Developing a Global Agricultural Monitoring System of Systems

Chris Justice
(University of Maryland)
and the
GEO Agricultural Monitoring (Ag0703) Community of Practice
Huge Gap Predicted In Supply Of Food
By Blaine Harden
Washington Post Foreign Service
Thursday, April 17, 2008; Page A14

Biofuel demand makes food expensive

Food Chain: Drought's Toll

Food aid to poorest countries slashed as price of grain soars
UN warns of drastic crisis as relief workers urge donor countries to help beat shortages by switching to giving cash or vouchers

Across Globe, Empty Bellies Bring Rising Anger

Bangladesh bans most rice exports
Bangladesh has banned exports of nearly all the rice it produces to prevent shortages and keep food costs down.
The government said the ban began on Tuesday and will last six months.

Rice Jumps to Record on Philippine Imports, Curbs on Exports

Food riots to worsen without global action: U.N.
Energy and Food Prices Closely Linked

*Energy prices affect ag inputs, processing, transportation, and biofuels*

Index: January 2005 = 100

Source: International Monetary Fund: International Financial Statistics
Context for Agriculture Monitoring

Agriculture is an essential component of societal well-being

- Systemic Challenges:
  - Changing global markets – changing supply and demand
  - Food Security for increasing populations
  - Increasing Productivity while sustaining natural resources
  - Climate change and increased extreme weather events
  - Growing demands for bio-fuels

Source: ULN, (Paul Jasa)
Source: FAS (Jim Crutchfield)
Source: WFP

USA Corn Acres

Price Rises in a single Year, March 2007-March 2008

Source: Bloomberg. except Rice: FAO/Jackson Sons & Co

WORLD POPULATION GROWTH

Source: UN

31% 74% 87% 130%

Source: Bloomberg. except Rice: FAO/Jackson Sons & Co
Meeting these challenges requires accurate agricultural information that can inform policy.

Agriculture monitoring systems can help meet these information needs:

- Timely information on agricultural production and markets
- Early indication of shortfalls in production
- Identification of Food Security risks
- Monitoring of agriculture land use change and trends for policy decisions

While there are currently multiple operational agricultural monitoring systems, they operate independently in a poorly coordinated way.
USDA FAS Global “Strategic Intelligence” with Satellites

(utilize “all data sources” & “convergence of evidence” approaches)

- Weather Data (stations & satellites)
- Crop models (stations & satellites)
- Crop Production Estimates Released Each Month
  - World Agricultural Supply & Demand Estimates (WASDE)
  - Production & Supply Database (PSD Online)
  - World Agricultural Production (WAP) Circular

- FAS Field Travel
- Official Country Reports
- News Wire
- FAS Attaché Reports
- http://www.fas.usda.gov/

Curt Reynolds USDA FAS
MARS-FOOD Crop Monitoring System
European Commission Joint Research Center (JRC)

System based on the use of global remote sensing and meteorological data and on the development of agrometeorological models.

Focus on 4 Regions: South America, East Africa, Russia/Central Asia, Mediterranean Basin.

Data collection & retrieval:
- Earth Observation Data
- Meteorological Data
- Agronomic Database
- WEB Information

European Media Monitor

Processing & analysis:
- Earth Observation Data
- Meteorological Data
- Agronomic Database

WEB Information
- European Media Monitor

Crop Assessment Process

Presentation in this Session

Olivier Leo
China Global Crop Monitoring 全球农情监测

- Crop condition monitoring. (monthly) 作物长势监测-每月
- Production forecast (season) 主要作物作物产量监测-每季
- Monitoring 26 countries 全球26个国家

Lu Shanlong
Poster on Crop Watch Central Asia
Poster Session this pm

Legend
- Non-monitoring Area
- Monitoring Area
FEWS – Famine Early Warning System

- Focus on access to food (Africa, Central America & Afghanistan)
- Geographically characterizes vulnerability and interprets hazards to food insecurity through:
  - Routine monitoring of rainfall, vegetation, crops, and market prices
UN FAO GIEWS-Global Information and Early Warning System

