Landsat; PALSAR, ASAR) (10 to 30 m) to retrieve crop LAI
- the Very High Resolution imagery (Kompsat) for crop type mapping in very fragmented landscape;
- the Very Low Resolution (3 to 5 km) MSG land products,
- the daily Low Resolution (1km) imagery from SPOT-VGT
GLOBAM field campaign (2007/08/09)

- Crop type
- GPS coord.
- Plant density
- Plant height

Same/similar field protocols in NEU, ETH and NCP
GLOBAM field campaign (2007/08/09)

- Leaf Area Index (LAI)
- Canopy cover
**GLOBAM field campaign (2007/08)**

- Top soil moisture
GLOBAM field campaign (2007)

Aerial Survey
GLOBAM field campaign protocol (2007/08) – Northern Europe
(when large scale aerial photographs or existing vector database allow identifying accurately
the crop type over blocks corresponding to about 3x3 MODIS 250m pixels)

**Calibration set**
60 fields visited
5 times to measure on SAR acq. dates
6 variables:
- Field geolocation
- Leaf Area Index
- Green canopy cover
- Canopy height
- Volumetric Top Soil Moisture (humid and dry weight)

**LAI validation set**
70 fields observed by photographs taken during
1 times to measure
2 variables:
- Field geolocation
- Green canopy cover

**Crop type validation set**
100 blocks of fields observed by photographs taken during
1 visit to measure
2 variables:
- Field geolocation
- Crop type
GLOBAM field campaign protocol (2007/08) – Ethiopia

(when, in addition to the calibration site, several HiRes images allow classifying accurately the crop type over the whole validation site thanks to DMC/AWiFs imagery)

**Calibration set**
- 36 fields visited
- 5 times to measure:
  - Field geolocation
  - Leaf Area Index
  - Green canopy cover
  - Canopy height

**LAI validation set**
- 30 fields visited
- 1 times to measure:
  - Field geolocation
  - Leaf Area Index
  - Canopy height

**Crop type validation set**
- 100 fields of various crops to train HiRes classification
- 1 visit to measure
- 2 variables:
  - Field geolocation
  - Crop type
GLOBAM field campaign protocol (2007) – case 2 (China)

(when, in addition to the calibration site, several HiRes images allow classifying accurately the crop type over the whole validation site thanks to DMC/AWiFs imagery)

Calibration set
18 fields visited
1 time to measure
6 variables :  
- Field geolocation
- Leaf Area Index
- Green canopy cover
- Canopy height
- Volumetric Top Soil Moisture (humid and dry weight)

Validation site (300 x 300 km)

LAI validation set
13 fields visited
1 times to measure
3 variables :  
- Field geolocation
- Leaf Area Index
- Canopy height

Crop type validation set
60 fields of various crops to train HiRes classification
1 visit to measure
2 variables :  
- Field geolocation
- Crop type

2nd GLOBAM Steering Committee Meeting, 23 Mar. 09
NEU - Landsat TM and AWIFS derived crop map (delivery time: pre-harvest and post-harvest)

ML-classification
Images of 12 March and 3 May
Landsat7-ETM+ derived crop map (post-harvest)

Missing values due to sensor failure

→ adapted ML-classifier: 86% instead of 36% of the pixels are classified
### NEU - Validation – current overall accuracy

<table>
<thead>
<tr>
<th></th>
<th>Pixel level</th>
<th>VITO field survey data (40%)</th>
<th>NUTS level (n= 49)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Landsat7-ETM+ (post-harvest)</td>
<td>Landsat7-ETM+ (pre-harvest)</td>
<td>IRS-P6 AWIFS (pre-harvest)</td>
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<tr>
<td>Winter wheat</td>
<td>91%</td>
<td>88%</td>
<td>80%</td>
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<tr>
<td>Winter barley</td>
<td>86%</td>
<td>49%</td>
<td>1%</td>
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<tr>
<td>Winter rapeseed</td>
<td>98%</td>
<td>99%</td>
<td>97%</td>
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<tr>
<td>Summer crops</td>
<td>-</td>
<td>82%</td>
<td>1%</td>
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<tr>
<td>Maize</td>
<td>83%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>92%</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Potatoes</td>
<td>81%</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>
NCP- Landsat TM, CBERS and AWIFS crop map
ETH – hard or sub-pixel land cover mapping crop map very challenging!

