Monitoring and Forecasting Water Availability in Food Insecure Regions

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Water availability, for what?

Soil water storage: agriculture & pasture (i.e. plant water availability), water points for people and animals

Groundwater storage: irrigation, domestic water supply

Surface water storage: reservoirs, lakes, streams used for domestic, agricultural and industrial needs

Snow water storage: irrigated agriculture and domestic water supplies
Soil water storage: agriculture & pasture (i.e. plant water availability), water points for people and animals

Groundwater storage: irrigation, domestic water supply

Surface water storage: reservoirs, lakes, streams used for domestic, agricultural and industrial needs

Snow water storage: irrigated agriculture and domestic water supplies

The Famine Early Warning Systems Network (FEWS NET) has long history of monitoring plant available water for agriculture and pasture with NDVI and rainfall statistics.

NASA LIS modeling capabilities let us model different storage reservoirs to monitor conditions that impact food security, beyond rainfed agriculture.

Water availability, for what?
FEWS NET LDAS (FLDAS) Africa

**Parameters:**
- IGBP MODIS landcover
- FAO soils, GTOPO30 elevation, NCEP albedo (quarterly/seasonal)

**LIS-based LSMs:**
- Noah3.3 10km x 10km resolution
- VIC 4.1.2 25km x 25 km resolution

**Meteorological Inputs:**
- MERRA-2, GDAS
- CHIRPS, CHIRPS-prelim, RFE2

**Daily & Monthly outputs:**
- Full water balance e.g. ET, SM, runoff
- Full energy balance e.g. sensible heat flux, ground heat flux, net radiation

**Evaluation**
- remote sensing (e.g. MODIS NDVI, SSEBop ET, ESA CCI SM), GRDC streamflow, GRACE TWS

**Data delivery:**
- LIS Data Portal
- USGS Early Warning Data Portal
- NASA GES DISC & GIOVANNI


Southern Africa was facing abnormally dry, abnormally hot and drought conditions as classified by NOAA CPC. We find that the Oct-Dec average surface and subsurface soil moisture is some of the driest since 1982.
FLDAS Reservoir Monitoring

Gaborone Dam, Botswana 2015-16 drought

Time series analysis and Standardized Runoff Index (SRI-1, SRI-24)
Upper Tana Basin, Kenya: 6-month (maroon) and 18-month (cyan) moving average

18-month anom.

Thika Dam construction

Thika Dam at 30%
2009, 2017

Thika Reservoir, Kenya Sept-2017

Time series analysis and Multi-month anomalies
Water Stress per Falkenmark Index (runoff per capita)


Water Stress Thresholds from Falkenmark

<table>
<thead>
<tr>
<th>Water Stress</th>
<th>Table 1. Annual and Monthly Falkenmark Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>category</td>
<td>m3/yr/cap</td>
</tr>
<tr>
<td>no stress</td>
<td>&gt;1700</td>
</tr>
<tr>
<td>stress</td>
<td>1000–1700</td>
</tr>
<tr>
<td>scarcity</td>
<td>500–1000</td>
</tr>
<tr>
<td>absolute scarcity</td>
<td>&lt;500</td>
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</table>

Maps updated twice a month at https://lis.gsfc.nasa.gov/projects/fewsnet
Maps of annual runoff and population change, and time series of the Lake Victoria Basin show the relationship between runoff and water stress.
Current Conditions & Historical Context

1-week & 2-week weather forecasts

NMME Probability for next 1 - 6 months

Water Availability Forecasts

April 1-15 avg streamflow w/ CHIRPS prelim

NMME May 2018 forecast, initialized April

NMME Precipitation Forecast Skill
Apr - initial conditions; season 1

NMME skill for May forecast, initialized April
### FLDAS Model Evaluation-East and Southern Africa

