GEO Agricultural and Land Use Change

Chris Justice (GEO-AG Task Co-Chair)
Inbal Becker-Reshef
University of Maryland
GEO, the Group on Earth Observations
An Intergovernmental Organization with 87 Members and 61 Participating Organizations

U.S. Department of State, Washington DC
July 31, 2003
The Vision for GEOSS…

…a world where decisions and actions are informed by coordinated, comprehensive and sustained Earth observations.
GEO is focused on societal benefit

Agriculture is one of the GEO societal benefit areas
Initial GEOSS/IGOL Agricultural Monitoring Workshop July 2007, UN-FAO

- Workshop to develop a strategy for global agricultural monitoring in the framework of GEO

- 47 participants representing 25 national and international organizations attended and established the ‘GEOSS/IGOL Agricultural Monitoring Community of Practice’

- Reviewed the current state of agricultural monitoring, identified gaps and developed a set of priorities and recommendations

- ISRO agreed to establish Task Secretariat (J.S. Parihar)

Today the CoP has over 300 members representing over 40 countries and organizations
Looking Forward

Agriculture is Facing Major Challenges

• Increasing pressures on agricultural land and production from:
  – Increased severe weather events and climate change
  – Population growth & changing diets
  – Fuel vs. Food vs. Feed
  – Limited water and suitable arable land
• Higher price volatility for major grains
• Crop yield variability is a main driver of short term changes in market equilibrium
  • Weather/climatic effects on production are triggers for price hikes
• Commodity markets are increasingly linked (good and bad)
• Rising fuel prices impact food prices (transport, fertilizer)

• NEED TO INCREASE GLOBAL PRODUCTION BY 70% BY 2050 TO MEET DEMAND (FAO)

→ Tools for monitoring and reliably forecasting production are essential for anticipating market imbalances and enhancing policy responses
## The GEO Global Agricultural Monitoring

(Restructured GEO Ag 0703 – **Now GEO Ag 01**)

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Organization</th>
<th>Country</th>
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<tbody>
<tr>
<td>Task Co-Leads</td>
<td>Chris Justice</td>
<td>University of Maryland</td>
<td>(USA) *</td>
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<tr>
<td></td>
<td>Olivier Leo</td>
<td>Joint Research Centre Ispra</td>
<td>(E.C,)</td>
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<td></td>
<td>Derrick Williams</td>
<td>USDA FAS</td>
<td>(USA)</td>
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<td></td>
<td>Wu Bingfang</td>
<td>IRSA, CAS</td>
<td>(China)</td>
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<tr>
<td>GEO Secretariat POC</td>
<td>Joao Soares</td>
<td>GEO Secretariat</td>
<td>(Brazil)</td>
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<tr>
<td>Task Executive Director</td>
<td>Jai Singh Parihar</td>
<td>ISRO</td>
<td>(India)</td>
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<tr>
<td>JECAM Comp. Lead</td>
<td>Ian Jarvis</td>
<td>Agric. and Agri-Food Canada</td>
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<td></td>
<td>Pierre Defourny</td>
<td>(Belgium)</td>
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<td>PAY Comp. Lead</td>
<td>Inbal Becker-Reshef</td>
<td>(USA), Meng Jihua</td>
<td>(China)</td>
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<tr>
<td>Cropland Mapping Lead</td>
<td>Steffen Fritz</td>
<td>IIASA</td>
<td>(Austria)</td>
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<tr>
<td>GEOGLAM Lead</td>
<td>Pascal Kosuth</td>
<td>(France)</td>
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<tr>
<td>Agricultural Drought Lead</td>
<td>Wu Bingfang</td>
<td>(China)</td>
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<tr>
<td>CEOS GEO Ag POCs</td>
<td>Prasad Thenkabail</td>
<td>(USA), Yves Crevier</td>
<td>(Canada)</td>
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</table>

* NASA Applied Sciences supported (Brad Doorn, NASA POC)
GEO Agriculture Monitoring Community of Practice
(an open community of Data Providers, Brokers and Users)