- Good result cult1, dense veg, forest
- Confusion cult1 & cult2
- Confusion cult & grassland

<table>
<thead>
<tr>
<th>Class</th>
<th>Intercept</th>
<th>Slope</th>
<th>R²</th>
<th>RMSE</th>
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<tr>
<td>Cultivated1</td>
<td>6.3</td>
<td>0.52</td>
<td>52.83</td>
<td>18.02</td>
</tr>
<tr>
<td>Cultivated2</td>
<td>3.8</td>
<td>0.38</td>
<td>38.32</td>
<td>13.04</td>
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<tr>
<td>Dense vegetation</td>
<td>7.0</td>
<td>0.53</td>
<td>50.56</td>
<td>19.52</td>
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<tr>
<td>Water logged</td>
<td>9.4</td>
<td>0.21</td>
<td>22.83</td>
<td>16.59</td>
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<tr>
<td>Grass</td>
<td>10.8</td>
<td>0.45</td>
<td>45.33</td>
<td>21.04</td>
</tr>
<tr>
<td>Forest</td>
<td>9.7</td>
<td>0.69</td>
<td>69.55</td>
<td>21.72</td>
</tr>
</tbody>
</table>

Kompsat Feb – Oct
Landsat March – Oct – Dec

Good result cult1, dense veg, forest
Confusion cult1 & cult2
Confusion cult & grassland
What EO instruments for crop type map accuracy in a given ag. landscape?

SPOT 5

crop area estimate / crop area change indicator / crop mask

MODIS
What EO resolution for what ag. landscape for what accuracy?

Belgium, EU

Surface estimation error (%) vs. EIFOV radius (m) vs. Spatial response purity (%)

(Duveiller et al.)

Surface estimation error for sample: hes01
What EO resolution for what ag. landscape for what accuracy?

Hengshui, North China Plain

Surface estimation error (%)

Surface estimation error for sample: hen01

ELFOV radius (m)

Spatial response purity (%)

(Duveiller et al.)
2nd GLOBAM Steering Committee Meeting, 23 Mar. 09

GEOSS Ag

Global/Regional croplands mask

Nat./sub-nat. crop type area

Crop type at parcel level

Spatial resolution

EO

5km - 1km

1km - 250m

250m - 60m

60m - 10m

5 m - 1m

hourly images
daily images
2 to 3 images per 10 days
1 to 2 images per 10 days
1 to 2 images per month

Revisiting capabilities

Crop Type Classification

MODIS/MERIS - DMC/AWIFS

LAI retrieval
Hi and SAR TS
MODIS/MERIS TS

Crop stages
Crop variables

Sub-parcel variability

Sample point interpretation

Meteo cond.

Area

Crop Growth

Agriculture / veg. state
Crop specific conditions
Anomalies assessment
every 10 days

Crop growth model
every 5 to 10 days

Yield

6 wks after sowing
2 months after sowing

Yield estimation
every 10 days

+ field report & socio-economic context by analyst

+ prod. quality, stocks & demand by info brokers

Area outlook

Area estimate
Monthly bulletin
Early warning
Precision farming
Yield forecast
Prod estimate
Vuln. report
Int market report

Sample point interpretation

Food security
Ag prod trade

Use

GEOSS Ag

Sample point interpretation

Sample point interpretation

Sample point interpretation

Sample point interpretation

Sample point interpretation

Sample point interpretation

Sample point interpretation

Sample point interpretation
RED and NIR profiles for 1 point

Terra and Aqua

Large = favorable OBSCOV
Dark = favorable VZA
NEU - More saturation effect in NCP due to Planimetric LAI – Need to remove bias?
CLOUD results - Impact of soil moisture estimation using SWAP

$V_m$ from Ground measurements

$V_m$ from SWAP

$n = 30$
CLOUD results - Impact of soil moisture estimation using ECMWF meteorological data

