VISUALIZATION OF A CROP SEASON
THE INTEGRATION OF REMOTELY SENSED DATA AND SURVEY DATA

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ABSTRACT

A visual map display of the complete 1999 growing season will be created for internal use on NASS's Intranet using GIS to display crop development and condition as supplementary information to the standard NASS collected survey data. The crop information comes mainly from expert opinion of USDA agricultural extension agents across the country. They submit weekly reports to NASS on crop development and condition which is summarized at the state level and published for external use in the "Crop Progress Report" and in the "Weekly Weather and Crop Bulletin." Using this information for a selected group of states at the county level with the purpose to expand the Agency GIS capabilities for internal analysis, crop progress of the specific stages of crop development for corn and soybeans, along with vegetative index maps, farmer reported yield data at the county level, weekly growing degree data, and NASS county estimate data provides a good visual overview of a growing season.

INTRODUCTION

The National Agricultural Statistics Service (NASS) is responsible for providing statistical data on U.S. agriculture. The major tools used to measure U.S. agricultural output are scientifically selected sample surveys from a very large list of farm operators (list frame) and from parcels of land of the entire country (area frame). Geographic information systems and the use of remotely sensed data provide additional tools for analysis. Along with vegetation index maps on our Internet site, new map products have been created on our Intranet site to supplement our survey data and AVHRR imagery and provide a visual monitoring of crop progress and crop condition on a weekly basis.

As with most crop seasons, the 1999 crop season had some substantial geographic variability due to the impact of certain weather conditions. The use of GIS and remotely sensed data along with survey data can be used as a visual tool to illustrate the effects of the weather and its influence on the various sources of information used in crop analysis. The graphic illustrations presented in this paper are based on Internet and Intranet products depending on the nature of the data involved.

The Internet visualization which includes AVHRR and our official end-of-season county estimates is available to the public. The Intranet version contains crop progress and condition data at the county level (too low a level of aggregation for publishing) and farmer reported survey data indications, which cannot be released.

These displays illustrate sample survey data at geographic levels such as county which, due to data confidentiality protections and statistical reliability concerns at a low level of aggregation, can only be used for internal crop analyst review. Some examples of this type of application are viewing monthly farmer reported yield data from a small sample at the county level along with month to month and year to year graphic comparisons and viewing weekly crop stage and condition data at the county level. The spatial patterns are the real interest and not the specific value for a given data cell.

A brief explanation of each of the data sources used to create the crop season visualization is given below. This is then followed up with examples of how AVHRR imagery and survey data can be integrated together to provide an important visual picture of the impact of weather on each of these sources of information.

CROP PROGRESS AND CONDITION

A national agricultural summary of crop progress and condition tables is published in the "Weekly Weather and Crop Bulletin" each week. The joint cooperators for this publication include the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), and the Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) and the World Agricultural Outlook Board (WAOB). NASS Headquarters releases a separate "Crop Progress Report" during the growing season. The report contains tables which show planting, phenological and harvest progress, and crop condition percent by categories for the major producing states at a state level only.

This summarized data is available on the NASS web site and this crop information comes from expert opinion of USDA agricultural extension agents across the country. They submit weekly reports to NASS on crop development stages and condition which NASS staff summarize at the regional, state, and sometimes the agricultural statistics district level.

To enhance the vegetative index data products discussed earlier, additional GIS maps have been added to NASS's Intranet visualization based on this weekly data of specific stages of crop development and condition at the county level for a selected 9 State pilot area covering important corn and soybean states. These visualizations aid the crop analyst in monitoring crop growth. Crop progress is monitored for the phenological development of a particular crop. For example, both corn and soybeans go through various phenological stages of maturity once planting takes place (USDA, National Agricultural Statistics Service, 1990). For corn the stages include emerged, silking, dough, dent and mature and for soybeans the stages are emerged, blooming, setting pods, and dropping leaves. Once these stages are complete, crop harvesting begins.