• Several global/regional scale systems in place – with common data needs, few common standards and protocols and inconsistent results
• Most countries have a national agricultural monitoring system
Agricultural Monitoring Task

Focused on:

1. Monitoring of Agricultural Production – timely information (GEOGLAM)
2. Quantifying Agricultural Extent and Land Use Change
3. Joint Experiments on Crop Assessment and Monitoring (JECAM) - global sites, method comparison
4. Earth observations - improving availability, frequency of observations, continuity, near real-time data w. CEOS
5. Developing a new Pasture/Rangeland biomass monitoring program (CSIRO lead)

Various Nations are supporting projects within these areas
Rapid expansion of agricultural land is underway in various parts of the World, crop type and rotations are changing and the precise extent and dynamics of irrigated lands are unknown.

Building on the recommendations from the IASSA 2011 Workshop an expanded global initiative is needed on mapping and characterizing (crop types/rotation) croplands using earth observations.
Context for GEOGLAM

Monthly Wheat Prices 1960-2011 ($/Metric Ton)

Source: World Bank

2008 Price hikes
Droughts: Australia & Ukraine

2010/11 Price hikes
Drought: Russia

1971/2’s price hike
Drought: Russia

Landsat 1
Launched (1972)

Nominal wheat price in US $/metric Ton
Need for Improved Agricultural Intelligence

International recognition of critical need for improved information including at the World Summit on Food Security 2009, G20 Action Plan on Food Price Volatility and Agriculture, 2011

official statement of The Extraordinary Joint Intersessional meeting of the Intergovernmental Group (IGG/FAO) on Grains, Rome 2010:

“Unexpected price hikes and volatility are amongst major threats to food security and their root causes need to be addressed, in particular regarding the lack of reliable and up-to-date information on crop supply and demand and export availability....”
The G20 Initiative: GEO-GLAM

G20 Final Declaration

44. We commit to improve market information and transparency in order to make international markets for agricultural commodities more effective. To that end, we launched:

- The "Agricultural Market Information System" (AMIS) in Rome on September 15, 2011, to improve information on markets ...;

- The "Global Agricultural Geo-monitoring Initiative" (GEO-GLAM) in Geneva on September 22-23, 2011. This initiative will coordinate satellite monitoring observation systems in different regions of the world in order to enhance crop production projections and weather forecasting data.

- The G20 Cannes Summit (November 2011) Action Plan on Food Price Volatility and Agriculture
- Reaffirmed GEOGLAM commitment at the 2012 G-20 Los Cabos Declaration & in Agriculture Ministers Report
G20 GEOGLAM Goal:

To strengthen the international community’s capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales through the use of EO

Outcome: an improved and more harmonized systems of systems taking advantage of new satellite assets and methods and a higher level of international coordination

• GEO-GLAM will be implemented in the framework of GEO
The GEOGLAM Initiative: Project Elements

1. GLOBAL/REGIONAL SYSTEM OF SYSTEMS
   Main producer countries, main crops

2. NATIONAL CAPACITY DEVELOPMENT
   for agricultural monitoring using Earth Observation

3. MONITORING COUNTRIES AT RISK
   Food security assessment

4. EO DATA COORDINATION (acquisition, availability, access)

5. METHOD IMPROVEMENT through R&D coordination

6. INFORMATION DISSEMINATION of Data and Products
Agricultural Market Information System (AMIS) hosted at the UN FAO focused on food producer countries
The GEOGLAM Initiative: 2011-2012 Progress

