NEWS

Monitoring 2005 Corn Belt Yields From Space

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The U.S. corn belt, centered on Illinois, suffered extreme drought conditions during the 2005 growing season (Figure 1). The April–September rainfall ranked 10th lowest of the past 113 years (see http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html#state). Throughout Illinois, counties were declared agricultural disaster areas and corn yields were predicted to be 30 percent less than the record year of 2004, which had the highest corn yields in the last 50 years [*Christian Science Monitor,* 2005].

However, the Illinois Agricultural Statistics Service estimated the overall corn yield was 145 bushels per acre, or just seven percent below the previous five-year average, with "many farmers…surprised by the better than expected yields after the drought conditions" (see http://www.agstats.state.il.us/releases/crop.pdf and http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bb/2005/crop1005.pdf). This better-than-expected yield has been attributed to advancements in seed genetics, equipment, and water-management practices [*Barrionuevo and Bradsher,* 2005].

While estimates based upon traditional drought-monitoring indices seem to have overestimated the severity of the crop loss for 2005, satellite-based crop monitoring indices appear to have had better success capturing the crop yield for 2005. This article presents results from one such index, the climate-variability impact index (CVII). This index is based on the leaf area index (LAI) product derived from the Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS data are significantly better for monitoring vegetation compared with data from previous sensors such as the Advanced Very High Resolution Radiometer [e.g., *Zhang et al.*, 2003]. In addition, LAI is an improved metric compared with the normalized difference vegetation index (NDVI) presently used by many monitoring agencies [*Sellers et al.*, 1997].

The CVII itself is designed to quantify the percentage of normal vegetation growth either gained or lost during a given month. For a given pixel p, let $L(p,m,y)$ be the LAI in month m and year y, and $\bar{L}(p,m)$ be the average LAI for the given month and pixel, based on the historical data. At the end of a given month, the index $CVII(p,m,y)$ for a given pixel can be calculated as

$$CVII(p,m,y) = 100 \times \frac{L(p,m,y) - \bar{L}(p,m)}{\sum_{m} \bar{L}(p,m)}$$

In addition, at the end of the growing season, the summation of the index over the growing season itself can provide an estimate of the fractional change in overall growth during the given year, which has been shown to capture vegetation loss during historical droughts [*Zhang et al.*, 2004] and is well correlated with agricultural yield at various spatial scales [*Zhang et al.*, 2005].

Figure 1 shows the six-month standardized precipitation index (SPI) and accumulated growing season CVII for 2005 and 2002 (the latter a year with significant crop loss in the corn belt region). The SPI [*McKee et al.*, 1993] is one of many meteorological indices used to monitor drought in agricultural settings. The six-month SPI indicates the corn belt suffered a severe drought during the 2005 growing season; however, conditions were slightly wetter than normal during 2002. U.S. Drought Monitor maps produced by the U.S. Department of Agriculture (USDA) and the U.S. National Oceanic and Atmospheric Administration also indicated 'extreme drought' conditions during 2005 compared with 'dry' conditions during 2002. Hence, it is not surprising that the 2005 harvest in Illinois was expected to be substantially worse than in 2002 [*Christian Science Monitor*, 2005]. However, the April–August integrated CVII maps for Illinois suggest a decrease in vegetation growth of only about 5–10 percent in 2005 compared with a 10–20 percent decrease in 2002.

While the CVII does not measure yield directly, by using reported corn yield and CVII values from 102 Illinois counties for 2000–2004, a CVII-based statistical model of yield can be trained and used to estimate the corn yield for 2005 [*Zhang et al.*, 2005]. Figure 2 shows the model and USDA estimates for the training period and for 2005. Significant decreases in crop yield during 2002 are successfully captured by the model, as are the record yields in 2004 (see http://www.agstats.state.il.us/releases/crop.pdf). More important, the model estimates a seven percent decrease in Illinois corn yield in 2005 (i.e., during the out-of-sample period), which is almost identical to the preliminary estimate of statewide yield from the Illinois Agricultural Statistics Service. Similar results are found for individual crop-reporting districts as well (not shown).

Drought-monitoring indices based upon meteorological data alone may be able to both overestimate (2005) and underestimate (2002) vegetation variations in drought-stricken regions. These discrepancies highlight

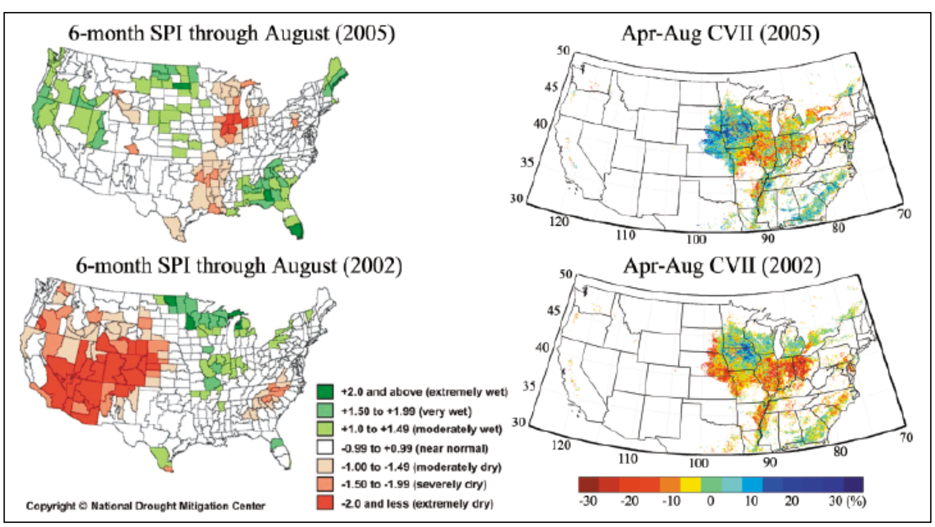

Fig. 1. Six-month standardized precipitation index (SPI) in 2002 and 2005 versus the growing-season climate-variability impact index (CVII) in 2002 and 2005. Six-month SPI maps are produced by the National Drought Mitigation Center (http://www.drought.unl.edu/monitor/spi.htm). CVII values represent fractional loss (red) or gain (blue) of vegetation growth during the growing season (April–August), compared with the 2000–2004 mean. Only broadleaf crops are shown.