Provides policymakers and policy-analysts with the most up-to-date information on food supply and demand
Provides regular bulletins on food crop production and markets at the global level and situation reports on a regional and country-by-country basis

Estimated rainfall from November 2006 to March 2007, southern Africa

Henri Josserand UN FAO
Global/Regional Monitoring Systems

• Several global/regional scale systems in place – with common data needs, few common standards and protocols and inconsistent results – (most countries have national systems)

MARS FOOD - Crop Monitoring for food security
GEOOSS Agricultural Monitoring Task (Ag 0703)

• Support the development and improvement of Operational Agricultural Monitoring Systems, *enhancing the current capabilities* by using Earth Observations in the areas of:

  – **Agricultural Monitoring** - sub task A (w. IGOL and GOFC/GOLD)
    • Agricultural Production Monitoring
    • Famine Early Warning
    • Agricultural Land Use Change

  – **Agricultural Risk** - Forecasting Weather and Predicting Climate - sub task B

  – **Capacity Building** for Agricultural Monitoring - sub task C
Initial GEOSS/IGOL Agricultural Monitoring Workshop July 2007, UN-FAO

- IGOL/GEO 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 and developed a set of priorities and recommendations

- ISRO agreed to establish Task Secretariat (J.S. Parihar)
GEO Agricultural Monitoring System of Systems: Approach

1. Develop a common vision for the system amongst the Community of Practice (CoP)
2. Establish the conditions under which such a system can develop (GEO partners)
3. Identify near term practical steps (task activities and initiatives) that would contribute to achieving the vision (CoP)
4. Raise awareness to the importance of EO for agricultural monitoring and the level of national commitments for the Task Activities (CoP)
GEO Agricultural Monitoring System of Systems: Functional Components

1. Global monitoring of agricultural production, facilitating reduction of risk and increased productivity at a range of scales

2. Timely and accurate national (sub-national) agricultural statistical reporting

3. Accurate forecasting of shortfalls in crop production and food supply

4. Effective early warning of famine, enabling a timely mobilization of an international response in food aid

5. Global mapping, monitoring and modeling of changes in agricultural land use, type and distribution, in their social and ecological context (land use change / climate change)
Global Agricultural Monitoring System

The Group on Earth Observations (GEO) / Integrated Global Observing Strategy (IGOS) Global Agricultural Monitoring Community of Practice was established in July of 2007 at the second IGOS/GEO workshop convened at the headquarters of the UN twenty-five national and international organizations in Ottawa. The IGOS/GEO workshop decided to establish the GEO as the focal point for the IGOS Global Agricultural Monitoring Community of Practice.

A number of global trends, including agricultural monitoring regions and implementation strategies, were discussed at the workshop. The workshop also considered the Millennium Development Goals (MDGs) and the need for better monitoring of agricultural production and related economic and social indicators.

The IGOS and the GEO

The IGOS is an alliance of organizations that are committed to providing accurate, timely, and cost-effective information on the state of the environment. The GEO is the umbrella organization for the IGOS and is responsible for coordinating the efforts of its members. The IGOS/GEO workshop decided to establish the GEO as the focal point for the IGOS Global Agricultural Monitoring Community of Practice.

Participating programs

Examples of Global to Regional Agricultural Monitoring Systems

The UNFAO Global Information and Early Warning System (GIEWS)

The GIEWS was established in 1975 to monitor food supply and demand at the global scale and to provide early warning of serious regional food shortages. Information from GIEWS is used to identify impending food security crises so that the UN World Food Programme and other international and national agencies can develop country-specific plans. GIEWS integrates satellite-derived information on land cover and land use with in situ data on agricultural statistics, livestock, agricultural markets, and weather. GIEWS monitoring is designed to enable direction of ground-based sampling to validate crop production estimates and development of quick, early, partial indemnity for immediate action.