International cooperation for the definition of GEOGLAM

- 09/2011 Geneva: First GEOGLAM international Workshop (*13 countries*)
- 11/2011 Istanbul: GEO VI Plenary Assembly
- 01/2012 Geneva: GEOGLAM coord. Group meeting
- 02/2012 Rome: Present to the 1st meeting of the AMIS coord. Group
- 02/2012 Canberra: International Workshop on crop monitoring
- 03/2012 Mexico: Present. to XIIth “Foro de expectativas agropecuarias”
- 03/2012 La Hoya: CEOS Strategic Implementation Team
- 04/2012 Tokyo: GEOSS in the Asian Pacific Symposium
- 4/2012 Italy: ESA Sentinel 2 workshop
- 5/2012 Geneva: GEO Workplan Meeting
- 6/2012 Mexico City: Meeting with SIAP (Min of Ag)
- 7/2012 Montreal: CEOS-GEOGLAM data requirements workshop
- 9/2012 Buenos Aires: Regional Ag Monitoring Systems workshop
- 10/2012 Beijing: Drought Monitoring Workshop w. GEO Water Task
- 10/2012 26th CEOS Plenary, Bangalore India
+ regional and national meetings and presentations
+ EU FP-7 Call for GEOGLAM proposal (Ag and Environment) 9 Million Euro
GEOGLAM Components

- **Component 1: Monitoring Global Producer Countries**
  - Focus: Crop outlooks, Production Monitoring, supporting global markets and trade, long term trends (climate change implications, extreme events, etc)

- **Component 2: National Monitoring Systems**
  - Focus: Improved national capacity for monitoring, improved statistics, supporting national policy, subsidies, insurance

- **Component 3: Countries at Risk**
  - Focus: Early Warning & Food security

- **Component 4: Observations Coordination**
  - Focus on acquisition, availability, access needed for GEOGLAM implementation – increased frequency, near real time data

- **Component 5: R&D**
  - Focus: Improved Data Sets, Operational R &D, Best practices, Joint Experiments - JECAM

- **Component 6: Information dissemination**
  - Focus on timely and transparent availability of information
4. EO DATA COORDINATION (acquisition, availability, access)

• **Goal**: secure the international data necessary to implement GEOGLAM

• GEOGLAM has substantive and specific observation data needs (what, where and when) which underpin its implementation – no one satellite system can meet the data needs – international cooperation is needed

• **Approach**: work in close partnership with CEOS (“the space arm of GEO”) and other data providers to:
  
  – Lay out the overall program observation requirements to enable the necessary information products to be generated (building on the experience with GEO FCT and GFOI)
  
  – Work with data providers to establish and implement data acquisition and dissemination systems
Tabulating the satellite observation requirements (spatial resolution, frequency, and period of coverage) for GEOGLAM
Recognition that cropping systems are inherently diverse which dictates the monitoring observations and methods.
GEOGLAM USER REQUIREMENTS WORKSHOP RESULTS

The results package includes the following elements:

a. A summary table of requirements developed taking into consideration the observation needs, the derived products they will serve, and high-level regional specificities;

<table>
<thead>
<tr>
<th>OBSERVATIONS</th>
<th>DERIVED PRODUCTS</th>
<th>GLOBAL</th>
<th>REGION SPECIFIC ACquisitions **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution</td>
<td>Spectral range</td>
<td>Effective observ. frequency (cloud-free)</td>
<td>Swath</td>
</tr>
<tr>
<td>2000 - 500 m</td>
<td>thermal IR + optical</td>
<td>few per day</td>
<td>global</td>
</tr>
<tr>
<td>100-300 m</td>
<td>optical + SWIR</td>
<td>2 to 5 per week</td>
<td>global</td>
</tr>
<tr>
<td>2-12 km</td>
<td>passive microwave</td>
<td>daily</td>
<td>global</td>
</tr>
<tr>
<td>150-75 m</td>
<td>SAR dual pol. (X,C,L)</td>
<td>5 per season</td>
<td>main crops</td>
</tr>
<tr>
<td>5-10 m</td>
<td>SAR dual pol. (X,C,L)</td>
<td>5 per season</td>
<td>main crops</td>
</tr>
<tr>
<td>20-70 m</td>
<td>optical + SWIR</td>
<td>1 per month (if possible same sensor)</td>
<td>croplands</td>
</tr>
<tr>
<td>Footprint</td>
<td>RADAR Altimetry</td>
<td>weekly</td>
<td>NRT products (P5)</td>
</tr>
<tr>
<td>50-100 m</td>
<td>thermal</td>
<td>daily ?</td>
<td>main crops</td>
</tr>
<tr>
<td>20-70 m</td>
<td>optical+SWIR</td>
<td>1 per week (min. 1 per 2 weeks)</td>
<td>main crops</td>
</tr>
<tr>
<td>5-10 m</td>
<td>optical (+SWIR)**</td>
<td>1 per month (if possible same sensor)</td>
<td>croplands</td>
</tr>
<tr>
<td>5-10 m</td>
<td>optical (+SWIR)**</td>
<td>1 per week (min. 1 per 2 weeks)</td>
<td>main crops</td>
</tr>
<tr>
<td>&lt; 5 m</td>
<td>optical</td>
<td>1 to 2 per month</td>
<td>croplands</td>
</tr>
</tbody>
</table>

