THE ANOMALOUS '93 GROWING SEASON -- HOW USDA USED AVHRR DATA

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ABSTRACT

The National Agricultural Statistical Service (NASS) has the Federal responsibility for domestic crop production estimates. To carry out this mission, sample survey methods provide the operational basis for forecasts and estimates. The Agriculture Research Service (ARS) has been working cooperatively with NASS to develop a remote sensing based process using the National Oceanic and Atmospheric Administration (NOAA) satellite sensor, Advanced Very High Resolution Radiometer (AVHRR) data to track and evaluate crop growth and vigor. The central processing is performed by the Land Analyses System (LAS) that was initially developed by the National Aeronautics and Space Administration (NASA) and is now used and supported by the U.S. Geological Survey (USGS), EROS Data Center. Cooperating USDA Agencies have developed some geographic information system features to supplement LAS. A description of procedures used are provided along with examples of the types of products that were created specifically to monitor crops from late May 1993 to harvest. These products included both images and statistics and involve change detection, specific classification procedures and display methods. Severity analysis, recovery tracking and late season frost risk analysis are highlighted as part of the flood and water damage assessment.

INTRODUCTION

The monitoring of crop growth and vigor relative to a normal or average season progression, here after referred to as "crop condition", is an important area where satellite remote sensing can be shown to be valuable. In spite of the lower (1.1 Km) spatial resolution of NOAA AVHRR sensor data as compared to Landsat and SPOT satellites (10 - 30 m) data, there is an increasing use of NOAA AVHRR data for vegetation monitoring during the past decade. Lower resolution is offset by the higher frequency of observation (daily). This is certainly an advantage when tracking drought and flood conditions in crop land areas. The National Agricultural Statistics Service (NASS) has the responsibility for monitoring crop conditions in the United States and providing monthly forecasts of the seasonal production. NASS has developed methods to assess crop growth and development from several sources of information including field sample surveys. This project was initiated to provide a near real time capability using NOAA AVHRR data, properly calibrated and edited, to monitor crop condition in the major production areas of the United States. The results reported here are for areas in the U.S. midwestern states affected by weather related delays in sowing spring planted crops and losses due to excessive summer rainfall and subsequent flooding. The timeliness of information obtained from this project proved to be very useful in damage assessment for USDA program response. The objective of this paper is to describe the image analysis techniques and products used in the assessment.

METHODS

Satellite derived index

Short duration changes in land surface conditions have been monitored and assessed using NOAA AVHRR data (Gallo et al., 1990; Tucker et al.,1986). The visible (Ch1) and near infrared (Ch2) bands are effective in separating the soil and vegetation surfaces because of their spectral differences. Temporal and spatial changes in natural and cultivated vegetation have been effectively assessed using the normalized difference vegetation index (NDVI). The magnitude of the index ranges from -1.0 to 1.0 and is computed as follows:

$$NDVI = (Ch2 - Ch1) / (Ch1 + Ch2) \qquad (1)$$

The NDVI is low for bare soils and water surfaces and high for green vegetation.

Processed data

Image analysis techniques used to assess crop damage resulting from rainfall and subsequent flooding are based on temporal and spatial changes in the NDVI. Pre-processed 1 Km pixel data were obtained from the U.S. Geological Survey, EROS Data Center, Sioux Falls, SD. NDVI values for each pixel were computed for the entire U.S.A. from a composite of data collected over a two week period to minimize the effects of cloud cover. The data values used to calculate the index were the maximum value of each pixel during the composite period. A Lambert Azimuthal Equal Area map projection is used (Eidenshink, J.C. 1992).

Ancillary mask files facilitated the overlay and extraction of geographic and political boundary information. For the purpose of this study, only states that were initially affected by heavy rainfall and subsequent flooding were extracted for the analyses. This area includes, Iowa and parts of Minnesota, Illinois and Missouri. This regional data set was further reduced by application of a 61 category crop mask derived from the land characteristics data base (Brown et al., 1993). The crop mask enabled selection of only cropland in the study area. For crop change comparison a 1992 data set was also prepared.

Image analyses

Biweekly image data files were created from late May through October. July is normally the period when summer crops are at peak vegetation. The unsupervised classification isodata clustering algorithm (ISOCLASS) with the Land Analyses System software (Ailts, et al., 1990) was applied. An evaluation of the types of crop cover present in the region resulted in a decision to develop a maximum of four classes of vegetation from NDVI values. To maintain uniformity in defining the classes, the same classification cluster means were used for the entire study. This standardization of the input statistics for each class enabled comparison of images not only within season but also between years.

