Vegetation Outlook for GHA
Experimental Model

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Outline

• Introduction
• Methods
• Preliminary Results: US vs GHA
• Next Steps
Introduction: What is VegOut?

- An experimental tool to provide future outlooks of general vegetation conditions (seasonal greenness) based on an analysis of information that integrates climate, satellite, biophysical, and oceanic data.
- Series of maps depicting future outlooks of general vegetation conditions at a 1-km² spatial resolution that are updated every 2 weeks.
  1) 2-week Vegetation Outlook map
  2) 4-week Vegetation Outlook map
  3) 6-week Vegetation Outlook map
VegOut Methodology

1. **Historical Database Development**
   - **Data Input Variables**
     1. Standardized Seasonal Greenness (SSG)
     2. Start of Season Anomaly (SOSA)

2. **Model Development**
   - Regression Tree Model

3. **Map Generation**
   - 2-week outlook
   - 4-week outlook
   - 6-week outlook

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**Biophysical Data**
- 1. Land use/cover type
- 2. Soil available water capacity (STATSGO)
- 3. Ecoregion type
- 4. Irrigation status
- 5. Elevation

**Oceanic Data**
- 1. Atlantic Multi-decadal Oscillation index (AMO)
- 2. Multivariate ENSO Index (MEI)
- 3. Madden-Julian Oscillation
- 4. Pacific North American index (PNA)
- 5. Pacific Decadal Oscillation (PDO)
- 6. Southern Oscillation Index (SOI)
- 7. North Atlantic Oscillation (NAO)

**Climate Data**
- Standardized Precipitation Index (SPI)

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(* Models developed from an 18-year historical record (1989 – 2006) of bi-weekly climate and satellite observations at 1,402 weather station locations.

Oceanic data are extracted for the same period of time.

Biophysical variables are static over time.

Figure. VegOut database, process (regression-tree rules generation), and outlook map production. (After Tadesse et al., 2010, GIScience & Remote Sensing)
<table>
<thead>
<tr>
<th>Data Set Name</th>
<th>Type</th>
<th>Acronym</th>
<th>Source</th>
<th>Data Set Name</th>
<th>Type</th>
<th>Acronym</th>
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<tr>
<td>Standardized Seasonal Greenness</td>
<td>Satellite (continuous, 14-day)</td>
<td>SSG</td>
<td>AVHRR NDVI</td>
<td>Atlantic Multidecadal Oscillation Index</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>AMO</td>
<td>CPC/NOAA</td>
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<tr>
<td>Start of Season Anomaly</td>
<td>Satellite (continuous, annual)</td>
<td>SOSA</td>
<td>AVHRR NDVI</td>
<td>Madden-Julian Oscillation</td>
<td>Oceanic/Atmospheric (same value for all sites, 14-day)</td>
<td>MJO</td>
<td>BoM/Australia</td>
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<tr>
<td>Standardized Precipitation Index</td>
<td>Climate ASCII (at sites), 1 km raster surface, continuous, 14-day</td>
<td>SPI</td>
<td>ACIS/ HPRCC</td>
<td>Pacific Decadal Oscillation</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>PDO</td>
<td>JISAO/UW/NOAA</td>
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<tr>
<td>Ecological Regions</td>
<td>Biophysical (categorical, static)</td>
<td>ECO</td>
<td>EPA Ecoregions</td>
<td>Southern Oscillation Index</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>SOI</td>
<td>CPC/NOAA</td>
</tr>
<tr>
<td>Soil Available Water Capacity</td>
<td>Biophysical (continuous, static)</td>
<td>AWC</td>
<td>STATSGO</td>
<td>North Atlantic Oscillation</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>NAO</td>
<td>CPC/NOAA</td>
</tr>
<tr>
<td>Digital Elevation</td>
<td>Biophysical (continuous, static)</td>
<td>DEM</td>
<td>USGS-EROS</td>
<td>Multivariate ENSO Index</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>MEI</td>
<td>CDC/NOAA</td>
</tr>
<tr>
<td>Land Cover</td>
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<td>NLCD</td>
<td>National Land Cover Database</td>
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<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td>PNA</td>
<td>CPC/NOAA</td>
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<tr>
<td>Irrigated Agriculture</td>
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<td>IrrAg</td>
<td>USGS-EROS</td>
<td>Pacific North American Index</td>
<td>Oceanic/Atmospheric (same value for all sites, monthly)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List of variables, update cycles, and data sources for the VegOut model.  
(Tadesse et al., 2010, GIScience & Remote Sensing)
Types of Vegetation Outlooks

1) Historical-pattern (time-series relationships) – outlooks based on series of historical records

   e.g., if the current climate, vegetation, and oceanic conditions are similar to previous drought years (e.g., 1989, 2002, etc), then the following 2-, 4-, and 6-week would have similar drought patterns as those drought years.