Figure: GIEWS map of countries in need of food aid in October 2007

The USDA Foreign Agricultural Service (FAS)

The goal of the Office of Global Analysis (OGA) of FAS, specifically within the International Productions Assessment Branch, is to produce reliable, objective, timely, transparent, accurate data on global agriculture production. FAS monitors world agricultural production and world supply and demand for agricultural products to provide baseline market information and information for US domestic early warning. FAS analyses rely upon a combination of meteorological data, field reports, and satellite observations at moderate and high spatial resolutions to aid in crop and growth stage identification and yield analysis. These data are used to confirm or deny unsubstantiated information about forecast crop yields and to identify unreported events likely to impact crop yields. To bring these disparate sources of data together, FAS has developed the Crop Explorer, a GIS-based decision support system. The Global Agricultural Monitoring (GAM) Project, jointly funded by USDA and the NASA Applied Sciences Program, is updating the FAS decision support system with the new generation of NASA satellite observations.

Figure: FAS decision support system images showing vegetation stress predominantly in croplands, during the 2008 drought, in southeastern Australia. The anomaly image compares NDVI values for the September 14 to September 29,
GEO Workshop on Best Practices for Crop Area Estimation with Earth Observations
5-6 June 2008 EC-IPBES

Chairs:
Chris Justice (USA),
Olivier Leo (EC),
Wu Binfang (China)

Secretariat:
Jai Parihar (India)
Monitoring of Agricultural Production
Observations and Models

Seasonal Forecast Models

Satellite Observations
- Coarse
- Moderate
- Fine
(optical, thermal, microwave)

Agrometeorological Data
- Rainfall,
- Temp, Humidity

In-situ Observations
- Rainfall
- Temperature

Crop Models

Area Planted Crop Type

Crop Growth/Condition

Field Reports
- Area Planted
- Crop Condition

Crop Yield
## 2. Goal for a GEO System of Systems - 2015 Vision

### Annual EO products for Ag. land cover change information

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Time Series</th>
<th>Swath Width</th>
<th>Processing</th>
<th>Coverage</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 – 250 m</td>
<td>X 10-day time series</td>
<td>1500 km</td>
<td>automated processing</td>
<td>Global coverage</td>
<td>Croplands map, ag. area change (US-GP, Br, Ar: crop area indicator)</td>
</tr>
<tr>
<td>60 – 10 m</td>
<td>X 3 – 20 images/season</td>
<td>200 - 700 km</td>
<td>standardized processing</td>
<td>Nat. ag. coverage</td>
<td>Crop gr. area indicator, crop group map (US-GP, Br, Ar: crop type area estimate)</td>
</tr>
<tr>
<td>5 – 1 m</td>
<td>X 1-2 images/season</td>
<td>10 km</td>
<td>object-based prelabeling</td>
<td>Local sample</td>
<td>Crop type area estimate</td>
</tr>
</tbody>
</table>

Expected error:
- Global coverage: 10-30%
- Nat. ag. coverage: ± 5-15%
- Local sample: ± 5%

---

**Note:** The table above outlines the goal for a GEO System of Systems for 2015, focusing on annual EO products for agricultural land cover change information. Each resolution level is associated with specific time series, swath width, processing methods, coverage areas, and corresponding products with their respective expected errors.
Concerns Raised about the Adequacy of Current Observation Capabilities

- Concerns about **inconsistent data policies** and pricing
- Concerns about **inadequacy of data coverage** and **coordination of acquisition strategies**
- Concerns about **timeliness of delivery**
- Concerns about **accuracy of the products**
- Concerns about **data continuity**
- Concerns about the need for expanded **capacity building**
GEO Ag Monitoring Workshop Beijing, February 2009
Focus on Agricultural Monitoring, Risk & Capacity Building
Operational Agricultural Monitoring requires reliable and timely data, at multiple scales, collected systematically over the long term (operationally)
Transitioning Research to Operations

Methods and Products

Fundamental Science

User Driven Research and Development

Operational Monitoring Systems

Continuity of Observations

Instruments and Data

Experimental RS Systems
e.g. MODIS, LDCM, EO1,

Operational RS Systems
e.g. AVHRR, NPOESS VIIRS, FLI?
Argentina is currently experiencing one of the worst droughts in decades. According to FAS estimates:

- Argentina 2009 Wheat production dropped to 8.4 Million tons from 16.3 in 2008
- Argentina 2009 Corn production dropped to 13.8 MT from 20.85 in 2008
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Blue</th>
<th>Green</th>
<th>Red</th>
<th>NIR</th>
<th>SWIR</th>
<th>Spatial Resolution (m)</th>
<th>Swath (~km)</th>
<th>Re-visit (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISS-I</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>72</td>
<td>140</td>
<td>22</td>
</tr>
<tr>
<td>LISS-II</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>36</td>
<td>70</td>
<td>22</td>
</tr>
<tr>
<td>LISS-III</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>24</td>
<td>140</td>
<td>24</td>
</tr>
<tr>
<td>LISS-IV</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>6</td>
<td>23/70</td>
<td>5</td>
</tr>
<tr>
<td>WiFS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>180</td>
<td>780</td>
<td>5</td>
</tr>
<tr>
<td>AWiFS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>56</td>
<td>780</td>
<td>5</td>
</tr>
</tbody>
</table>
Monitoring Crop Growth Indicators & Crop Area Using RS Data

Kharif (dB) - Microwave RS
Rabi (NDVI) - Optical RS
Crop Area Fraction

Sigma 0 (dB)

Days From June 1

NDVI / Crop Area Fraction

Parihar ISRO
International Ground Stations

- New Ground Stations for IRS-P6
- Existing
- New Stations for IRS-P5

Parihar ISRO
State of the Practice – *R&D Community*

Global land cover / croplands product

- ESA-GLOBCOVER MERIS 300m product released in 2008

- Forthcoming MODIS 250 m crop likelihood product
Crop area indicator from MODIS

Soy acreage, 2002 from NASS data

<table>
<thead>
<tr>
<th>Year</th>
<th>Regression</th>
<th>r^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>$y = 1.1044x + 341$</td>
<td>0.8059</td>
</tr>
<tr>
<td>2002</td>
<td>$y = 1.0389x + 2314$</td>
<td>0.7459</td>
</tr>
<tr>
<td>2003</td>
<td>$y = 1.0826x + 1086$</td>
<td>0.8125</td>
</tr>
<tr>
<td>2004</td>
<td>$y = 1.1251x + 1800$</td>
<td>0.8292</td>
</tr>
<tr>
<td>2005</td>
<td>$y = 1.007x + 554$</td>
<td>0.9031</td>
</tr>
<tr>
<td>2006</td>
<td>$y = 1.0778x + 237$</td>
<td>0.9071</td>
</tr>
<tr>
<td>2007</td>
<td>$y = 1.0798x + 3013$</td>
<td>0.9057</td>
</tr>
</tbody>
</table>
China Landuse Changes in 1990 - 2000

Residential area expansion

Degree

0~2% 2~10% 10~20% 20~100%

Change type

Dryland->paddy field
Arableland->forestry/grassland
Water area expansion
Residential area expansion
Forestry->arableland
Forestry ->grassland
Grassland ->arableland
Grassland ->forestry
Water area withdraw
No changes

Jiyuan Lui, CAS
Crop area estimation - Ethiopia

IKONOS, Landsat, and SRTM used in a statistical framework

Non-CV Estimate vs HR

\[ y = 0.9945x + 0.0005 \]

\[ R^2 = 0.9159 \]

Full area ETM+ and SRTM

Agreement between IKONOS and model

IKONOS at sample locations
Operational Crop Monitoring Scheme

National Centre of Space Research and Technology
National Space Agency, Kazakhstan

Presentation by Nadiya Muratova
Poster by Alexey Terekhov
This pm
Recognize the need for **Enabling Conditions** for a Global Agricultural Monitoring Systems of Systems

- **Expanded International Cooperation** amongst space agencies and the community of practice (CoP)
- **Non-prohibitive Data Pricing Policies**, allowing for free and open sharing of data and enabling affordable regional agricultural monitoring – improve accessibility (GEO Sec)
- **Coordinated Data Acquisition** over critical agricultural areas during the growing season (GEO Sec/CEOS)
- **EO Data Continuity** > operational systems (CEOS)
- Improved coverage of meteorological stations especially for Africa (GEO Sec / WMO)
- Established best practices, standardized data products and reporting (COP)
- The integration of the satellite data into operational monitoring systems in developing countries (GEO Partners)
GEO Agricultural Monitoring Task Initiatives

• Initiative 1. A Multi-source Production, Acreage and Yield (PAY) database on a common platform. This will enable inter-comparison of results from different global and national reporting systems.