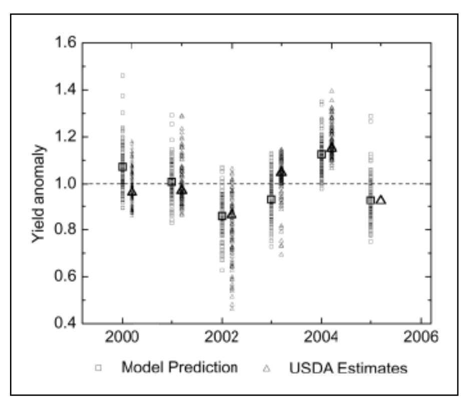

Fig. 2. Model predictions (squares) versus USDA estimates (triangles) of normalized yield in 102 Illinois counties; see text for details. Yields of 1.0 represent average conditions. Bold symbols represent the statewide average; light symbols represent individual counties. The recently released USDA estimate for 2005 only includes a preliminary statewide value.

the need for monitoring vegetation growth directly when estimating yield.

By augmenting ground-based yield estimates (as done by agricultural services, for instance), satellites can provide a secondary, independent estimate that can pinpoint regions where agricultural failure is greatest. In addition, because the satellite data are available approximately two weeks after the image is taken, these data can provide yield estimates before the end of the growing season. For instance, the seven percent loss presented here was produced after the August data release (i.e., in early September) compared with the USDA's release in mid-October. Such information may be able to help predict decreases in production even before harvesting and provide relief where it is most needed, particularly if it can be effectively employed in a timely manner.

Acknowledgements

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Future of Environmental Satellite Program Uncertain

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The National Polar-orbiting Environmental Satellite System (NPOESS), over budget and behind schedule, is undergoing a mandatory review process that could leave the program cut back or canceled. However, the outcome of the review will not be known until June, witnesses testified at a 30 March hearing before the U.S. Senate Commerce, Science, and Transportation Subcommittee on Disaster Prevention and Prediction.

NPOESS is a set of six satellites that are intended to replace the U.S. National Oceanic and Atmospheric Administration's (NOAA) Polar-orbiting Operational Environmental Satellite (POES) program and the U.S. Department of Defense (DOD) Defense Meteorological Satellite Program, which collects weather data for the military. POES supports many of NOAA's environmental monitoring programs.

Over the last several years, NPOESS has fallen increasingly behind schedule and gone over budget. The first satellite launch is now delayed by more than three years, to 2012, and the program budget has ballooned from $6.5 billion to $10 billion, according to data from the U.S. Government Accountability Office (GAO).

David Powner, director of Information Technology Management Issues at the GAO, noted that the first NPOESS satellite had originally been scheduled to be ready in case the launch of the last POES satellite failed. Now, though, there is a potential for a multi-year gap if that satellite fails to launch and no NPOESS satellites are complete. Such a gap would leave NOAA and DOD without the observations necessary for weather prediction, climate research, and other applications.

Gregory Withee, assistant administrator for Satellite and Information Services at NOAA, said, "Our first priority is no gap in service." He said that NOAA does have a backup plan in place in case the POES satellite is lost.

Because the budget overrun crossed a 25 percent threshold, NPOESS is now going through a mandatory DOD review process, which is expected to be complete by 6 June. The DOD review will evaluate the value of the program to national security, cost estimates, management structure, and alternatives. Options include increasing funding for the program to meet the cost overrun, canceling the program, reducing the number or functions of the satellites, or relying on European satellites, according to Powner.

Gary Payton, deputy under secretary of the Air Force for Space Programs, said that the DOD was required by law to consider cancellation but that the review did not appear to be going that way. "We all know that we have to have a polar-orbiting environmental satellite program," he said.

Powner told the subcommittee that although the delays and budget problems were due in part to technical problems experienced in the development of the satellite sensors, poor oversight and contract management were the primary problems.

David Ryan, NPOESS program director at Northrop Grumman Corporation (the program's main contractor), said that the program had gotten back on track for 2006 and has been meeting key milestones on time.

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In Brief

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U.S. ocean research plan drafted The U.S. Committee on Ocean Policy, which coordinates ocean-related activities throughout the federal government, released an ocean research priorities draft plan and implementation strategy on 27 March for a 45-day public comment period. The plan is intended to set priorities for ocean science and technology across a wide range of societal interests.

The plan covers seven themes: enhancing human health, improving ecosystem health, sustaining natural resources, promoting marine operations, the ocean's role in climate change and variability, mitigating effects of natural hazards, and improving quality of life. Under each theme, the plan identifies challenges, and research, infrastructure, and technical needs.

At an 8 March public policy forum in Washington, D.C., Richard Spinrad, assistant administrator for the Office of Oceanic and Atmospheric Research at the U.S. National Oceanic and Atmospheric Administration, said that the final document would guide the development of future federal agencies' budgets. In addition, he said that he hoped that this would be a national plan for research and development, applicable beyond the federal government.

Following the public comment period, which ends on 15 May, the plan will be reviewed by the Ocean Studies Board of the U.S. National Academies of Science's National Research Council. The draft plan, which should be finalized before the end of 2006, is available at http://ocean.ceq.gov

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