Input statistics for each of the four classes were selected from preliminary runs of the ISOCLASS procedure. Selection of a biweekly period image was based on the need to have vegetation in the image with all four classes. The biweekly period of June 26 - July 8, 1992 was selected as the initial period and means of the four classes were calculated as the standard input for all the 1992 and 1993 images analyzed. The classes also represented vegetation cover at different stages of crop development during the growing season.

RESULTS AND CONCLUSIONS

A cold moist spring in 1993 delayed plantings in Iowa and Minnesota. Unusually heavy summer rain started around the third week in June in north-central Iowa and southcentral Minnesota. Rains continued in Iowa through July, resulting in surface runoff and flooding along the Missouri and Mississippi rivers and their tributaries. Due to the virtually continuous cloud cover over the region, the biweekly maximum NDVI composite data was most useful for this study.

The biweekly images were generated and analyzed for the entire crop season through harvest to update the effects of water and flood damage on regional crop production. Late June to early July analysis products were provided to USDA policy makers responsible for assessment of rainfall and flood damage to crops prior to July 8, 1993. Figures 1 and 2 are classified images for the June 26 - July 8, 1992 and 1993 periods respectively. The lowest vegetation class of NDVI values (0 - 0.42) is representative of bare soils with minimal vegetation. For the study area, a maximum NDVI value of 0.7 occurs in early August.

After comparing the 1992 with the 1993 images, the areas impacted can be delineated. There is a clear indication from the low NDVI values in 1993 that late planting followed by excessive June rainfall substantially delayed early season development of the corn and soybean crop. Table 1 is an analysis of the areas that were affected prior to July 8, 1993 in Iowa, the southern half of Minnesota, northern half of Missouri and western half of Illinois.

Although this paper has emphasized the effect of rainfall and flood on crops, other benefits came from this effort. ARS and NASS have jointly developed an analytic capability with LAS during the two year period. However, the 1993 growing season provided both a unique and rigorous operational test of those capabilities that provided very favorable results. The urgent need for information, regarding the flooding, enhanced user interaction and encouraged very rapid development of our processing capabilities.

This paper did not cover other products that were developed and evaluated by users. Another paper will address these products in more detail. NASS has added to LAS capabilities by developing other map products using geography information capabilities of ARC/INFO (product of ESRI, INC., Redlands, CA, U.S.A.). Among these products are the following:

1). Biweekly difference image maps created by subtracting NDVI values of 1992 from 1993 and displaying the values created with five colors to show broad ranges of crop condition ranging from much worse to much better than the previous year.
2). The overlay of climate related parameters including frost isolines and weather station isohyet.

One interesting observation about the difference image was that an East coast drought in the Carolinas had much the same appearance as did the flooding in Iowa and Minnesota. Consequently, the need for weather, crop information, and other ground obtained observations is clearly a necessity for correctly making interpretations of the difference images. Because of this successful start, NASS is planning to provide a regular product for delivery to users during the next growing season.

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The analytical capability, jointly developed by ARS and NASS over a two year period using LAS, received a rigorous operational test with very favorable results. Also, because of the urgent nature of the situation, user interaction in product development progressed quickly. Although not covered in this paper, a number of different products were developed and evaluated by users. Among these were several levels of land cover classification maps. Different categorical variable renditions of image data were generated depicting from three to five classes of land cover types. USDA/NASS and ARS intend to publish a document describing these products in more detail.