2) Scenarios – outlooks based on implementation of the model using percentage(s) of precipitation expected over the specific outlook period.

   e.g., 50% of normal precipitation over the next 2 week period used to calculate the 2-week VegOut map

   • Multiple scenarios using different %
     - 0%, 50%, 100%, and 150% of normal precipitation

   • Scenarios can be done over the different time intervals
     - 2-weeks, 4-weeks, and 6-weeks
Time-series relationship model
(Historical Pattern)

Model

• Method: Given the current independent input variables, what would be the value in the following 2 weeks based on the historical pattern? (the next 4 and 6 week?)

• The VegOut modeling approach:
  \[ \text{VegOut}_{t=2 \ wk} = f_{t=0}(\text{SSG}) + f_{t=0}(\text{SPI}, \text{LCLU}, \text{Eco}_R, \text{Per}_{\text{Irrig}}, \text{AWC}, \text{SoS}_{\text{anom}},) + f_{t=\text{priorMonth}}(\text{MEI}, \text{MJO}_{\text{RMM}1}, \text{NAO}, \text{PDO}, \text{SOI}, \text{AMO}, \text{SSTA}, \text{PNA}) \]
Table. The SSG values were classified into seven general vegetation condition classes based on the standard deviation (STDEV) of the SSG: (1) Extreme stress is less than -2 STDEV, (2) Severe stress is between -2 and -1 STDEV, Poor vegetation is between -1 and -0.5 STDEV, Fair (Near normal) is between -0.5 and +0.5 STDEV, Good vegetation is between +0.5 and +1 STDEV, Very good vegetation is between +1 and +2 STDEV, and Excellent vegetation is greater than +2 STDEV.

<table>
<thead>
<tr>
<th>SSG values (STDEV)</th>
<th>Vegetation Condition</th>
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<tbody>
<tr>
<td>-2.0 and less</td>
<td>Extreme stress</td>
</tr>
<tr>
<td>-1.0 to -2.0</td>
<td>Severe stress</td>
</tr>
<tr>
<td>-0.5 to -1.0</td>
<td>Poor vegetation</td>
</tr>
<tr>
<td>-0.5 to +0.50</td>
<td>Fair (Near normal)</td>
</tr>
<tr>
<td>+0.5 to +1.0</td>
<td>Good vegetation</td>
</tr>
<tr>
<td>+1.0 to +2.0</td>
<td>Very good vegetation</td>
</tr>
<tr>
<td>+2 and above</td>
<td>Excellent vegetation</td>
</tr>
</tbody>
</table>

Figure. Observed seasonal greenness (SSG) for July 28, 2008
Figure 4. (a) Observed seasonal greenness (SSG) for July 28, 2008; (b), (c), and (d) are 2-, 4-, and 6-week outlooks; (e), (f), and (g) are observed SSG for August 11, August 25, and September 8 that correspond to the 2-, 4-, 6-week outlooks, respectively; (h), (i), and (j) are the change maps (the difference between the predicted and observed) for the 2-, 4-, 6-week outlooks, respectively. (After Tadesse et al., 2010, GIScience & Remote Sensing)
Comparing Six-week outlook with actual observation

(a) Predicted seasonal greenness (SSG) for September 8, 2008

(b) Observed seasonal greenness (SSG) for September 8, 2008
Table 2. Evaluation of the VegOut model. The mean absolute difference (MAD) values, relative error (RE), and coefficient of determination ($R^2$) between the observed and predicted SSG are shown for each period and the corresponding outlooks in all periods of the growing season. (Tadesse et al., 2010, GIScience & Remote Sensing)
Scatter plots of observed and predicted SSG values for period 12 (i.e., first half of June), and coefficient of determination ($R^2$) showing the accuracy of the prediction across the growing season. Figures 3a, 3b, 3c, 3d, 3e, 3f, and 3h show the scatter plots of the observed and the 2-, 4-, 6-, 8-, 10-, 12-, 14-, and 16-week predicted SSG values, respectively. Figure 3i shows the $R^2$ across the growing season. (Source: Tadesse et al., 2010, GIScience & Remote Sensing)
Tables (a), (b), and (c) show percentage contribution of individual variables (attributes) to the period 15 (July 14-28) VegOut models for 2-week, 4-week, and 6-week outlooks, respectively. At the top row of each table, the number of rules and cases for each individual model are shown. In the table, the Conditional Statement column shows the approximate percentage of cases for which the input variable appears in a condition of an applicable rule, and the Regression Model column gives the percentage of cases for which the variables appear in the model of applicable rules.