Each of these developmental stages generally occur within a general time frame depending on when planting takes place. Progress percents relate to acres and should indicate the progress of field activities or crop development. Generally, an acre should be considered in or beyond a phenological stage when 50 percent or more of the plants in that acre are in or beyond that stage.

Weather data such as frost information can also provide supplemental information to analyze the current crop condition. The 30 year average first fall freeze date contours from the U.S. National Oceanic and Atmospheric Administration (NOAA) are overlaid onto the crop progress maps during September to monitor both corn and soybeans. Displaying frost isolines for the mean first fall freeze date as a map overlay helps in the evaluation of possible crop damage from freezing in late maturing crops.

Frost isolines can also provide another overlay or GIS layer to the AVHRR images. Analysts can use these isolines to locate areas where the first frost might produce possible crop damage. The crop's development can be analyzed and compared with the mean dates calculated from thirty years of historic data of the first frost. These maps are available to crop analysts to provide a useful visual interpretation of possible areas for crop damage monitoring.

Along with the crop progress, crop condition is also monitored on a weekly basis. Based on 5 condition categories - very poor, poor, fair, good and excellent, each category is given a percentage based on the condition of the crop and each category's percent then adds up to 100 percent. For the crop visualization, the shading is based on the condition category with the highest percentage for each county in the 9 State area. Along with condition the topsoil and subsoil moisture are also monitored. Shading is based on 4 moisture categories - very short, short, adequate, and surplus using the moisture category with the highest percentages for each county in the 9 State area and again each category's percent adds up to 100 percent.

A state focus is also included in the visualization, highlighting one particular state each week, showing detailed information on condition and soil moisture by displaying box charts in each county. Each box chart based on condition represents the 5 condition categories and their assigned percentage and is displayed along with the crop progress for each county. The box chart based on soil moisture represents the 4 moisture categories and their assigned percentage. Polylines created from the crop condition are also used along with the AVHRR data for a state focus.

GROWING DEGREE DAYS

Growing degree days is also used in the 1999 crop visualization. Growing degree day units is a method to relate the cumulative effects of temperature above a given base to plant growth. The base temperature varies with the type of crop.

Growing degree days can be a tool in describing the relative maturity of a plant as opposed to tracking the days a specific variety requires to reach maturity. Growing degree days are calculated for each 24 hour day and accumulated from the time the crop is planted until maturity (Aldrich, 1986).

Therefore, growing degree days could be a useful indicator of the total effect of temperature during the growing season. Although degree days is not a perfect tool for monitoring maturity, it can be useful in providing a more thorough picture of crop maturity stages and is helpful in showing year to year comparisons.

MONTHLY AGRICULTURAL YIELD SURVEY DATA

Survey data is also being mapped to provide a supplemental visual tool along with AVHRR and crop progress and condition. Agricultural Yield Surveys are conducted monthly during May through November. All States, except Alaska and Hawaii, participate in the Survey. The months for which individual States participate will depend on the estimating program needs for that State. The survey provides the primary indications for the monthly Crop Production report that publishes forecasts of production during the growing season. The crop acreage and yield data are collected by mail and telephone. The sample consists of a sub-sample of operators who reported the crop of interest during the March and June Agricultural Surveys. For the visualization, we take the SAS data set of survey data created by Headquarters and generate summary statistics in Arc/Info to produce county level yield responses for corn and soybeans.

For the visualization, this survey data is used in the months of August through November. Currently, maps are created from the Monthly Agriculture Yield Surveys which provide data based on individual responses of farmer reported yield and once the data is aggregated, displays the weighted average by county. A weight for each individual observation was created by dividing each respondents's harvested acreage by the county total. After multiplying the weight times each respondent's corn and soybean yield, the weighted yield responses where summed to the county level.

These visualizations can be used to monitor year to year differences of yield data and month to month comparisons. These maps can be used to compare the survey data with crop progress and condition maps as well as the AVHRR data. Again, the spatial patterns (clusters of counties) are the item of interest rather than the data value for any given data cell.