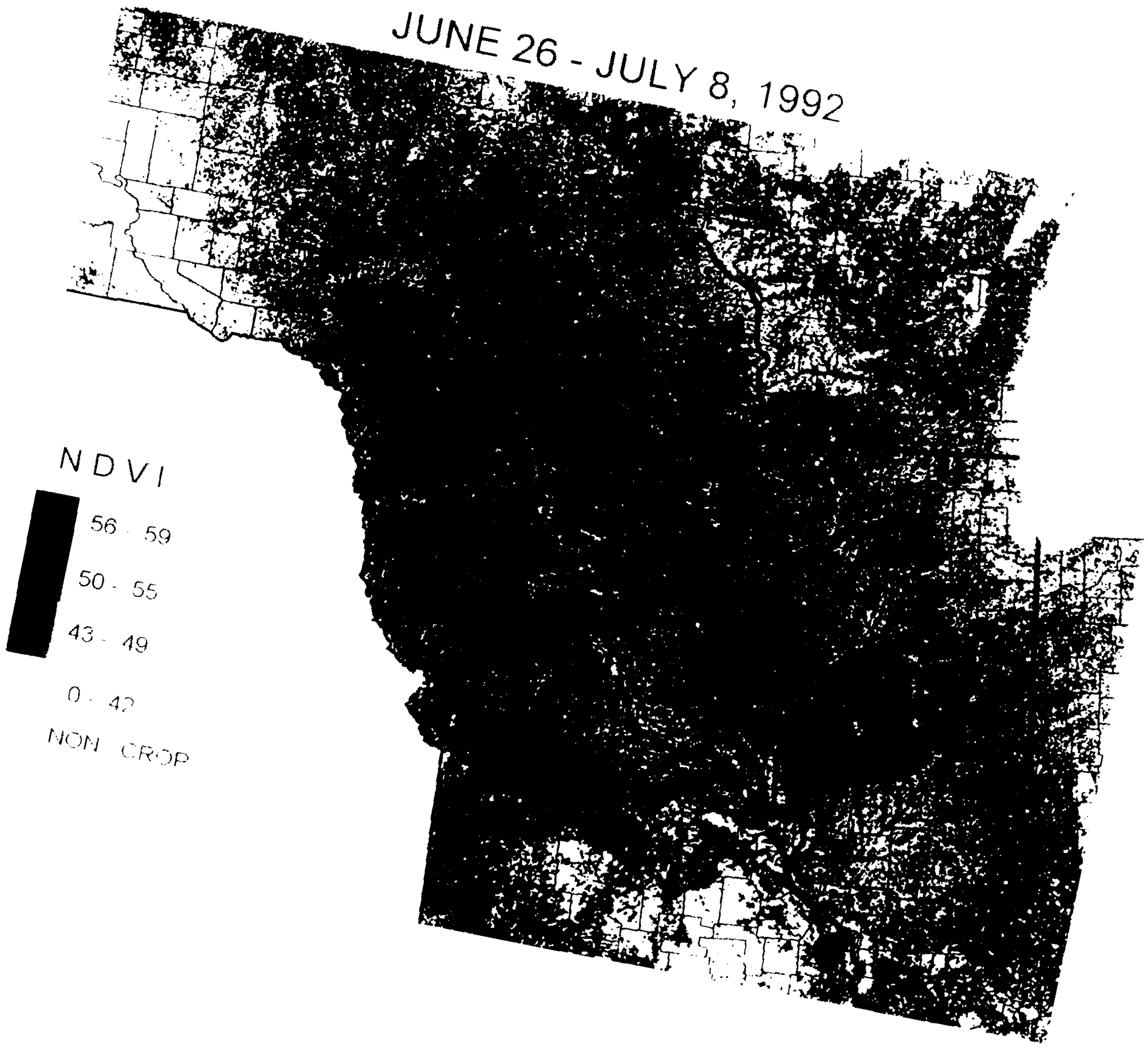
A well received product type was differences between biweekly and seasons, maps. These were also generated in a categorical variable format with symmetric "better" and "worse" difference being classified around the "0" difference bracket. It is interesting to note that with this type of analysis, the east coast Carolinas drought classified in much the same way as water damage in the midwest. Other climate related parameters such as frost isolines were included in later season products for harvest risk loss evaluation. As a result of the successful start, plans are underway for regular product delivery to users next growing season.

Table 1. Comparison of the June 26-July 8, 1992 and 1993 statistics of (a) vegetation classes by acreage and (b) percent of vegetation in each class by state.

NDVI	Class 1 Soil (0. - .42)		Class 2 Sparse Vegetation (.43 - .49)		Class 3 Low Vegetation (.50 - .55)		Class 4 High Vegetation (.56 - .59)	
	1992	1993	1992	1993	1992	1993	1992	1993
(a)				*Thousands of Acres*				
IA	4.5	10645.2	1086.2	5882.5	20184.2	15550.3	21157.5	10354.4
IL	418.6	3130.2	1104.5	819.8	8221.0	9100.0	10393.5	6673.1
MO	0.6	1381.1	1789.5	242.2	12074.8	7295.9	3903.1	8848.9
MN	6.9	3434.3	880.6	4375.3	4740.9	2781.9	6450.0	1486.9
(b)				*% within each class*				
IA	0.	25.0	2.5	13.9	47.6	36.6	49.9	24.4
IL	2.0	15.8	5.6	4.1	41.7	46.1	52.7	33.8
MO	0.	7.7	10.0	1.3	67.9	41.1	21.9	49.8
MN	0.	28.4	7.3	36.2	39.2	23.0	53.4	12.3

Figure 1. Vegetation classifcation of a NOAA AVHRR composite image over the U.S. midwest for the biweekly period, June 26 -July 8, 1992.

Figure 2. Vegetation classifcation of a NOAA AVHRR composite image over the U.S. midwest for the biweekly period, June 26 -July 8, 1993.


JUNE 26 - JULY 8, 1992
N D V I
56 - 59
50 - 55
43 - 49
0 - 42
NON CROP

JUNE 26 - JULY 8, 1993