Vm from SWAP and Ground meteo data

Vm from SWAP and simulated meteo data

n = 23
Leaf Area Index estimation over large areas to be assimilated in crop growth model
Crop Growth Models Calibration - NEU

1. Set of Large field (pure pixels) on the whole 300X300km core site
2. Field data of LAI curve and yield of each large field
3. Calibration of the two models with the set of field observations (phenology, LAI, fAPAR, yield)
4. Sensitivity analysis by Kalman Filters (to be done)
5. Validation of the calibrated models at NUTS3 level based on the official stats figures
Crop Growth Models Calibration - NCP

- 25x25km grid
- 74 weather stations
- Weather data 1990-2007
- FAO 1:5M soil DB
- Spatial aggregation based on area statistics (LTA)
- Winter-wheat calibration taken from previous study
- Grain maize calibration based on 5 agromet stations (left)
Analysis of possible contribution of MSG products: Evapotranspiration, fCOVER and LAI
First comparison between LSA-SAF ET and CGMS Temperature

LSA-SAF ET (mm) 11-20 April 2007, NEU

CGMS T (mm) 11-20 April 2007, NEU
**GEOSS Ag**

**Global/Regional/croplands mask**

- **Crop Type Classification**
  - MODIS/MERIS - DMC/AWIFS
  - LAI retrieval
  - Hi and SAR TS
  - MODIS/MERIS TS
  - LAI assimilation in Crop Models

**Spatial resolution**

- **Global**
  - 5km - 1km
- **Regional / National**
  - 1km - 250m
- **Sub-nat.**
  - 250m - 60m
- **Local**
  - 60m - 10m
  - 5m - 1m

**Revisiting capabilities**

- **EO**
  - 5km - 1km: hourly images
  - 1km - 250m: daily images
  - 250m - 60m: 2 to 3 images per 10 days
  - 60m - 10m: 1 to 2 images per 10 days
  - 5m - 1m: 1 to 2 images per month

**Crop Type Classification**

- **Crop stages**
  - every 10 days
- **Crop variables**
  - every 5 to 10 days
- **Anomalies assessment**
  - every 10 days

**Yield estimation**

- **Global**
  - 6 wks after sowing
- **Regional / National**
  - 2 months after sowing

**Sample point interpretation**

- **Area outlook**
  - Area estimate
  - Monthly bulletin
  - Early warning
  - Precision farming
  - Yield forecast
  - Prod estimate
  - Vulnerab. report
  - Int market report

**Use**

- **Food security**
  - Ag prod trade
  - Int market report

**Meteo cond.**

- **Area**
  - Global/Regional croplands mask
  - 6 wks after sowing

**Crop Growth**

- **Crop specific conditions**
  - every 10 days

**Yield**

- **Sample point interpretation**
  - Area estimate
  - Monthly bulletin
  - Early warning
  - Precision farming
  - Yield forecast
  - Prod estimate
  - Vulnerab. report
  - Int market report

**GEOSS Ag**

- + field report & socio-economic context by analyst
- + prod. quality, stocks & demand by info brokers
GLOBAM – Methodological tuning and robustness assessment

Field and EO campaigns in NEU, ETH and NCP+ sites for 2010

+ GEOSS Joint Experiment Crop Area Monitoring site
GLOBAM flowchart

Coordination
WP1- UCL

Local Field Observation
WP2-UCL/VITO/ULg

Multi-sensor Observation
WP2-UCL/VITO

Ag Practices & Statist. Meteo Data Collection
WP2-ULg/Alterra/JRC

EO Data Pre-Processing
WP3-VITO/UCL/KMI

MSG ET & LST Products
WP7-KMI...

Main Crop Growth Models
WP6-ULg/Alterra

LAI & Biomass Retrieval
WP5-UCL

Crops Area Estimate
WP4- VITO

Wide-Scale Field Validation
+ Existing Survey and Monitoring Systems (CGMS)

Croplands & Crop Mapping
WP4- VITO

Crop Production Indicators
WP10-UCL/ULg/JRC

Error budget
WP10-UCL/VITO

Assimilation for Yield Estimate
WP8-CRA-UCL...

2nd GLOBAM Steering Committee Meeting, 23 Mar. 09