Drought Monitoring and Early Warning Systems

Robert Stefanski
Chief, Agricultural Meteorology Division
Climate and Water Department
Summary

• Review of High-Level Meeting on National Drought Policies

• Introduction to Drought Monitoring and Early Warning Systems

• Different Drought Indices and Data Issues

• Successful examples/ongoing initiatives
World Meteorological Organization

- United Nations agency for weather, climate, hydrology and water resources and related environmental issues.

- 191 Members from National Meteorological and Hydrological Services (NMHS) – New Member – South Sudan (Dec 2012)

- 10 major scientific & technical programmes (Secretariat)

- 8 Technical Commissions advise & guide activities of programmes (Experts)

- 6 Regional Associations involved in implementation
Global Framework for Climate Services

- Goal:
  - Enable better management of the risks of climate variability and change and adaptation to climate change at all levels, through development and incorporation of science-based climate information and prediction into planning, policy and practice.
Priorities

- Agriculture
- Disaster risk reduction
- Water
- Health
High-Level Meeting on National Drought Policies

- March 11-15 2013
- Over 414 participants from 87 countries
- Main Partners – UNCCD, FAO, WMO
- Key message: Help countries move from reactive to proactive drought policies

- 12 representatives of UN agencies and international and regional organizations (UNU, IFRC, IOM, CBD, WFP, IAEA, UNECA, JRC, ICARDA, GWP, ACMAD, ISDR)
- Final Declaration adopted – www.wmo.int/hmndp
HMNDP Main Organizers and Partners

- World Meteorological Organization (WMO)
- United Nations Convention to Combat Desertification (UNCCD)
- United Nations Food and Agriculture Organization (FAO)
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- United Nations Development Programme (UNDP)
- UN-Water Decade Programme on Capacity Development (UNW-DPC)
- United Nations International Strategy for Disaster Reduction (UNISDR)
- World Food Programme (WFP)
- Global Water Partnership (GWP)
- International Fund for Agricultural Development (IFAD)
- A total of 17 Organizations
Scientific Segment

• 9 substantive sessions in the Scientific Segment plus 2 synthesis/reporting sessions (regional breakout groups and summary)

• 28 posters in three poster sessions. 16 Side events

• All sessions produced summaries and recommendations

• Compendium from July 2011 Workshop revised as HMNDP Science Document
HMNDP Science & Policy Documents

www.wmo.int/hmndp.org

See items 18-26
Launch of initiatives

• 2013 World Day to Combat Desertification, UN Decade for Deserts and the Fight against Desertification, and UN Decade on Biodiversity

• Integrated Drought Management Programme (IDMP) with WMO & GWP

• National Drought Management Policies Initiatives (NDMP) with UNW-DCP, FAO, UNCCD, & WMO
Introduction
Why Monitor Drought?

• Drought is a *Normal* Part of the Climatic Cycle
• Drought *Impacts* are Significant & Widespread
• *Many* Economic Sectors Affected
• Drought is *Expensive*
  – Droughts cause more deaths and displace more people than any other kind of natural disaster.
  – Since 1980, major droughts and heat waves within the U.S. alone have resulted in costs exceeding 100 billion dollars

Source: Svoboda, 2009
Importance of a Drought Monitoring System

- allows for *early* drought detection
- improves response (*proactive*)
- “triggers” actions within a drought plan
- a critical *mitigation* action
- *foundation* of a drought plan

Source: Svoboda, 2009
Components of a Drought Monitoring System

• timely data and timely acquisition
• synthesis/analysis of data used to “trigger” set actions within a plan
• efficient dissemination network (web, media, extension, etc.)

Source: Svoboda, 2009
Potential Monitoring System Products and Reports

- **Historical analysis** (climatology, impacts, magnitude, frequency)
- **Operational assessment** (cooperative data, SPI and other indices, automated networks, satellite and soil moisture data, media and official requests)
- **Predictions/Projections** (SPI and other indices, soil moisture, streamflow, seasonal forecasts, SST’s)

Source: Svoboda, 2009
Components of a Drought Early Warning and Information System

- Monitoring **AND** Forecasting
- **Tools** for decision makers
- Drought risk assessment and planning
- **Education** and awareness

Source: Wilhite, 2013
Indices and Data Issues
Approaches to Drought Monitoring

- Single index or parameter
- Multiple indices or parameters
- Composite index

Source: Svoboda, 2009
Précipitations décadaires du 21 au 31 Mars 2015

Well above average
Above average
Near average
Below average
Well below average
Monthly Precipitation in percentage of average for Feb 2015

