Integration of drought monitoring tools for proactive food security management under evolving climate

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1. Overview of Drought and its impact
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4. Drought Early Warning systems/Indicators
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Drought and its impact

- affects lives causing considerable damages
Drought impacts take different forms in each country, and region because of differences in economy, culture, and government/institutions.

Overall impact could be:
- economic losses &/or
- famine & loss of lives

Need to address drought impacts on food security and mitigation/adaptation strategies.
Overview of Drought

Drought: A deficiency of precipitation (intensity) from expected or “normal” that extends over a season or longer period of time (duration) ...

Meteorological Drought and is sufficient to meet the demands of human activities and the environment (impacts).

Users

- Agricultural Drought
- Hydrological Drought
- Socio-economic Drought
Drought Types

- **Meteorological drought** (defined on the basis of degree of dryness)
  - Simply expressed in terms of a rainfall deficit in relation to some average amount and duration of drought period.
  - Definitions must be considered as region specific (some definitions identify as number of days with precipitation less than some threshold value)
  - Longer term rainfall time series data should be available

- **Hydrological drought:** Effects of periods of rain shortfall on surface and subsurface water supply
  - They lag behind meteorological and agrometeorological droughts
  - Groundwater drought is outlined by lower than average annual recharge for more than one year

- **Socioeconomic drought:** associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought.
  - occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.
Agricultural drought:

- Links various categories of meteorological and hydrological drought to agricultural impacts, focusing primarily on soil water deficits and differences between actual and potential evapotranspiration.

- Should consider situations with insufficient soil moisture level to meet the plant needs during growing season.

- A good definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity.

- Can be caused by an abrupt and marked increase in air temperature while soil temperature remains low.

- Affected by temporal variability of water availability (precipitation distribution during growing season).
Natural and Social Dimensions of Drought

Decreasing emphasis on the natural event (precipitation deficit)
Increasing emphasis on the water/natural resources management

Increasing complexity of impacts and conflicts

Source: D. Wilhite
Crisis vs Risk Management
The Cycle of Disaster Management

Source: D. Wilhite
Early Warning Systems

Data and information on climate and water supply, including seasonal forecasts, must be integrated to provide decision makers with a comprehensive picture or representation of current conditions and future outlooks.

Integration of meteorological, hydrological, and agricultural services.

Potential users of climate information must be educated on how that information can be applied to reduce the risks associated with drought.

Improved delivery systems (e.g. web delivery) must be developed to get information in the hands of decision makers in a timely manner.

This requires a better understanding of user needs and their preferences on how this information is displayed or presented.
Key Indicators For Monitoring Drought

- climate data (precipitation, temperature)
- soil moisture
- stream flow
- ground water
- reservoir and lake levels
- snow pack
- short, medium, and long range forecasts
- vegetation health/stress and fire danger

Source: D. Wilhite
Climate-based Drought Indices

- Percent of Normal
- Standardized Precipitation Index
- Palmer Drought Severity Index
- Crop Moisture Index
- Surface Water Supply Index
- Reclamation Drought Index
- Deciles

Source: http://drought.unl.edu/Planning/Monitoring/ComparisonofIndicesIntro.aspx
Remote Sensing for Environmental Monitoring

Satellite-based remote sensing has been widely used over the past ~ 30 years for national to global-scale many environmental monitoring activities, including drought monitoring.
Advantages of Remote Sensing for Drought Monitoring

1. Spatial continuous measurements across large geographic areas.
   - Important in locations where weather stations or other ground observations (human) are sparse or non-existent.

2. Frequent revisit time for image acquisition
   - Several satellites acquire image data every 1-2 days or a 1-2 week basis for same location.

3. Historical record of conditions
   - Several instruments (AVHRR and Landsat) provide 30+ years of information with some newer sensors (MODIS) approaching 10+ years of observations.
   - In Africa, other satellite data sources e.g., METEOSAT and SPOT

Satellite image of relative vegetation greenness for Ethiopia
Remote Sensing of Drought Monitoring

Rainfall Estimate (RFE)

Uses a combination of satellite-based observations (cloud temperature and cold cloud duration) and ground-based rain gauge information.

