Overview of Data Needs for Remote Sensing-Based Agricultural Monitoring

James Verdin
U.S. Geological Survey / Earth Resources Observation and Science
Famine Early Warning Systems Network
National Integrated Drought Information System
NOAA/ESRL, Boulder, Colorado, USA
Email of September 27
Instruction for the AGRISAT keynote speakers
“…a critical perspective of what is currently operational, achievable and to be expected in the future…”

Email of October 6
Announcing availability of the CEOS Database and EO Handbook
“The database features details of 258 Earth observing satellite missions and 771 instruments, which are currently operating or planned for launch in the next 15 years…”

AGRISAT Workshop
October 13, 2010 – Brussels, Belgium
Why Agricultural Monitoring?

- Detection of *trends* and *anomalies* that might trigger action by decision makers at multiple levels and time scales
- Implicit is the need for *homogeneous time-series* of the relevant variables
  - To provide necessary historical context
  - Continuously updated and consistently processed
  - Accessible with minimum delay after acquisition
Area x Yield = Production

Status of the Resource Base
- Multi-year trends due to policies (ag, energy, environment), population growth, technological advance, etc
- Inter-annual variations due to market, conflict, climate shocks

Status of the Crop
- Inter-annual fluctuations due to climatic conditions, water availability, accessibility of inputs, etc
- Multi-year trends due to ag policy, technological advance, etc

Status of Food Availability
Food Access
Food Utilization
Food Security Status

AGRISAT Workshop
October 13, 2010 – Brussels, Belgium
Data as “Food” for Agricultural Monitoring

Availability
· Do the required observational data exist, or could they feasibly be collected?

Access
· Are there barriers – cost, license requirements, copyright restrictions, etc – preventing use of available data?

Utilization
· Are there issues of scientific understanding, suitability of algorithms, computational intensity, data formats, etc, that prevent more effective use of accessible data?
Area: Where are the crops?

General Land Cover Maps

- Coarse to medium resolution products
- Source imagery: MODIS, MERIS, SPOT VGT, AVHRR, Landsat
- Examples: Global Land Cover Characteristics Data Base, MODIS Land Cover Type, GLOBCOVER, GeoCover-Land Cover, Africover

<table>
<thead>
<tr>
<th>Availability</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>High</td>
</tr>
<tr>
<td>Utilization</td>
<td>Low/Medium</td>
</tr>
</tbody>
</table>
Area: Where are the crops?

Crop Masks

- Coarse to moderate resolution products
- Source imagery: AVHRR, MODIS, MERIS, SPOT VGT
- Examples: IWMI Global Map of Rainfed Cropland Areas & Global Irrigated Area Map; University of Frankfurt Global Map of Irrigated Areas; MODIS Global Cropland Extent; USGS National Irrigated Lands Map

<table>
<thead>
<tr>
<th>Availability</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>High</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Area: What is the crop area?

Area Frame Sampling

- Satellite imagery used in support of ground survey sampling: Landsat, SPOT, AWiFs, Rapid Eye

- Example: USDA National Agricultural Statistics Service

<table>
<thead>
<tr>
<th>Availability</th>
<th>High/Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>High/Medium</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>

USDA NASS

AGRISAT Workshop
October 13, 2010 – Brussels, Belgium
Area: What is the crop area?

Area Frame Sampling

• Satellite imagery used for “virtual” site visits: IKONOS, QuickBird, WorldView

• Examples: FEWS NET Ethiopia, Guatemala, Haiti, etc

<table>
<thead>
<tr>
<th>Availability</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Low</td>
</tr>
<tr>
<td>Utilization</td>
<td>Low</td>
</tr>
</tbody>
</table>
Yield: Vegetation Index Imagery

A measure of chlorophyll density in the plant canopy

• Coarse to medium resolution products

• Source imagery: AVHRR, SPOT VGT, MODIS, MERIS, Landsat, AWiFs; future VIIRS

• Challenge of inter-compatibility of products, continuity of the time-series

<table>
<thead>
<tr>
<th>Availability</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>High</td>
</tr>
<tr>
<td>Utilization</td>
<td>High/Medium</td>
</tr>
</tbody>
</table>

NDVI 250 m, NASA LANCE – USGS eMODIS
Yield: Precipitation Station Data

Systematic sample on the 1st, 11th, and 21st of month

Of the 1232 GTS stations in Africa:
25% missed one or zero reports
40% did not report on any of the 36 days of the sample

<table>
<thead>
<tr>
<th>Availability</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Low</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Issues of climate data management, data rescue
Climatological zones not well represented by the GTS datasets, see prioritized areas numbered in red (1,2,3...7).

Inconsistent data delivery via GTS.

Identified GTS data gaps in vulnerable food insecure areas and also climate-change hot-spots.

Raingauge data readily available at Met Services could help improve the GTS daily representative coverage of raingauge observations.