Working to have the program endorsed by CEOS (SIT)
## Requirements from Asian Rice Crop Monitoring Team

<table>
<thead>
<tr>
<th></th>
<th>Fine (1m-100m) 4-5 images/year</th>
<th>Moderate (100-1000m) daily - Monthly</th>
<th>Coarse (4km-25km) Hourly - Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VIS/IR</td>
<td>SAR (Fine Mode)</td>
<td>SAR (ScanSAR)</td>
</tr>
<tr>
<td><strong>Crop Calendar</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Rice Paddy Field Mapping</strong></td>
<td></td>
<td>Landsat, ASTER, ALOS, THEOS, IRS, ALOS-3</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X</td>
</tr>
<tr>
<td><strong>Cultivated Area (every year)</strong></td>
<td></td>
<td>Landsat, ASTER, ALOS, THEOS, IRS, ALOS-3</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X (dual polarization or full polarimetric data)</td>
</tr>
<tr>
<td><strong>Inventory of agricultural facilities such as tertiary irrigation network audit</strong></td>
<td>ASTER, ALOS, THEOS, IRS, ALOS-3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Early Warning</strong></td>
<td>Agro-meteorology</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Crop Growth</strong></td>
<td>-</td>
<td>-</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X</td>
</tr>
<tr>
<td><strong>Yield Estimation</strong></td>
<td>Agro-meteorology</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X (dual polarization or full polarimetric data)</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X</td>
</tr>
<tr>
<td><strong>Statistical mode-based</strong></td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X (dual polarization or full polarimetric data)</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X</td>
<td>-</td>
</tr>
<tr>
<td><strong>Crop Growth</strong></td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X (dual polarization or full polarimetric data)</td>
<td>ALOS, ALOS-2, Radarsat, sentinel-1, terrasar-X</td>
<td>-</td>
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5. R and D in support of operational monitoring systems

• Goal: to expand the investment in User-Driven ‘operational’ R and D activities for agricultural monitoring:
  – Quantify Agricultural Area extent and change
  – Automated cropland and crop-type mapping
  – Improved satellite retrievals of Soil Moisture and ET
  – Improved global Ag Drought indices and alerts
  – Inter-comparison of EO-driven methods for yield estimation (JECAM)
  – Enhance procedures for EO data inter-use
  – Increase timeliness of delivery systems
  – Increased use of Geospatial and Information Technologies e.g.
    • Satellite data dissemination systems
    • Mobile phone (in situ) data collection and dissemination
NASA Near Real Time EOS Data for Agricultural Monitoring

Timely data is critical for crop monitoring!!