- RFEs updated at multiple time intervals
  - daily
  - dekad
  - weekly
  - monthly

Satellites:

- Meteosat (used since 1995)
- Special Sensor Microwave/Imager (SSMI)**
- Advanced Microwave Sounding Unit (AMSU)*

**Implemented in 2000.
Satellite Remote Sensing of Drought

The Traditional Approach

Normalized Difference Vegetation Index (NDVI)

**NDVI as operational tool:** The visible red and NIR bands were readily available on ‘global imagers’ such as the Advanced Very High Resolution Radiometer (AVHRR) since the 1980s, which has provided near-daily global observations of the Earth’s land surface for operational activities such as drought monitoring.

**Historical Records:** Data from satellite have been used for ~30 years for a wide range of large-area environmental applications including drought monitoring and early warning.
Drought Monitoring Efforts Using NDVI

Many drought monitoring efforts are using long-term, time-series NDVI data sets that include:

- U.S. Drought Monitor (USDM)
- North American Drought Monitor (NADM)
- USDA National Agricultural Statistics Service (NASS)
- Famine Early Warning System (FEWS)
- USDA Foreign Agricultural Service Global Crop Monitoring
- Australian Bureau of Meteorology Drought Monitoring

Most efforts rely on NDVI anomaly measures that compares the current vegetation conditions (as expressed by NDVI) to historical conditions.

- Percent of historical average
- Departure from a prior date (month or year)
NDVI and Vegetation Monitoring

Challenges for Drought Monitoring:
1) Discrimination of drought-impacted areas from locations experiencing other types of stress (pests, plant disease, flooding, and fire) or land use/land cover change.
2) Classification of different drought severity levels (e.g., moderate, severe, and extreme).
Historical database development of satellite, climate, and biophysical data extracted for 2,000+ weather station locations.

Satellite Data:
- PASG
- SOSA
- Out of Season

Climate Data:
- 36-week SPI
- Self-calibrated PDSI

Biophysical Data:
- Land Use/Land Cover Type
- Irrigation
- Soil Available Water Capacity
- Elevation
- Ecoregion

* 20-year historical record of observations (1989 – 2008)

Step 1
Training Data

Step 2
Regression tree analysis to develop bi-weekly VegDRI models (rules)

Step 3
Gridded image generation of near real-time data inputs

Step 4
Application of bi-weekly model to near real-time gridded inputs for VegDRI map generation

Operational VegDRI Map Production
Modeling VegDRI for Africa (VegDRI-Africa)

### Input Data
- MODIS - NDVI &/or AVHRR NDVI
- Standardized Vegetation Index (SVI)
- Future
- VIIRS, LDCM, GPM, SMAP, etc

### GIS Layers and Data Processing
- Calculate variables
- Extract attributes
- Reprojection
- Derive metrics
- Interpolation
- Creating grid surfaces
- Extracting text files
- Creating metadata

### Modeling and Research
- Modeling of VegDRI-Africa (Regression-tree Model)

### Dynamic Inputs (over time)
- Model Formulation, Implementation, and Recurring Operations
- Static Inputs (over time)

Web-delivery

Internet Portal for Data Access and Distribution/NASA-SERVIR-East Africa
Overview of the Vegetation Outlook (VegOut) Model

**Climate data**
- Palmer Drought Severity Index (PDSI)
- Standardized Precipitation Index (SPI)

**Satellite data**
- Standardized Seasonal Greenness (SSG)
- Start of Season Anomaly (SOSA)
(derived from 1-km AVHRR NDVI data)

**Oceanic data**
- Multivariate ENSO Index (MEI) Index
- Southern Oscillation Index (SOI) Index
- Pacific Decadal Oscillation (PDO) Index
- North Atlantic Oscillation (NAO) Index
- Pacific/North American (PNA) Index
- Madden-Julian Oscillation (MJO) Index
- Atlantic Multi-decadal Oscillation (AMO) Index

**Biophysical data**
- Ecoregion (Omernik Level III)
- Elevation
- Irrigated Lands (MODIS-derived)
- Land Use/Land Cover Type (NLCD 2001)