Identification of GTS data delivery gaps vis-à-vis Climatological Zones & Food Security Map

Gideon Galu, FEWS NET
Yield: Satellite rainfall estimates

- Satellite rainfall estimates can help fill gaps in the station network
- There is no homogeneous global time-series of precipitation grids at scales suitable for agricultural monitoring (2 – 10 km)
- FEWS NET software allows integration of dekadal local station data to augment GTS stations ingested by NOAA
- FEWS NET has trained met service employees to use the software, but it has not been adopted for routine use

September 2010, Dekad 3

<table>
<thead>
<tr>
<th>Availability</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Medium</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Yield: Satellite rainfall estimates

Looking Ahead

GPM is coming, an international constellation of microwave missions

Launch of the Core Spacecraft by NASA scheduled for 2013
Yield: Potential Evapotranspiration

Stations with observations for ET calculation, to quantify atmospheric water demand, are even sparser than precipitation stations.

Atmospheric models can fill the gap, though presently at coarse resolution: NOAA, ECMWF, NASA.

Agricultural monitoring requires 2–10 km, daily/sub-daily

---

**Potential Evapotranspiration (PET) – 08 Oct. 2010**

- **Availability**: Medium
- **Access**: Medium
- **Utilization**: Low
Yield: Actual Evapotranspiration

Calculated by crop water balance using grids of precipitation, PET, soil properties

Implementations by FEWS NET, JRC, AGRHYMET, WFP, etc.
Yield: Actual Evapotranspiration

Calculated by crop energy balance using Land Surface Temperature (LST) imagery (sometimes with grids of PET)

Coarse to medium resolution LST data are used: GOES/Meteosat, AVHRR, MODIS, Landsat, ASTER

<table>
<thead>
<tr>
<th>Availability</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>High</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Yield: Soil Moisture

Stations with soil moisture observations are quite sparse, though more are being added for drought monitoring.

Newly formed International Soil Moisture Network (GEO, GEWEX, CEOS, ESA) addressing problems of data sharing and harmonization.

<table>
<thead>
<tr>
<th>Availability</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Medium</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Yield: Soil Moisture from Satellite Data

AMSR-E: Limited by vegetation cover

ESA SMOS: Recently commissioned

NASA SMAP: Launch in 2013

- Soil Moisture on Earth Grid at 10 km with 24 hr latency
- Surface and Root Zone Soil Moisture on Earth Grid at 10 km with 7 day latency

<table>
<thead>
<tr>
<th></th>
<th>Availability</th>
<th>Access</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSR-E</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

AGRISAT Workshop
October 13, 2010 – Brussels, Belgium
Water: Snow Pack

Manual snow courses and automated snow telemetry (SNOTEL) stations provide direct observations.

In the U.S., there are ~750 SNOTEL, ~900 snow course; Canada, fewer; Central Asia, fewer; elsewhere?

<table>
<thead>
<tr>
<th>Availability</th>
<th>Medium/Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Medium/Low</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium/Low</td>
</tr>
</tbody>
</table>

USDA NRCS  SNOTEL

AGRISAT Workshop
October 13, 2010 – Brussels, Belgium
Water: Snow Pack

Models are needed to fill in spatially and provide homogeneous historical time-series

<table>
<thead>
<tr>
<th>Availability</th>
<th>Low/Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>Utilization</td>
<td>Low/Medium</td>
</tr>
</tbody>
</table>
Water: Surface Water

Reservoir storage: USDA/NASA satellite altimeter

Curt Reynolds, USDA
Water: Surface Water

Stream flow: DFO/JRC hydrographs from AMSR-E

Over 2500 sites world wide

<table>
<thead>
<tr>
<th>Availability</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Medium</td>
</tr>
<tr>
<td>Utilization</td>
<td>Medium</td>
</tr>
</tbody>
</table>
SWOT combines surface water hydrology with physical oceanography.

100 m rivers, 1 km² lakes, slope 1 cm/1 km
Water: Ground Water

Total water storage

GRACE mission

Mass decrease, groundwater depletion
Rodell et al., 2009, Tiwari et al., 2009

GRACE trend: ~ 40 mm/year over Rajasthan

Scanlon et al., University of Texas
Summary

- Meteorological data and models: need to be managed for climate requirements as well as weather forecast requirements
- Vegetation index imagery: need to somehow maintain continuity of the time series, and lengthen it
- Precipitation station networks: need more stations reporting more often on the GTS
- Satellite precipitation: need grids worldwide with a homogeneous reanalysis as the basis for SPI
Summary

- Evapotranspiration: need to increase resolution of globally available grids from 100 km to 2-10 km at daily/sub-daily temporal scale, with t/s
- Satellite soil moisture: need to organize concurrent campaigns of satellite and ground data collection
- Water: need to assimilate remote sensing data into land surface models to obtain long time-series and ongoing estimates of surface water levels and flows, ground water levels, and snow water equivalent
Thank you