• Initiative 2. Joint Experiments on Crop Assessment and Monitoring (JECAM) undertaking data, modeling and monitoring method intercomparisons, accuracy assessments and integration, based on multi-source satellite and in-situ data – prototyping a system of systems.

• Initiative 3. Coordinated Data Initiatives for Global Agricultural Monitoring (CDIGAM).
  – To ensure the on-going, frequent and timely acquisition, accessibility of satellite data during agricultural growing season and the continuity of those observations necessary for agricultural monitoring,
  – Compile the best available information on agricultural areas, crop calendars and cropping systems,
  – To fill the gaps in the current in-situ observations.

• Initiative 4. GLAMSS Thematic Workshop Series (GTWS). Community workshops will be held on thematic methodological issues and topics to improve communication amongst the CoP, develop best practices and standards and encourage cooperation, coordination and data sharing.
Agricultural CoP Near-term Activities

- **PAY** (Shared Production Database) – *in development* (USDA, JRC, IRSA – *initial development complete in 2009*)

- **JECAM** (Regional Experiments) on methods, inter-comparison and accuracy assessment (China, Argentina, Ethiopia, Canada, Brazil) - *China Pilot - start 2009 – Leadership Role from Canada in discussion*

- **CDIGAM** (Data initiatives) -
  - *Compilation best available crop mask and calendars* (FAO GIEWS 2009)
  - *Global cropland and crop type mask at 250m resolution* (NASA/USDA/SDSU – 2010)

- **GTWS** (Thematic Workshops – *Planned*)
  - *2nd Workshop Satellite Rainfall Estimation*, JRC Ispra (Fall 2009)
  - *ISPRS/GEO Climate Change and Agriculture*, India (Dec 2009)
    - Development of a New Initiative of Climate and Agricultural Change

- Ag Monitoring Best Practices Document
GEOSS - JECAM Initiative
Joint Experiments on Crop on
Agricultural Monitoring
JECAM - Joint Experiment on Crop Assessment and Monitoring

- The proposed JECAM experiment aims to bring together the Community of Practice to undertake inter-comparison of EO data, analysis techniques, monitoring methods and models around a series of experimental data sets acquired for a small set of pilot sites around the World representing a range of agricultural systems.

This joint scientific experiment has two strategic objectives:

- (i) to offer a unique opportunity for the ag. community to collaborate on selected sites to compare and share methods and products
- (ii) to demonstrate the fitness of in orbit EO instrument and their effective acquisition capabilities according to the different cropping systems in various regions.
The following set of EO data is required from the most suitable sensors currently available belonging to GEO-partner space agencies:

- Very high res. imagery for area estimate production and crop mapping validation: 3 acquisitions over samples distributed in the site from ALOS 2,5m sensor and Resourcesat VHR sensor

- Wide swath instrument for crop mapping and crop monitoring: all possible acquisition of AWiFs and HJ-1

- Coarse instrument for crop condition monitoring: daily FR MERIS SAR instrument for crop area indicator: all possible acquisition using ENVISAT ASAR and ALOS PALSAR

*Also requested but already systematically acquired MODIS, SPOT-VEGETATION, LANDSAT, RADARSAT2*
JECAM - Kazakhstan?

• Is there an interest from Kazakh scientists in developing a GEOS Agricultural Experiment to test methodologies and data types to improve operational monitoring of agricultural production using satellite observations?

• If so, are there some agricultural test sites already in place that could be built upon?

• How should we proceed?
– ANNOUNCEMENT –

International GEO Workshop on Synthetic Aperture Radar (SAR) to Support Agricultural Monitoring

Workshop: 2 – 4 Nov 2009
Training Course (by invitation): 31 Oct – 1 Nov 2009

Alberta, Canada
The GEOS Ag CoP welcomes anyone interested to participate in this international program

Please contact:
Chris Justice
Olivier Leo
Inbal Becker Reshef

Thank You