**Data integration algorithms**
- Modeling using regression tree
Hybrid (Climate- and satellite-based) Drought Monitoring

International Interest on hybrid drought monitoring models
- Canada – seamless U.S.-Canada coverage for North American Drought Monitor
- Mexico
- Czech Republic
- India – Indian Agricultural research Center
- China
- Ethiopia and Great Horn of Africa
Current and Future satellite-based Monitoring

New Remote Sensing Data
- will be considered as inputs for transitioning and/or maintaining data continuity as well as improving the models and products
  - The Visible Infrared Imager/Radiometer Suite (VIIRS)
  - Landsat Data Continuity Mission (LDCM): the operational land imager (OLI) and the thermal infrared sensor (TIRS)
  - The Global Precipitation Measurement Mission (GPM)
  - Soil Moisture Active-Passive Mission (SMAP)

Source: NASA website
Global products (examples):
NASA TRMM Near-real time global rainfall
NASA TRMM 30-day avg. rainfall and anomalies
Daily NOAA GFS 1-day forecast
Daily NOAA GFS 7-day total forecast
Daily Potential Evapotranspiration (PET)
Daily Northern Hemisphere Snow Depth

http://trmm.gsfc.nasa.gov/
East Africa Satellite Drought Information System (EASDIS)

Integrated Drought Monitoring

Value & Benefit to the Society

Policy Decision
(Government, International and national Organizations, etc.)
- Increased Agricultural productivity
- Improved seasonal yield estimates
- Early warning of food shortages
- Early identification of problems in major agricultural commodities
- Improved efficiency of water use

Agricultural & Food Security for Africa

Management Decision
(Government ministries, International and national agricultural and food security managers, farmers, etc.)

Data

Earth Science Observations

Vegetation Monitoring Models Development

Implementation of New and Improved Outputs/Products

New Model/Product

VegDRI/VegOut-Africa - NDMC

Improved Products

Standardized Vegetation Index (SVI) - NDMC
Evaporative Stress Index (ESI) - USDA
VegET-WRSI - USGS
Soil Moisture - USGS
GRACE-DAS drought indicators - JHU
Rainfall Estimates- (RFE)- USGS/RI

EASDIS
Estimated food security conditions, 2nd Quarter 2013 (April-June 2013)

USAID/FEWS NET: Global Monitoring of food security

East Africa: Ethiopia

Central America: Guatemala

Source: http://www.fews.net/Pages/default.aspx
National Monitoring

Figure. Moisture Index as of 3rd dekad Feb 2013.


Figure. Croplands Water Requirements Satisfaction Index (WRSI) as of 3rd Dec 2012.
Impact of Global Climate Change:

Increase in temperatures result in:

- Higher water demand of vegetation – less Ground Water recharge
- Higher evaporation from surface waters, including reservoirs
- Higher water demand of all economic sectors, esp. agriculture

(right). Stippling is omitted for clarity (see text). Anomalies are relative to the average of the period 1980 to 1999.
Impacts of Global Climate Change

- Storms
- Floods
- Droughts

Increased frequency of extreme weather events
Africa – Climate Change & its impact

What experts indicated:

• By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change. {WGII 9.4, SPM}

• By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition. {WGII 9.4, SPM}

• Towards the end of the 21st century, projected sea level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5 to 10% of GDP. {WGII 9.4, SPM}

• By 2080, an increase of 5 to 8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (high confidence). {WGII Box TS.6, 9.4.4}
Final Thoughts

- Integrated climate, satellite, and environmental information offer significant potential to advance drought monitoring capabilities beyond the use of traditional climate indices.
- A hybrid (climate- & satellite-based) remote sensing ‘tool kit’ is rapidly emerging to characterize key components of the hydrologic cycle related to drought.
- The field of remote sensing offers many new opportunities to support research not only in the area of drought, but also other natural disasters to address issues related to agriculture, climate, ecology, natural resources, and water.
- Drought monitoring and prediction models should consider the ever increasing climate change to provide reliable information for decision makers to support adaptation strategies.
Thank you for your attention!

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