<table>
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<tr>
<th>Data Type</th>
<th>Variable</th>
<th>Conditional Statement</th>
<th>Regression Model</th>
<th>Variable</th>
<th>Conditional Statement</th>
<th>Regression Model</th>
<th>Variable</th>
<th>Conditional Statement</th>
<th>Regression Model</th>
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<td>100%</td>
<td>SSG</td>
<td>39%</td>
<td>100%</td>
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<td>SPI</td>
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<td>NAO</td>
<td>&lt;1%</td>
<td>72%</td>
<td>NAO</td>
<td>&lt;1%</td>
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<td>AWC</td>
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<td>ECO</td>
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<td>ECO</td>
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<td>&lt;1%</td>
<td>LCLU</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>LCLU</td>
<td>&lt;1%</td>
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</tbody>
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Getachew Berhan, Ph.D., 2013, Addis Ababa University. Dissertation title:  "Knowledge discovery from satellite images for drought monitoring in food insecure areas of Ethiopia."
- Principal Advisor: T. Tadesse, Ph. D.

- Financial support: AAU & USGS-EWS
# Attributes used to develop the VegOut-Ethiopia model

<table>
<thead>
<tr>
<th>No.</th>
<th>Attribute</th>
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<th>Type</th>
<th>Format</th>
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<tr>
<td>1</td>
<td>Standardized Deviation of NDVI</td>
<td>SDNDVI</td>
<td>Satellite</td>
<td>Raster</td>
<td>NOAA AVHRR</td>
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<td>Raster</td>
<td>USGS</td>
</tr>
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<td>Soil Water Holding Capacity</td>
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<td>Raster</td>
<td>USGS</td>
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<td>Landcover</td>
<td>Biophysical</td>
<td>Raster</td>
<td>ESA</td>
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<td>6</td>
<td>Three-Month Standardized Precipitation Index</td>
<td>SPI_3month</td>
<td>Climate</td>
<td>Raster</td>
<td>IRI</td>
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<td>PDO</td>
<td>Oceanic/Atmospheric</td>
<td>Point data</td>
<td>CPC/NOAA</td>
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<td>Atlantic Multi-decadal Oscillation Index</td>
<td>AMO</td>
<td>Oceanic/Atmospheric</td>
<td>Point data</td>
<td>CPC/NOAA</td>
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<td>9</td>
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<td>PNA</td>
<td>Oceanic/Atmospheric</td>
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<td>CPC/NOAA</td>
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<td>MEI</td>
<td>Oceanic/Atmospheric</td>
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<td>CPC/NOAA</td>
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## Preliminary Results: VegOut-Ethiopia model

<table>
<thead>
<tr>
<th>Month</th>
<th>Outlooks</th>
<th>Predicted Month</th>
<th>Evaluation on test data</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MAD (T)</td>
</tr>
<tr>
<td>June</td>
<td>1-month</td>
<td>July</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>2-month</td>
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<tr>
<td></td>
<td>3-month</td>
<td>September</td>
<td>0.52</td>
</tr>
<tr>
<td>July</td>
<td>1-month</td>
<td>August</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>2-month</td>
<td>September</td>
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</tr>
<tr>
<td>August</td>
<td>1-month</td>
<td>September</td>
<td>0.22</td>
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Table 2. Evaluation of the VegOut-Ethiopia model. The mean absolute difference (MAD) values, Relative Error (RE), and correlation coefficient (R²) between the observed and predicted SDNDVI are shown for each month and the corresponding outlooks in all months of the growing season (i.e., June to September).

