Order Number 9022999

Coarse spatial resolution satellite remote sensing of drought conditions in Nebraska: 1987–1988

Peters, Albert John, Ph.D.

The University of Nebraska - Lincoln, 1989

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

COARSE SPATIAL RESOLUTION SATELLITE REMOTE SENSING OF DROUGHT CONDITIONS IN NEBRASKA: 1987 - 1988

by

Albert John Peters

A DISSERTATION

Presented to the Faculty of

The Graduate College in the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Geography

Under the Supervision of Professor Donald C. Rundquist

Lincoln, Nebraska

December, 1989

COARSE SPATIAL RESOLUTION SATELLITE REMOTE SENSING OF DROUGHT CONDITIONS IN NEBRASKA: 1987 - 1988

Albert J. Peters, Ph.D.

University of Nebraska, 1989

Advisor: Donald C. Rundquist

Neither the Palmer Drought Severity Index (PDSI) nor the Crop Moisture Index (CMI) allow for detection of the onset, spatial extent, severity, and termination of drought. The dearth of sampling stations, the generally irregular geographic pattern of these data-collection sites, and certain inherent time-lag factors all combine to reduce the practical utility of both the PDSI and CMI. Therefore, the purpose of the research was to evaluate satellite remote sensing with systems of coarse spatial resolution as a potential tool for detecting and monitoring drought conditions in Nebraska. Twenty-two datasets acquired by the NOAA Advanced Very High Resolution Radiometer (AVHRR) during 1987 and 1988 were transformed to Normalized Difference Vegetation Indices (NDVI). Analyses focused on individual crop-reporting districts in Nebraska. Digital processing was accomplished with hardware systems and software packages which are available commercially.

Results of the research included a better temporal correlation between average NDVI and CMI than between NDVI and PDSI, seasonal NDVI curves that were free of

radiometric errors, good correlations between seasonal NDVI and precipitation, and evidence that the NDVI transformation is less useful in semi-arid Western Nebraska than in more humid portions of the state. Analysis of seasonal NDVI measurements allowed correct identification of the geographic core of the 1988 drought in Nebraska. The necessity of real-time acquisition of AVHRR data for an operational drought-monitoring system is highlighted.

TITLE

COARSE SPATIAL RESOLUTION SATELLITE REMOTE SENSING

OF DROUGHT CONDITIONS IN NEBRASKA: 1987-1988

BY

Albert John Peters

APPROVED	DATE
Donald C. Rundquist	December 6, 1989
Kenneth F. Dewey	December 12, 1989
Merlin P. Lawson	December 7, 1989
Blaine L. Blad	December 6, 1989

SUPERVISORY COMMITTEE

GRADUATE COLLEGE   UNIVERSITY OF NEBRASKA

GRAD 83002 300 8-86m

ACKNOWLEDGMENTS

There are a number of people without whose help, guidance, and encouragement, I would never have completed my graduate studies. First, I would like to thank my parents who never had an opportunity to go to college. Thanks also to Michael McIntyre who supported me through my graduate work at San Jose State University many years ago, and who encouraged me to continue on with graduate work at Nebraska. Don Rundquist, a friend and fellow student at the University of Nebraska and later my advisor, was most influential in my decision to return to school to finish this project. Don, thank you very much; this achievement would not have been possible without you. Merlin Lawson, also as friend and advisor, was of great assistance through his encouragement, and he cleared the way for my return to graduate school after a hiatus of many years; thank you Merlin. To the other members of my graduate committee, Kenneth Dewey, Blaine Blad and Jim Merchant, thank you for your help and support. I thank Don Wilhite for his kind support and technical assistance on my dissertation topic. I also acknowledge others at the Conservation and Survey Division who were most helpful to

me, in particular Bernice Goemann, Donn Rodekohr, and Dee Ebbeka. Finally, no one has sacrificed more than my wife Bjarnhild and son Erik, who had the love, patience and courage to put me through school twice. No words could adequately express my gratitude to you both.

TABLE OF CONTENTS

Chapter | Page

ILLUSTRATIONS

Figure		Page

Figure | Page

Figure | Page

TABLES

Tables | Page

CHAPTER I

INTRODUCTION

Palmer (1965) defined drought as "an interval of time, generally on the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically appropriate moisture supply." But, droughts are more than just rain-free periods because the intensity and length of drought depends not only on meteorological parameters but also on the characteristics of a region's vegetation, soil water, and soil-fertility conditions. Therefore, drought can be defined more specifically as a dry period bringing about crop disaster through chemical and biochemical irregularities (Albrecht, 1956). In this manner, drought can also be defined in an economic sense, and the impact is often severe. In fact, drought is the largest single cause of all insured crop losses in the United States. Borchert (1971) reports that, during a drought in the Great Plains, wheat yields may be reduced 20-25 percent from those of normal years, while cattle production may decline by 6-25 percent.