- Well above average
- Above average
- Near average
- Below average
- Well below average
Fig.4: NUMBER OF RAIN DAYS
Figure 8: Hydrogramme du Fleuve Niger à Niamey de la Troisième décennie de juillet 2014
Fig 5 : ISBE des cultures annuelles en début de croissance végétative ou en maturité

Fig 6 : ISBE des cultures annuelles en pleine croissance végétative

Fig 7 : ISBE des cultures annuelles en phase reproductive ou cultures pérennes

Stress hydrique
Pas de Stress hydrique
6. CONDITIONS HYDRIQUE DES CULTURES DU RIZ ET DU MAÏS
6.1 Situation hydrique du 01 au 10 avril 2015

TABLEAU 2 : Indice moyen de satisfaction des besoins en eau de la culture de maïs de 4 mois (120 jours) 01 au 10 avril 2015

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STRESS \hspace{1cm} PAS DE STRESS HYDRIQUE
Fig. 9 : NDVI à la 2ème décade d’avril 2015

Fig. 10 : Anomalies des différences d’images d’indices de végétation entre la 2ème décade d’avril 2015 et la moyenne 2001-2010
Analyse du démarrage de la saison
2014 comparée à la moyenne 1999_2013
Période du 1er mai au 11 juillet

2014 en AVANCE
- 3 décades
- 2
- 1
- 0
- 1
- 2
- 3 décades

2014 en RETARD

Carte: Geographic, WGS 84 - Résolution: 1km
Source: analyse dérivée des profils NDVI METOP/AVHRR
 Réalisée par AGRHYMET/VITO
Africa Standardized Precipitation Index (SPI) for the indicated accumulation periods as of November 10, 2014.
Figure 1: Seasonal forecast of precipitation for March-April May 2015
Indicators & Triggers
Definitions

• **Indicators**: Variables to describe drought conditions.
  
  Examples: precipitation, streamflows, groundwater, reservoir levels, soil moisture, Palmer indices, …

• **Triggers**: Specific values of the indicator that initiate and terminate each level of a drought plan, and associated management responses.
  
  Example: precipitation below the 5th percentile for two consecutive months is a Level 4 Drought.

Source: Svoboda, 2009
## Time during normal conditions

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Triggers</th>
<th>Actions</th>
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<tbody>
<tr>
<td>I-1</td>
<td>Level 1  (SPI 0.0 to -0.99)</td>
<td>Level 2</td>
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<tr>
<td>I-2</td>
<td>Level 2  (SPI -1.0 to -1.49)</td>
<td>Action 2: Dig extra wells for livestock and wildlife in area</td>
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<tr>
<td>I-3</td>
<td>Level 3  (SPI -1.5 to -1.99)</td>
<td>Action 3: Reduce irrigation of annual crops by 50%</td>
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<tr>
<td>I-4</td>
<td>Level 4  (SPI ≤ -2.0)</td>
<td>Level 2</td>
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</tbody>
</table>

Consider I-1 is SPI

Consider Action 1: Ban watering lawns
Consider Action 2: Dig extra wells for livestock and wildlife in area
Consider Action 3: Reduce irrigation of annual crops by 50%
Importance of Drought Indices

- **Simplify** complex relationships and provide a good communication tool for diverse audiences
- **Quantitative** assessment of anomalous climatic conditions
  - Intensity
  - Duration
  - Spatial extent
- **Historical** reference (probability of recurrence)
  - Planning and design applications

Source: Svoboda, 2009
Considerations in Choosing Indicators / Triggers

- Proper and Timely Detection of Drought
- Spatial and Temporal Sensitivity
- Supplies and Demands
- Drought In / Drought Out
- Composite and Multiple Indicators
- Data Availability, Validity, and Clarity
- Ease of Implementation

Source: Svoboda, 2009
Key Variables for Monitoring Drought

- climate data
- soil moisture
- stream flow / ground water
- reservoir and lake levels
- snow pack
- short, medium, and long range forecasts
- vegetation health/stress and fire danger
- remote sensing products
- impacts

Source: Svoboda, 2009
Lincoln Workshop

- Inter-Regional Workshop on Indices and Early Warning Systems for Drought held in Lincoln, Nebraska, USA from 8 to 11 December 2009