COUNTY ESTIMATE SURVEY DATA

The county estimates program uses data collected through cooperative agreements with each State individually. The States cooperate with NASS in exchange for data that provide estimates of their agricultural economies at the county level. County crop estimates are usually prepared from surveys mailed to a large sample. Samples for these surveys measure year to year change with many respondents included in the sample from one year to the next (USDA, National Agricultural Statistics Service, 1995, p.9).

The current system for county estimates merges the procedures and data with those of other surveys (cattle, sheep, and quarterly agricultural surveys, to name a few). This approach helps to distribute the larger operations within the county estimates, thereby strengthening their validity. The county estimates are also employed in weighting other NASS reports back to the districts to ensure that the reports from a particular district are accorded their proper weight, or significance; those districts with the highest acreage, for instance, receive the greatest weights.

The many sectors that make up the agriculture industry depend on county estimates when pinpointing production shifts and concentrations, determining sales areas and markets, and locating new processing plants. Crop county estimates are relied on heavily by government agencies as well. The Federal Crop Insurance Corporation counts on them to calculate premiums and loss payments, and the Farm Service Agency relies on them as one of the factors in administering farm programs. State governments use them to administer some of their programs, and to assess the relative importance of agriculture to the total cash receipts of their counties.

County estimates are used to develop choropleth maps for NASS Headquarters and the State Statistical Offices (SSO's) as well as being placed on the Internet for public access. Once the county estimates are prepared, this survey data can be used to finalize the visualization of the crop season. The SSO's are responsible for sending the county estimates to Headquarters during February and March. Currently, the commodities produced for distribution include all wheat, barley, corn, cotton, durum wheat, oats, peanuts, rice, sorghum, soybeans, spring wheat, sunflowers and winter wheat. These maps along with the AVHRR are available at NASS's Internet site: ***www.usda.gov/nass*.**

REMOTE SENSING DATA

Information gathered by satellites supplements the data collected by enumerators. There are several types of satellites circling the globe in continuous polar orbits, collecting and transmitting information about the Earth's resources and weather. These satellites measure energy reflected and emitted by the Earth's surface for the smallest unit of measurement called a pixel. The pixels create a map of a particular area which can be used to assess weather patterns and crop progress.

The Eros Data Center (EDC) of the U.S. Geological Survey prepares vegetation vigor indices based on the advanced, very-high-resolution radiometer (AVHRR) sensor readings from the NOAA-14 polar orbiting weather satellite for a biweekly composite period. These data have proven valuable to USDA policy officials in providing geographic location and monitoring information for vegetation condition in crop areas (Wade et al., 1994; Mueller et al., 1996).

The limitations of the AVHRR data are primarily related to pixel size with each pixel representing approximately 230 acres, and also atmospheric interference such as clouds or haze. The data does not produce crop specific yields that are as precise as those computed from the collected survey data. But the data are excellent for timely views of large areas that are behind or ahead of previous seasons, or areas that are under stress due to drought, excessive moisture, or disease. Every 2 weeks, AVHRR data provide a valuable view of the Nation's vegetation for crop analysts and statisticians. When observing agriculturally intensive areas, low NDVI values delineate those areas that are likely to be under stress due to drought, excessive moisture, or disease. Higher NDVI values pinpoint areas with improved crop development. Although the AVHRR sensor has a 1.0 square kilometer spatial resolution (after processing by EDC), the (in some case daily) observations make the AVHRR a good resource for vegetation monitoring (Eidenshink et al., 1992). The AVHRR are a good supplementary data source since NDVI values have been shown to have a close relationship to the phenological growth stages of crops (Perry et al., 1984; Goward et al., 1985; Tucker et al., 1985). Consequently, the maps assist in seeing relationships between NDVI values and crop estimates.

In the growing season visualization, AVHRR and crop progress and condition are shown in a side by side map display, allowing for a comparison of these different sources of data. However, an awareness is necessary that the AVHRR is best when dealing with extremes such as large area floods, droughts, diseases, etc. and there is not always an exact correlation between the different sources of data.