Droughts can be associated with certain geographic factors. They seem to be prevalent within large land areas where the effects of "continentality" are important: i.e., where the weather is highly variable. Therefore, in the

United States, droughts may be expected to occur in mid-continent (Albrecht 1956). In fact, Kendrew (1927) went so far as to state:

> In the United States the strip of country between the foot of the Rockies and 100 degrees west longitude has a mean rainfall between 12 and 20 inches. It is liable to vary very much from year to year, and is so low in bad years that agriculture cannot be safely carried on.

Of course, this statement was made prior to irrigation development in certain parts of the Plains, but, nonetheless, the statement serves to point up the hazards of dry farming in that region.

In addition, droughts seem to vary spatially with regard to duration and intensity. That is, even in a widespread drought, some localized areas seem to suffer greater damage than others.

Drought has long been recognized as a serious environmental problem in Nebraska. The "Dust Bowl" era of the 1930s serves as the epitome of climatic extremes in precipitation, temperature, and evaporation, but other time periods have been difficult, while perhaps not as devastating as the 1930s. Various parts of Nebraska experienced drought conditions in the 1950s, 1970s and 1980s (personal communication with Donald Wilhite, Associate Professor of Agricultural Meteorology and Climatology, University of Nebraska, Lincoln).

Because drought is not solely a meteorological phenomenon and is manifested geographically, agricultural-resources managers are faced with the problem of monitoring the landscape to detect not only the presence of drought but also its severity and spatial extent. Such information is important for a number of reasons including verification of insurance claims, federal-disaster assistance, and government crop-production/yield estimates.

Drought Indices

Drought is a characteristic feature of the climate of the Great Plains, and attempts have been made to define its intensity, duration, and spatial coverage in the form of an index. Most traditional assessments of drought have been based on either the Palmer Drought Severity Index (PDSI) or the Crop Moisture Index (CMI). These measures include the following common features: 1) estimates of potential evapotranspiration; and 2) estimates of soil-moisture depletion. While widely used in the United States, PDSI and CMI are not without shortcomings.

Palmer Drought Severity Index

The PDSI is standardized to allow direct comparisons of values on both a spatial and temporal basis. Index values are published jointly by the U.S. Departments of Commerce and Agriculture in the Weekly Weather and Crop Bulletin for each division in the U.S. to help in monitoring growing conditions.

Background information and the equations used to derive the Palmer Drought Severity Index can be found in his original research report (Palmer, 1965). Following is a brief and general outline of the components and assumptions making up the PDSI. A set of initial conditions, a set of appropriate climatic coefficients, and monthly observations of precipitation and temperature are required to begin the calulation of PDSI values for each climatic division. The initial conditions provided by the user include: station latitude, annual mean temperature, and the available water capacity of the soil. The four ratio-based climatic coefficients used to calculate PDSI are the mean evapotranspiration (ET) to mean potential evapotranspiration (ET_p), mean soil moisture recharge to mean potential soil moisture recharge, mean runoff to mean potential runoff, and mean soil moisture loss to mean potential soil moisture loss (which would be the loss due to evaporation if

precipitation was zero for the period). The four coefficients are clearly dependent on the climate of an area, and a separate set of coefficients are calulated for each month of the year. Thus, the index is based on the principles of moisture supply and demand. Palmer began with a water balance, designing his drought computations around average monthly values of precipitation and temperature. However, man-made changes, such as irrigation and water storage reservoirs, in local supply and demand are not taken into consideration (Karl 1986).

The PDSI, as it is currently calculated by the National Weather Service, relies on Thornthwaite's method for calculating potential evapotranspiration (PET). This method uses only day length and temperature to derive PET estimates, ignoring solar energy and sensible-heat advection, both major sources of energy that drive the evapotranspiration process in the Great Plains region. Thus, there is concern that the Thornthwaite method underestimates PET in subhumid and semiarid regions (Rosenberg et al. 1983) and, consequently, that the PDSI tends to underestimate drought severity. The reliability of this index when applied to specific agricultural situations is questionable since plant response was not taken into account in the derivation of the index. Yet, for lack of more crop -specific indices, the PDSI has been

used by federal officials as the principal criterion for the declaration of drought disaster areas (Wilhite, 1983).

Crop Moisture Index

The Crop Moisture Index (Palmer, 1968: National Weather Service 1977), an outgrowth of the PDSI, was developed to provide information on moisture conditions over large agricultural regions. The CMI depicts changes in the soil-moisture situation more rapidly than does the PDSI. Issued weekly, maps of the CMI show areas of favorable or unfavorable crop moisture conditions. However, like PDSI, CMI estimates of PET also use the Thornthwaite method, and the CMI, too, is not crop specific.

Though closely related, values of the CMI and the PDSI may vary considerably. The primary reason for this variance is that the CMI only includes the moisture anomoly of the ongoing month, whereas the PDSI more heavily weights the moisture anomoly of previous months. CMI values will therefore, indicate more favorable moisture conditions over a particularly wet or dry month even in the middle of a serious long-term drought or wet period.