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INTEGRATING SATELLITE AND CLIMATE DATA FOR US DROUGHT MAPPING AND MONITORING: FIRST STEPS

Jesslyn F. Brown*
USGS/EROS Data Center, Sioux Falls, South Dakota

Tsegaye Tadesse
University of Nebraska, Lincoln, Nebraska

Bradley C. Reed
USGS/EROS Data Center, Sioux Falls, South Dakota

1. INTRODUCTION

Although droughts are normal, recurring climate phenomena, they challenge our current ability to plan, predict, monitor, and provide relief to drought stricken areas. Because of the spatial and temporal variability of droughts, we need to improve the tools available to map and monitor them on many scales from local to national. A team of researchers from the US Geological Survey's EROS Data Center, the National Drought Mitigation Center, and the High Plains Regional Climate Center are developing a prototype system for regional-scale drought monitoring for the conterminous US. This project is in its first year of development. The ultimate goal is to deliver near real-time geo-referenced information (in the form of maps and data) about drought-impacted areas in the US, using the Internet as a primary delivery mechanism.

For the pilot study, the project team is developing methods to integrate satellite data and traditional climate data over the central US. Although, these two information sources reflect different spatial resolutions they should prove complementary for the mapping goals of the project. During the summer of 2002, much of the Great Plains and the Southwest U.S. experienced drought conditions. We initiated a case study in South Dakota and Nebraska to develop and test methods.

**corresponding author address*: Jesslyn F. Brown, USGS/EROS Data Center, Sioux Falls, SD 57198-0001; e-mail: jfbrown@usgs.gov.

2. BACKGROUND

Satellite data collected from the Advanced Very High Resolution Radiometer (AVHRR) sensor provide synoptic daily measurements of surface reflectance at a 1-km resolution. Data from this sensor has contributed to many studies of regional to global scale ecosystem dynamics and patterns because of its frequent temporal coverage and moderate spatial resolution (Loveland and others 1991; Tucker and others 1985; Malingreau 1986; Defries and others 1995; Reed and others 1996; Reed and Yang 1997). Many studies based their analysis on vegetation indices computed from combinations of visible red and near-infrared spectral measurements collected from satellite-borne sensors. The advantages of using these numerical transforms rather than strictly spectral observations include minimizing soil and other background effects, reducing data dimensionality, providing a degree of standardization for comparison, and enhancing the vegetation signal (Curran 1981; Malingreau 1989; Goward 1989). One of the more commonly used vegetation indices, the normalized difference vegetation index (NDVI), takes advantage of the reflective and absorptive characteristics of plants in the red and near-infrared portions of the electromagnetic spectrum and has been used in research on vegetation yield and productivity. Anomalous patterns in vegetation index data have been shown to correspond with drought (Kogan 1995, 1997; Peters and others 2002).

Many climate indicators and indices of drought exist. Commonly used drought indices in the U.S.

include the Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI), and Standardized Precipitation Index (SPI). Each of these indices has recognized strengths and weaknesses. The SPI is a simple calculation solely based on rainfall with a temporal flexibility that is theoretically suited to the quicker responses in vegetation detected by satellite imagery. It is a statistical measure on the surplus or lack of precipitation during a given period as a function of the long-term average precipitation (McKee and others 1993; McKee and others 1994).

3. METHODS

Previous studies have established significant relationships between satellite-derived vegetation indices and climate variables mainly over non-irrigated crops and grasslands (Wang and others 2001; Yang and others 1998). This drought project builds upon previous research by investigating methods to integrate the information from climate-based drought indicators with satellite measures of vegetation greenness derived from multi-temporal NDVI data.

3.1 Satellite Data Processing

For this study, we calculate a seasonal greenness (SG) product that is updated every 14 days based on the 14-day NDVI composites distributed by the USGS/EROS Data Center (Eidenshink 1992). SG is calculated as a daily integration of the NDVI curve between the start of season and the current date.

For vegetation monitoring, the SG metric for the any period is compared to the mean of the same time period from the historical (from 1989 to current year) database. The measure is expressed as a percentage by the formula:

Percent of Average SG = (current SG / mean SG) * 100

Areas that are above and below the mean SG are highlighted by this calculation. Areas below the mean may result from a variety of influences including standing water, drought, deforestation, or urbanization. Climate data and drought indicators are necessary to determine where drought is causing patterns of below average SG.

3.2 Meteorological Data Processing

For the pilot study, we retrieved and analyzied meteorological variables and drought indices for weather stations in the central U.S. using the Unified Climate Access Network (UCAN) as implemented at the High Plains Regional Climate Center (HPRCC). Variables like air temperature, humidity, solar radiation, wind speed, and precipitation affect the rate of evapotranspiration and, in turn, determine whether soil moisture is sufficient for vigorous growth and development of plants. These variables are available for both the HPRCC Regional Network and in the NOAA TD3200 data sets in the UCAN system. The pilot study uses meteorological data as input to drought indices like the PDSI and the SPI. Our analysis focuses on determining which variables correlate best with the SG data and at what time scales.