Source: Tadesse et al., 2014. Water Resource Research
Preliminary Results: VegOut-Ethiopia

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)
- 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 (Oromia Level III)
  - Elevation
  - Irrigated Lands (MODIS-derived)
  - Land Use/Land Cover Type (NLCD 2001)

### NASA GHA: VegOut-GHA Database Development

<table>
<thead>
<tr>
<th>No.</th>
<th>Input parameters</th>
<th>Resolutions</th>
<th>Data years</th>
<th>Updated year</th>
<th>Source</th>
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<tr>
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<td>Landcover</td>
<td></td>
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<td>2</td>
<td>Normalized Difference Vegetation Index (NDVI)</td>
<td>Dekadal</td>
<td>2001 - 2013</td>
<td>2013</td>
<td>USGS famine early warning systems network (FEWS NET)</td>
</tr>
<tr>
<td>3</td>
<td>Digital Elevation Model (DEM)</td>
<td></td>
<td></td>
<td>1 km</td>
<td>2010</td>
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<td>4</td>
<td>Standard Precipitation Index (SPI)</td>
<td>Dekadal</td>
<td>1981 - 2013</td>
<td>2013</td>
<td>Climate Hazards Group Infrared Precipitation with Stations (CHIRPS)</td>
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<td>Ecoregion</td>
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<td></td>
<td>2008</td>
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<td>6</td>
<td>Evaporation Stress Index (ESI)</td>
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<td>2000-2013</td>
<td>2013</td>
<td>USDA/NOAA</td>
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<td>Soil map and Available water content (AWC)</td>
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<td></td>
<td>2014</td>
<td>European Soil Portal - Soil Data and Information Systems</td>
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</tbody>
</table>

### Oceanic/Atmospheric Indices

<table>
<thead>
<tr>
<th>No.</th>
<th>Index</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Atlantic Multi-decadal Oscillation (AMO)</td>
</tr>
<tr>
<td>2</td>
<td>Dipole Mode Index (DMI)</td>
</tr>
<tr>
<td>3</td>
<td>Multivariate ENSO Index (MEI)</td>
</tr>
<tr>
<td>4</td>
<td>North Atlantic Oscillation (NAO)</td>
</tr>
<tr>
<td>5</td>
<td>Pacific Decadal Oscillation (PDO)</td>
</tr>
<tr>
<td>6</td>
<td>Pacific/North American (PNA)</td>
</tr>
<tr>
<td>7</td>
<td>Southern Oscillation Index (SOI)</td>
</tr>
</tbody>
</table>
Dynamic input variables for the VegOut-GHA model

- **SSG_0 (SSG2102)**
  - High: 4.00
  - Low: -4.00

- **ESI2102**
  - High: 3.46
  - Low: -3.46

- **ZSCR2102**
  - High: 5.00
  - Low: -5.00
Static input variables for the VegOut-GHA model

- **DEM**
  - High: 5778 m
  - Low: -151 m

- **AWC**
  - High: 26
  - Low: 0

- **Land use**
  - High: 200
  - Low: 11

- **ECO regions**
Oceanic/Atmospheric indices for the VegOut-GHA model

AMO July 2002: AMO = -0.4
DMI July 2002: DMI = -0.53
MEI July 2002: MEI = 0.61
NAO July 2002: NAO = 0.65
PDO July 2002: PDO = -0.31
PNA July 2002: PNA = 0.4
SOI July 2002: SOI = -0.8
Satellite-based dekadal (10-daily) Standardized Seasonal Greenness (SSG)

VegOut01
VegOut02
VegOut03
SSG2102
SSG2202
SSG2302
SSG2402

High: 4.00 (Healthy vegetation)
Low: -4.00 (vegetation stress)

Prediction
Observation
Difference

Dekad | R-squared
Vegout2 | 0.96
Vegout3 | 0.94
Vegout4 | 0.92

Difference Map
VegOut - SSG (STD)

< -1.0
-1.0 to +1.0
> +1.0

1-10 August 2002
11-20 August 2002
20-31 August 2002
Satellite-based dekadal (10-daily) Standardized Seasonal Greenness (SSG)

High: 4.00 (Healthy vegetation)
Low: -4.00 (vegetation stress)

Dekad R-squared
Vegout6 0.86
Vegout9 0.83
Vegout12 0.77

Difference Map
VegOut - SSG (STD)

- < -1.0
- -1.0 to +1.0
- > +1.0

20-31 July 2002

Prediction
Observation
Difference
Future Activities

• Regional vs. Country based models
  – comparisons

• Seasonality
  – Objective regionalization/ Climatically homogenous zones

• Evaluation based on
  – Case studies
  – feedback from users & potential users (e.g., ranchers, university extension agents, and managers)

• Assess temporal and spatial relationships between
  – Climate & vegetation dynamics
  – Oceanic dynamics & climate
  – Spatial variability of drought indices

• Use this relationships to determine which variables to integrate in modeling the VegOut-GHA to improve prediction accuracy
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