- Co-Sponsors:
  - National Drought Mitigation Center (NDMC)
  - United States Department of Agriculture (USDA)
  - United States National Oceanic and Atmospheric Administration (NOAA)
  - United Nations Convention to Combat Desertification (UNCCD)
  - University of Nebraska-Lincoln, School of Natural Resources
  - World Meteorological Organization

http://www.wmo.int/pages/prog/wcp/agm/meetings/wies09/index_en.html
Natural and Social Dimensions of Drought

Decreasing emphasis on the natural event (precipitation deficiencies)

Increasing emphasis on water/natural resource management

Increasing complexity of impacts and conflicts

Meteorological

Agricultural

Hydrological

Socio-economic

Source: Wilhite 2006
Lincoln Declaration - Recommendations

- The National Meteorological and Hydrological Services (NMHSs) are encouraged to use SPI to characterize meteorological droughts and provide this information in addition to indices currently in use.

- A comprehensive user manual for the SPI should be developed that describes the index, computation methods, specific examples of current use, the strengths and limitations, mapping capabilities, and how it can be used.
# Probability of Recurrence

<table>
<thead>
<tr>
<th>SPI</th>
<th>Category</th>
<th># of times in 100 yrs.</th>
<th>Severity of event</th>
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</thead>
<tbody>
<tr>
<td>0 to -0.99</td>
<td>Mild dryness</td>
<td>33</td>
<td>1 in 3 yrs.</td>
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<tr>
<td>-1.00 to -1.49</td>
<td>Moderate dryness</td>
<td>10</td>
<td>1 in 10 yrs.</td>
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<tr>
<td>-1.5 to -1.99</td>
<td>Severe dryness</td>
<td>5</td>
<td>1 in 20 yrs.</td>
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<td>&lt; -2.0</td>
<td>Extreme dryness</td>
<td>2</td>
<td>1 in 50 yrs.</td>
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Standardized Precipitation and Evapotranspiration Index (SPEI)

- New variation of the SPI index by Vicente-Serrano et al. (2010) includes a temperature component.
- The inputs required are precipitation, mean temperature, and latitude of the site(s) to run the program on.
- More information can be explored through obtaining the SPEI at http://sac.csic.es/spei/index.html.

Data Issues I

- Accurate and long-term weather data is needed
- Need at least years 30 years of rainfall data for SPI
- Can use fewer years but SPI will become unreliable
- For Agricultural and Hydrological drought need other data
  - Potential evapotranspiration (ETP)
  - Departure of ETP from normal?
  - Affected crops – conditions, growth stages
  - Soil moisture (measurement/simulation/departure from normals)
Data Issues II

- Gridded datasets can be used (i.e. GPCC-Global Precipitation Climatology Centre)
- Remotely sensed data
- Reanalysis of weather model data

- Vulnerability and impact data are limited in area and length of record
Ongoing Initiatives
Integrated Drought Management Programme (IDMP)
IDMP Objectives

- To support stakeholders at all levels by providing policy and management guidance and by sharing scientific information, knowledge and best practices for Integrated Drought Management.
- Contributes to global coordination of drought-related efforts of existing organizations & agencies:
  - Better scientific understanding & inputs for drought management;
  - Drought risk assessment, monitoring, prediction and early warning;
  - Policy and planning for drought preparedness and mitigation across sectors; and
  - Drought risk reduction and response
Areas of Work

1) Development of Tools
2) Capacity Building
3) Demonstration Projects
4) Responding to Regional and National Needs
5) Development of Drought HelpDesk
Organizations interested to participate (Status November 2014)

- Food and Agriculture Organization of the United Nations (FAO)
- United Nations Convention to Combat Desertification (UNCCD)
- Australian Bureau of Meteorology
- Convention on Biological Diversity (CBD)
- International Center for Agricultural Research in the Dry Areas (ICARDA)
- International Commission for Irrigation and Drainage (ICID)
- International Water Management Institute (IWMI)
- Joint Research Centre (JRC)
- Mexico’s National Water Commission (CONAGUA)
- Stockholm Environment Institute (SEI)
- U.S. National Drought Mitigation Center (NDMC)
- UNDP Cap-Net
- United Nations Development Programme (UNDP)
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- United Nations Environment Programme (UNEP)
- United Nations Office for Disaster Risk Reduction (UNISDR)
- University of Nebraska Daugherty Water for Food Institute
- University of Southern Queensland
- UN-Water Decade Programme on Capacity Development
- World Bank
Regional Programmes and Initiatives

Support action and implementation on the ground, adding to existing efforts the strength of IDMP and its partners

**Central and Eastern Europe (2013):** Bulgaria, Czech Republic, Hungary, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia, Ukraine

**Horn of Africa (2014):** Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda.

**West Africa (2014):** First in Burkina Faso, Niger and Mali, and then share lessons learned with other neighbouring countries through the WMO partners, GWP Country Water Partnerships and other partners.