Analysis presented here is based on a small sample of 4 weather stations listed in Table 1.

Table 1. Sample weather stations

Code	Station Name	Latitude (deg.min)	Longitude (deg.min)	Land Cover
C392429	Dupree	45.03	101.36	Small grains
C393452	Gregory	43.14	99.26	Row crop, grass, pasture
C254440	Kimball	41.16	103.39	Grass, fallow
C257665	Scottsbluff AP	41.52	103.36	Grass, fallow

4. EARLY RESULTS

SPI and corresponding Percent of Average SG satellite data for 2001 and 2002 show encouraging, although preliminary, results (Figure 1). The drought data points, shown in the lower left quadrant, are show expected patterns with the possible exception of Scottsbluff AP. It is possible that irrigated agriculture or other human interventions are influencing this data point. However, the correlation for these few data points was fairly strong (R^2=0.75). Further research will involve analysis over hundreds of weather stations within a number of ecological regions in the U.S.

Period length is an important consideration for the SPI measure. This index can be calculated based on a number of different period lengths ranging from one week to 52 weeks. We selected a 24-week period for this preliminary study based on prior research by Wang (2001). Their study correlated precipitation and temperature variables with mean annual NDVI over Kansas. The authors investigated different time periods for accumulating precipitation, and provide evidence that longer periods, up to 28 weeks, had higher correlation coefficients with NDVI.

5. SUMMARY

Climate-based drought indicators, such as the SPI, measure where precipitation amounts are lower than normal, although they represent conditions at points (e.g., weather stations) or within political units (e.g., counties or climate divisions). Satellite-derived data show vegetation condition for the current growing season and are represented by a continuous surface. Integrating these two data types should result in spatially-continuous maps of drought impacted vegetation at a 1-km resolution.

It is predictable that the relationships between the SPI and the percent of average SG will vary based on environmental factors including land cover, land management practices, and soils. Future modeling efforts will include these factors.

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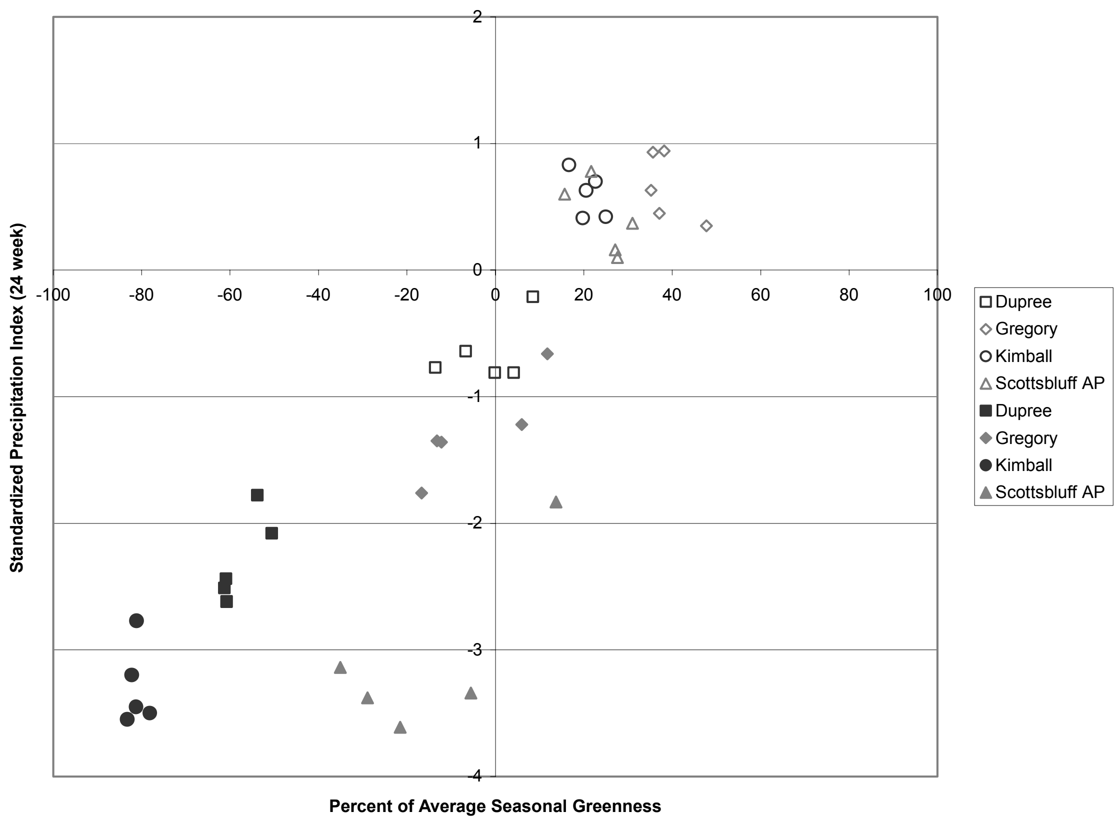

Figure 1. SPI (24-week) and percent of average SG data for South Dakota and Nebraska weather stations. The solid symbols are 2002 data and the open symbols are 2001 data.