Comparisons of phenological variability and precipitation of ecoregion and grassland cover types in the northern Great Plains from 1988 to 1993
by Linda E Gillett

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science In Earth Sciences
Montana State University

Abstract:
The Normalized Difference Vegetation Index (NDVI) is useful in identifying land cover types and in monitoring land cover changes through time. This study compared selected temporal NDVI metrics and evaluated their association with precipitation in the northern Great Plains during the period .1988-93. The study area covered parts of Montana, Nebraska, North Dakota, South Dakota and Wyoming, and measured 364,400 km^2 in extent. Nine unique ecoregion/ grassland areas were identified from Omerik's ecoregion map (42-Northwestern Glaciated Plains; 43-Northwestern Great Plains; 46-Northern Glaciated Plains) and the EROS land cover database (1-grass/crop; 2-grassland; 3-grass/shrub), although 46-3 was later eliminated because of its small area. Two-week maximum composite NDVI values were calculated for 1 km^2 cells and monthly precipitation totals were compiled for 69 stations during the 1988-93 growing seasons. The 1993 mean total NDVI was 20.5 percent larger than the 1988 mean and these years also displayed the lowest (1993) and highest (1988) variability. 1988 was very dry and 1993 very wet. The 1990-92 NDVI values were very similar and the 1989 values split the difference between these and the 1988 values. The largest NDVI values occurred in ecoregion/grassland types 46-1 and 46-2. Types 43-1 and 42-1 came next. Types 43-2, 42-2, and 42-3 displayed intermediate values. Type 43-3 recorded much lower NDVI values and greater year-to-year variability. ANOVA was used to test for significant differences between the eight ecoregion/grassland areas. The null hypothesis was rejected when ecoregions, grasslands, and ecoregion/grassland cover types were separated in five, six, and three years, respectively. This result was repeated when multiple regression models were constructed to examine the relationships between growing season NDVI and monthly precipitation. Slightly less than 50 percent of the variability in NDVI were explained by ecoregion/grassland areas (included as indicator variables), prior monthly precipitation, and their interactions. Overall, the results demonstrate that different ecoregion/grassland cover types have unique NDVI signatures that respond to the timing and quantity of precipitation in the northern Great Plains. Additional work to characterize the lag between precipitation events and NDVI metrics may permit the construction of more powerful regression models.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date

Chairperson, Graduate Committee

Approved for the Major Department

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Date

Head, Major Department

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ABSTRACT

The Normalized Difference Vegetation Index (NDVI) is useful in identifying land cover types and in monitoring land cover changes through time. This study compared selected temporal NDVI metrics and evaluated their association with precipitation in the northern Great Plains during the period 1988-93. The study area covered parts of Montana, Nebraska, North Dakota, South Dakota and Wyoming, and measured 364,400 km^2 in extent. Nine unique ecoregion/ grassland areas were identified from Omerik's ecoregion map (42-Northwestern Glaciated Plains; 43-Northwestern Great Plains; 46-Northern Glaciated Plains) and the EROS land cover database (1-grass/crop; 2-grassland; 3-grass/shrub), although 46-3 was later eliminated because of its small area. Two-week maximum composite NDVI values were calculated for 1 km^2 cells and monthly precipitation totals were compiled for 69 stations during the 1988-93 growing seasons. The 1993 mean total NDVI was 20.5 percent larger than the 1988 mean and these years also displayed the lowest (1993) and highest (1988) variability. 1988 was very dry and 1993 very wet. The 1990-92 NDVI values were very similar and the 1989 values split the difference between these and the 1988 values. The largest NDVI values occurred in ecoregion/grassland types 46-1 and 46-2. Types 43-1 and 42-1 came next. Types 43-2, 42-2, and 42-3 displayed intermediate values. Type 43-3 recorded much lower NDVI values and greater year-to-year variability. ANOVA was used to test for significant differences between the eight ecoregion/grassland areas. The null hypothesis was rejected when ecoregions, grasslands, and ecoregion/grassland cover types were separated in five, six, and three years, respectively. This result was repeated when multiple regression models were constructed to examine the relationships between growing season NDVI and monthly precipitation. Slightly less than 50 percent of the variability in NDVI were explained by ecoregion/grassland areas (included as indicator variables), prior monthly precipitation, and their interactions. Overall, the results demonstrate that different ecoregion/grassland cover types have unique NDVI signatures that respond to the timing and quantity of precipitation in the northern Great Plains. Additional work to characterize the lag between precipitation events and NDVI metrics may permit the construction of more powerful regression models.