NASA EOS near-real-time daily observations are processed and integrated into USDA FAS system (< 3 hours from observation)

A contribution to GEO-GLAM

lance.nasa.gov
New Data Initiative for Agricultural Landuse from Landsat and Sentinel 2 (NASA, CNES, ESA)

Goal 1: Create consistent, merged Landsat and Sentinel-2 reflectance dataset
- builds on MODIS, MERIS, and Landsat processing heritage
- builds on previous data initiatives among NASA, ESA, and USGS
- establishes consistent radiometric data set for land phenology

Goal 2: Leverage new datasets for agricultural monitoring (e.g. GEOGLAM prototyping)

Goal 3: Support transition to operational agencies
- GEOGLAM, USDA FAS and EC JRC MARS programs
- examples: UMD/USDA MODIS GLAM – MODIS LANCE

Four year effort (2013 – 2016)
- Phase 1: prototype with limited geographic scope (4-5 demonstrator countries);
- Phase 2: expand to support global Ag monitoring with demonstration of success
The picture shows the number of times LDCM and the Sentinel 2 satellites accessed areas on the ground over an 80 day period of time.

- 21 accesses indicates a **maximum revisit interval of ~3 days 19 hours**
- 46 accesses indicates a **minimum revisit interval of ~1 day 18 hours**

The large number of blue colored bands (>41 accesses) indicate that the revisit interval over the majority of the region is on the order of 2 days.

Courtesy Brian Killough, NASA LARC
The MODIS GLAM System Web Interface Available for Querying and Analyzing Time Series Data
Prototyping: tracking impacts of 2012 droughts on crop condition through daily satellite observations

• Severe drought conditions are hampering crop production across the northern hemisphere.

• The US, which is the world’s largest corn and soy producer, is currently experiencing its worst drought in over 50 years.

• Compounding the effects of the US drought, large areas of the Black Sea region (Russia, Ukraine and Kazakhstan) are also in the midst of a wide spread drought. The Black Sea countries account for a quarter of the world’s wheat exports.

• Focus on agricultural area only and sensitive crop stage for 4 primary crops (wheat, corn, soy, rice)
Northern Hemisphere Crop NDVI Anomalies, Aug 13th, 2012

CROP CONDITION GLOBAL OUTLOOKS: BUILDING INTERNATIONAL CONSENSUS

Crop NDVI Anomaly

-0.4 Worse than normal
0 normal
0.4 Better than normal

Non Cropland
Not shown

Canada
USA
Russia
Ukraine
Kazakhstan
China
India

CROP CONDITION GLOBAL OUTLOOKS:

- Kazakhstan, Kostanai
- Orenburg, Russia
- Russia, Chelyabinsk.
- US, Illinois
- US, Kansas

Spring Wheat
Spring Wheat
Spring Wheat
Corn/Soy
Winter Wheat/Corn

Current season crop development (2012)
Average season development (2000-2011)
Northern Hemisphere Crop Condition Anomaly, June 1st, 2012

Highlights:
- US drought developing
- Drought in Ukraine affecting winter wheat
- Drought in Spain affecting winter wheat
- Drought in Russia, Kazakhstan during planting
- Dry conditions in India during planting

Crop stage sensitive to moisture and temperature
Crop stages largely based on USDA/NOAA Joint Agricultural Weather Facility (JAWF)
Northern Hemisphere NDVI Crop Anomaly, August 1st, 2012

Highlights:
- US drought continues to spread and intensify
- Drought in Ukraine continues to intensify in south east
- Drought in Russia, Kazakhstan intensifying, affecting spring wheat and corn
- Rains in India mitigate dry conditions, during the sensitive stages of the growing season
- Rains mitigate dry conditions in Ontario, good conditions in the western Canada

Crop stage sensitive to moisture and temperature
Crop stages largely based on USDA/NOAA Joint Agricultural Weather Facility (JAWF)
The GEO Agriculture Task

• Increased participation of South Asian scientists and practitioners in any aspect of the GEO Agricultural Task would be most welcome

• Active involvement of ISRO in the design and implementation of a coordinated GEOGLAM Data Acquisition Program with CEOS is needed
  – NASA LCLUC would also be interested in developing an IRS component to the Sentinel 2/ LDCM Study

Thank You for your Attention