**South Asia Drought Monitoring System (2014) with IWMI in:** Bhutan, Bangladesh, Nepal, India, Pakistan and Sri Lanka

**Central America (2013) Regional workshop leading to training on SPI and assessment of current drought.**

**South America (tbc 2015) Regional workshop in Bolivia potentially leading to follow-up activities with partners.**
Help Yourself

- Drought Management Tools
- Questions and Answers bank
- Reference Centre databases
- Discussion group using social media

Get Help

- Personal assistance for Drought Management (policies, laws, strategies)
- Capacity building
- A rapid guidance to the tools of the Help Yourself
Outcomes of Sep 2014 IDMP Meetings

- **Proposed publications:**
  - Integrated Drought Management Framework Document
  - Drought Indices Handbook
  - Series of Case Studies

- Engage with partners to exchange information on drought to further enhance HelpDesk

- Develop cooperation mechanism with partners to allow contributions to IDMP in consistent way avoiding duplications.

- Consider organizing an international conference on drought management in 2016
Examples
U.S. Drought Monitor

September 8, 2009
Valid 8 a.m. EDT

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, September 10, 2009
Author: Rich Tinker, CPC/NCEP/NWS/NOAA
The Drought Monitor is widely used:

- **Policy:** Farm Bill/IRS/USDA/NOAA DGT/State drought plan triggers
- ~3.75M page views and ~2M visitors/year
- **Media:** The Weather Channel and all major newspapers/Internet Media/ Network News/ CNN/NPR/etc.
- **Presidential/Congressional briefings**
- **A model of interagency/level collaboration**

Source: Svoboda, 2009
Some Examples of Decision Making Using the Drought Monitor

- USDA Dried Milk Program 2002-03
- USDA CRP Release hot spot trigger
- Numerous states use as a drought trigger (Governor’s declarations)
- 2006-07 USDA Livestock Assistance
- 2006-07 IRS (tax deferral on livestock losses)
- 2008 Farm Bill
- NWS Drought Information Statements

Source: Svoboda, 2009
• The focus of the workshop is to **review current understanding of drought worldwide**, and **developing plans for moving forward with an experimental global drought information system (GDIS)**.

• **Workshop sponsors:**
  – WCRP
  – NIDIS
  – WMO
  – GEO
  – JRC
  – USCLIVAR
FAO-Agriculture Stress Index System (ASIS)

Developed by:

In collaboration with:

Presented by: Oscar Rojas (FAO)
Agricultural Stress Index System is based on the Vegetation Health Index (VHI) (Kogan et al. 1995)

Vegetation condition index (VCI):

$$VCI_i = \frac{NDVI_i - NDVI_{i \text{min}}}{NDVI_{i \text{max}} - NDVI_{i \text{min}}}$$

Temperature condition index (TCI):

$$TCI_i = \frac{BT_{max} - BT_i}{BT_{max} - BT_{min}}$$

Vegetation Health Index (VHI):

$$VHI = a \cdot VCI + (1-a) \cdot TCI$$
ASIS assess the severity (intensity, duration and spatial extent) of the agricultural drought.
Agricultural Stress Index (ASI)
% of cropland area affected by drought per GAUL 2 region
from: start of SEASON 1
to: deced 2 November 2013
Non-cropland pixels excluded
METOP-AVHRR
WGS84, Geographic Lat/ Lon

GIEMS
Global Information and early Warning System for Food and Agriculture
Breakout Sessions
Group Questions

• **Group A:** What are the current procedures/challenges on early warning systems?

• **Group B:** What are the meteorological and hydrological networks, data quality, sustainability needed?

• **Group C:** What mechanisms are in place for communicating and liaising drought monitoring and early warning information between national institutions?
Breakout Group Guidelines

• Each Group will have a facilitator.

• Group identifies leader and rapporteur.

• Either group leader or rapporteur makes presentation in Session 3c.

• Each group will spend 45 minutes on main group question and 15 minutes each on other questions