INTEGRATION OF REMOTELY SENSED DATA AND SURVEY DATA

The 1999 crop season displayed some good examples of geographic variability due to weather conditions. The use of GIS and remote sensing along with survey data provides a good visual illustration of these weather effects. The use of NDVI vegetative index is related to plant chlorophyll activity and is a good indication of overall vegetation vigor, but does have its limitations due to the resolution and possible atmospheric interferences, such as cloud cover or haze. The use of the weekly crop weather from agricultural experts provides additional data. Both sets of information are gathering data about similar events and both datasets have their strengths and weaknesses. When both are in agreement, however, there is increased confidence in any conclusions based from the weekly data.

When a large area event takes place such as the massive flood of 1993, the drought in Texas in 1998, or the bumper crop conditions for Winter Wheat in the southern Plains in 1997-1998 then plant vigor or plant stress is highly related to eventual crop yields. However, NASS uses considerably more sophisticated survey methods for crop yield which is forecasted monthly and this supplemental visual data basically acts as an early warning in outlining the areas potentially effected.

During 1999, the corn and soybean growing season began with generally favorable weather for planting and plant emergence across the growing area of the United States. However, during July, across the southern and eastern Corn Belt, mostly dry weather, accompanied by increasing heat reduced soil moisture for reproductive corn and soybeans. A drought during the months of July and August can be damaging to corn yields since ear fertilization and development is critical during that time frame.

The impact of this dry weather and reduced soil moisture can be seen in ***Figure 1.*** showing corn condition for the week ending August 1, 1999 and ***Figure 2.*** showing topsoil moisture supplies for the same time period reflecting the adequate amounts of soil moisture in the western Corn Belt and the shorter amounts reflected in parts of Missouri, Illinois, Indiana and Ohio. Continued dry weather brought further drought intensification from the mid-Atlantic States into New England as shown in ***Figure 3.*** and is a good visualization of the widespread vegetation stress over Pennsylvania, New Jersey, Maryland, northern Virginia and northeastern West Virginia. The time period presented in this figure is July 16 - July 29, 1999 as compared to the median of 1995-1998 for the same two week period reflecting the ratio of the current year normalized difference vegetative index (NDVI) to the median. ***Figure 4.*** provides a visual summary of the effects of the dry weather and reduced soil moisture by showing 1999 corn yield as a percent of 1998 survey data based on farmer reported yield summarized to a county level. The corn areas under stress are reflected by lower yield values in the southeastern part of the Corn Belt and the mid-Atlantic states, especially in Pennsylvania.

However, despite lower yields in the drought stressed areas, especially the mid-Atlantic region, growing conditions were generally favorable in several major producing areas such as Iowa, southern Minnesota, Nebraska, and most of Illinois. The U.S. Crop Production report forecasted that based on November 1 conditions, yields were expected to average 134.5 bushels per acre, up 1.0 bushel from last month and up 0.1 bushel from a year ago. This could possibly be the third largest production and the second highest yield on record. Ideal weather conditions provided rapid harvest progress and limited harvest loss throughout the Corn Belt (USDA, National Agricultural Statistics Service, 1999).

SUMMARY

NASS is working with crop analysts to provide timely and useful imagery and data products. The primary purpose of this visualization is to provide near real-time capability using satellite data to monitor crop growth and progress in the major production areas of the United States. The satellite data provides an independent source of supplementary information to the survey data collected by our enumerators. Crop analysts use the satellite imagery integrated with a geographic information system to help in their assessment of current crop condition and vegetation vigor. NASS uses its GIS capability to combine various layers of information, to overlay image data with State and County boundaries, frost isoline data, and crop information. This visualization concentrates on the integration of GIS map products including AVHRR image data, crop progress of the specific stages of crop development, crop condition, frost isolines and survey data. The Intranet version allows for visualization of crop progress and condition data at the county level (too low a level of aggregation for publishing) and farmer reported survey data indications, which cannot be released.