CHAPTER 1

INTRODUCTION

Scope and Purpose

The Advanced Very High Resolution Radiometer (AVHRR) sensor onboard the National Oceanic and Atmospheric Administration (NOAA) series of polar orbiting satellites has been an important source of data for numerous investigations of vegetation cover and dynamics at regional, continental and global scales for more than a decade. These studies have shown that the Normalized Difference Vegetation Index (NDVI), derived from a ratio of Channels 1 and 2 of the AVHRR sensor, is useful in identifying land cover types (e.g., Justice et al., 1985; Goward et al., 1987; Townshend et al., 1987; Loveland et al., 1991; Soriano and Pareulo, 1992), monitoring land cover over time (e.g., Malingreau, 1986; Andres et al., 1994), and measuring phenological response to climatic fluctuations (e.g., Hellden and Eklundh, 1988; Paruelo et al., 1993) over large areas. NDVI shows significant correlation to green biomass and net primary production (e.g., Tucker et al., 1983, 1985; Prince, 1991; Mougin et al., 1995), and is related to rangeland and crop vitality (e.g., Wade et al., 1994; Hobbs, 1995), crop production (e.g., Gallo and Flesch, 1989; Nicholson et al., 1990; Benedetti and Rossini, 1993; Quarmby et al., 1993; Fischer, 1994), soil moisture (e.g., Nicholson and Farrar, 1994) and precipitation (e.g.,Tucker and Choudhury, 1987; Johnson et al., 1993). Goward et al. (1985) demonstrated that AVHRR NDVI temporal curves correspond to the known seasonal variability of vegetation in North America, and that they are also valuable in monitoring the extent and diversity of vegetation spatially and temporally over large areas. Loveland et al. (1991) suggest that the importance of using AVHRR data resides in its capability to monitor seasonal plant variations within and between years.

AVHRR NDVI information is currently a primary data source in surface cover identification because the low cost and timely, continuous coverage is unmatched by any other sensor. Though SPOT and Landsat images offer much greater resolution for land cover studies, their infrequent coverage and cloud contamination results in land cover information derived from only one, or at best, a few images during a growing season (Table 1).

To date, applications using AVHRR NDVI have concentrated on a continental or global scale using 4 km^2 or 16 km^2 resolution data, which may be too coarse for some regional studies. Regional analysis is a crucial step in monitoring environmental phenomena, and choosing and evaluating environmental management options. Many researchers (e.g., Roller and Colwell, 1986; Lozano-Garcia et al.,1991; Paruelo and Laurenroth, 1995) recommend partitioning landscapes into homogenous units for description and statistical analysis.

Table 1. AVHRR, SPOT and Landsat Satellite Data Comparisons.

Satellite	Orbit Repeat	Altitude	Resolution	Price
AVHRR[1]	12 hours	833 km	1.1 km^2	$ 32 per CD
SPOT[2]	26 days	832 km	20 meter	$ 2000 + per img
Landsat[2]	16 days	705 km	30 meter	$ 2000 + per img

[1] Kidwell (1991)
[2] Lillesand and Kiefer (1987)

One logical, natural stratification for regional studies at the 1 km^2 scale is the ecoregion (Kemp et al., 1996). Omernik (1995) describes ecoregions as mosaics of distinct patterns reflecting land use, land cover, weather patterns, soil, altitude, and topography. He also suggested that further analysis of pattern differences within these subsystems to investigate their utility in examining variations in land cover is needed. A current, comprehensive land cover database was developed by Loveland et al. (1993) (Figure 1) based on AVHRR NDVI and ancillary data, and this was used in conjunction with Omernik's (1995) ecoregion classes to differentiate regional-scale study zones within the Northern Great Plains for this project.

In an effort to improve ecosystem studies, some researchers have recently expanded their analysis of NDVI temporal signatures beyond the traditional minimum and maximum NDVI, and mean and total seasonal NDVI (ΣNDVI) metrics. The time of minimum and maximum NDVI, rate of green-up and