<table>
<thead>
<tr>
<th>Basin</th>
<th>SSEBop ET vs Noah33 (R)</th>
<th>GRACE TWS vs Noah33 (R)</th>
<th>Streamflow (R) (#stations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Nile</td>
<td>0.49</td>
<td>0.85</td>
<td>0.46-0.94 (11)</td>
</tr>
<tr>
<td>Awash</td>
<td>0.72</td>
<td>-</td>
<td>0.47-0.72 (3)</td>
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<tr>
<td>Juba-Shabelle</td>
<td>0.8</td>
<td>-</td>
<td>0.41-0.53 (4)</td>
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<tr>
<td>Upper Tana</td>
<td>0.64</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Rufiji</td>
<td>0.56</td>
<td>-</td>
<td>0.41-0.61</td>
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<tr>
<td>Pangani</td>
<td>0.74</td>
<td>-</td>
<td>0.41-0.81</td>
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<tr>
<td>Orange</td>
<td>0.72</td>
<td>0.74</td>
<td>0.61-0.66 (3)</td>
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<tr>
<td>Zambezi</td>
<td>0.72</td>
<td>0.76</td>
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<tr>
<td>Limpopo</td>
<td>0.78</td>
<td>0.66</td>
<td>0.41-0.61</td>
</tr>
<tr>
<td>Wami-Ruvu</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Additional evaluation published in McNally et al. 2016 & 2017 and Jung et al. 2017

**FLDAS Noah33 CHIRPS+MERRA-2 estimates are well correlated with independent observations in Southern and Eastern Africa basins.**

Streamflow correlations are a function of human influence (e.g. irrigation, dams).
FEWS NET LDAS (FLDAS) Central Asia

Parameters:
UMD-AVHRR landcover, FAO soils, GTOPO30 elevation, NCEP albedo (quarterly/seasonal)

Meteorological Inputs:
6 hourly GDAS - NCEP Global Data Assimilation System Final (FNL) Operational Global Analysis

LIS-based LSMs:
Noah3.6
1km x 1km resolution, 1 hr model timestep, No snow assimilation

Daily - near real time outputs:
Snow water equivalent
Snow covered area
Snow depth
Air temperature

Evaluation
remote sensing (e.g. MODIS & Landsat
Snow Cover Fraction, SSM/I & AMSR-2 snow depth)

Data delivery:
LIS Data Portal, USGS Early Warning Data Portal

Central Asia Snow Modeling

Estimates of Snow Water Equivalent (SWE) and Snow Depth are provided daily to USGS Early Warning https://earlywarning.usgs.gov

These estimates are then used by CPC NOAA and FEWS NET to track conditions in Afghanistan.

https://lis.gsfc.nasa.gov/projects/fewsnet
The Daily SWE by basin’s tool allows us to compare the current season’s evolution to historic season time series.
Central Asia Evaluation

Modeled estimates of SCA are routinely compared to MODIS.

Mean snow cover fraction corresponds well at the basin level during the peak snow season (Water Year 2016).

Probability of Detection (POD) > 0.6 and False Alarm Rate (FAR) < 0.2.
Central Asia
Applications

These snow estimates contribute to Food Security Outlooks produced by FEWS NET.

For the current 2017/18 season the low snowpack in Afghanistan is expected to impact crop production.
Summary &
Next Steps

• NASA GSFC routinely runs custom instances of the NASA Land Information System for FEWS NET to provide information on water availability in Africa and Central Asia.

• Ongoing efforts include:
  - Expanding the modeling domain globally &
  - Developing hydrologic forecasts using input from NMME models.

https://lis.gsfc.nasa.gov/projects/fewsnet
References


FLDAS Africa evaluation:


FLDAS Model Evaluation

FLDAS Noah33 & VIC412 estimates are well correlated with GRACE terrestrial water storage (TWS), SSEBop evapotranspiration (ET) and in situ streamflow in the Orange Basin, Southern Africa.
FLDAS Model Evaluation

FLDAS Noah33 streamflow estimates are well correlated (R=0.73) with in situ streamflow from SWALIM. Correlations decline downstream, likely due to human abstractions.

Gauges from FAO’s Somalia Water and Land Information Management (SWALIM) http://sddr.fao.swalim.org/

Noah and SSEB ET anomalies
Central Asia Evaluation

Mean snow cover fraction corresponds well at the basin level during different water years.

When considering a full water year, probability of Detection (POD) metrics are moderate and False Alarm Rate (FAR) is relatively low. Cloud contamination likely contributes to poor statistics.