NASS uses the collected data for monthly reports on farmers' planting intentions, estimates of crop acreage planted and expected to be harvested, and forecasts of crop yield and production during the growing season. After crop harvest, NASS estimates harvested crop acreage, crop yields, and crop production using the above surveys. The final crop estimate is determined based on survey data indications, administrative data and all other known information to produce official estimates. The GIS and remotely sensed data provide a supplemental tool for the visualization of a growing season.

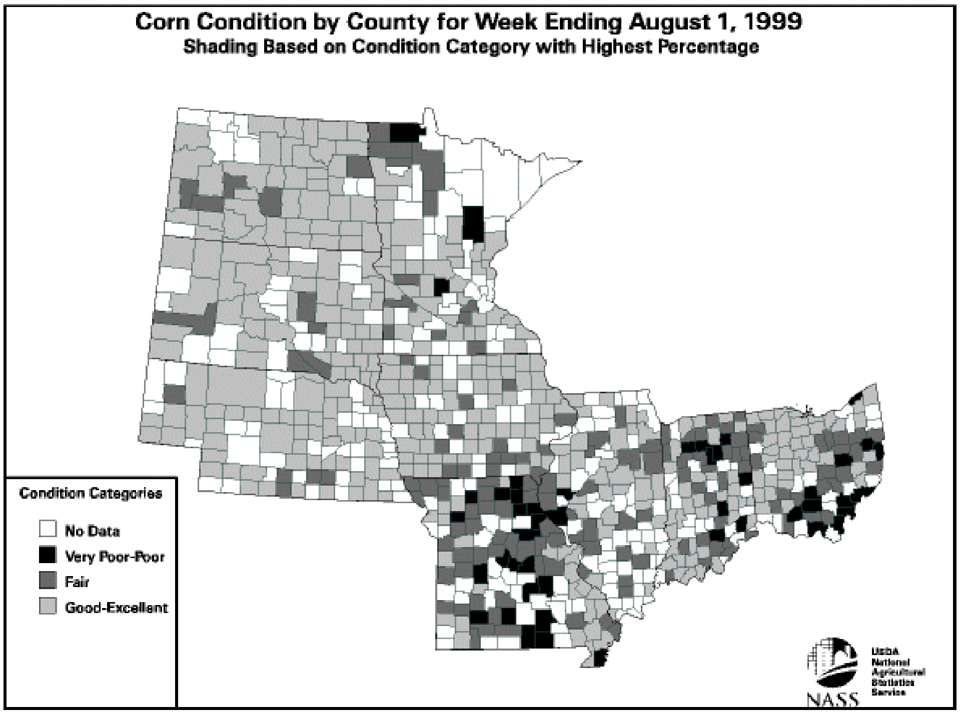

Figure 1. Corn condition

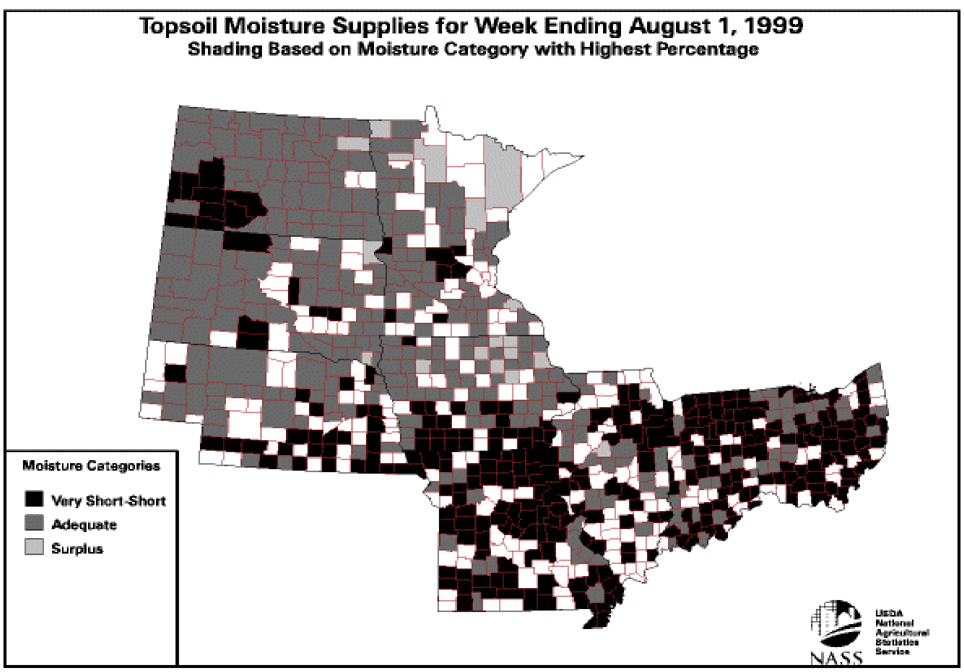

Figure 2. Topsoil moisture supplies

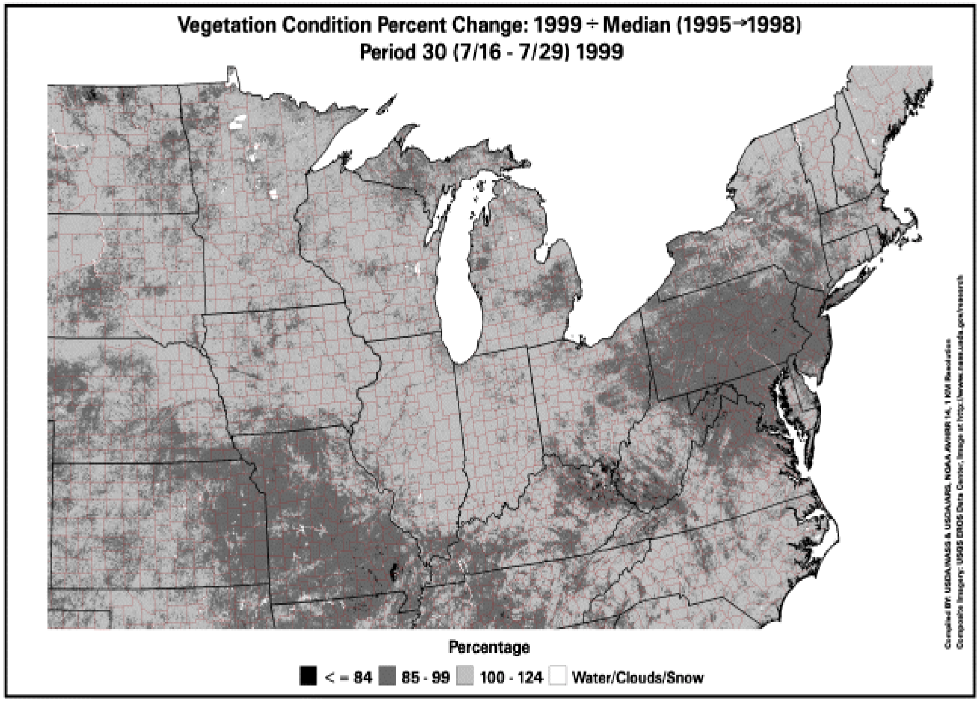

Figure 3. Vegetation condition percent change

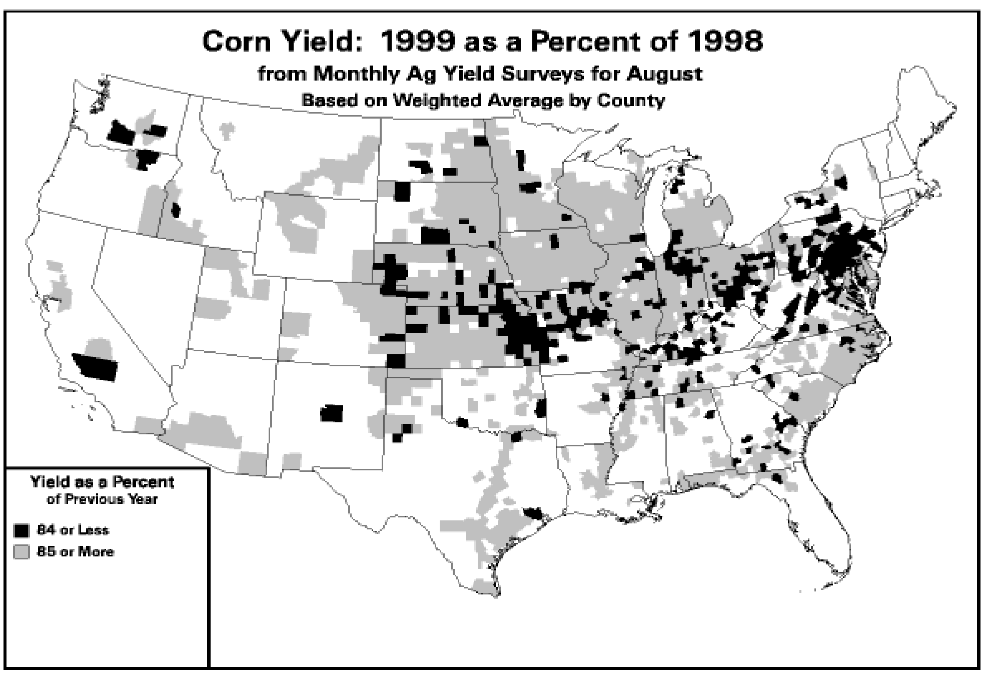

Figure 4. Corn yield shown as a percent of the previous year

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REFERENCES

Aldich, S.R., W.O. Scott, and R.G. Hoeft, 1986. *Modern Corn Production*. Champaign, IL: A&L Publications, Inc.

Eidenshink, J. C., and R. H. Hass, 1992. "Analyzing vegetation dynamics of land systems with satellite data," *Geocarto International*, 7(1), pp. 53-61.

Goward, S.N., C.J. Tucker, and D.G. Dye, 1985, "North American vegetation patterns observed with NOAA-7 Advanced Very High Resolution Radiometer," *Vegetation*, 64, pp. 3-14.

Perry, C.J., and L.F. Lautenschlager, 1984. "Functional equivalence of spectral vegetation indices," *Remote Sensing of Environment*, 14, pp. 169-182.

Mueller, R., G. Wade, and P. Cook, 1996. "Agricultural Statistics Board AVHRR and GIS Product Development," Proceedings, ASPRS/ACSM Annual Convention and Exhibition, Washington, DC,Vol. 1, pp. 625-635.

Tucker, C.J., C.L. Vanpraet, M.J., Sharman, and G. Van Ittersum, 1985. "Satellite remote sensing of total herbaceous biomass production in Sengegalese Sahel: 1980-1984 ," *Remote Sensing of Environment*, 17, pp. 233-249.

U.S. Department of Agriculture, National Agricultural Statistics Service, 1990. *USDA's National Agricultural Statistics Service: Estimation Manual*, USDA South Building, Washington D.C. 20250-2000.

U.S. Department of Agriculture, National Agricultural Statistics Service, 1999. *Crop Report*, USDA, Agriculture Statistics Board, Publications Office, USDA South Building, Washington D.C. 20250-2000.

U.S. Department of Agriculture, National Agricultural Statistics Service, 1995. *USDA's National Agricultural Statistics Service: The Fact Finders of Agriculture.* USDA, Agriculture Statistics Board, Publications Office, USDA South Building, Washington D.C. 20250-2000.

Wade, G., R. Mueller, P. Cook, and P. Doraiswamy, 1994. "AVHRR map products for crop condition assessment: A geographic information systems approach," *Photogrammetric Engineering & Remote Sensing*, 60,(9), pp. 1145-1150.