MONITORING CROP YIELD IN USA USING A SATELLITE-BASED CLIMATE-VARIABILITY IMPACT INDEX

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INTRODUCTION

The interannual variations of crop yields are strongly affected by the environment and its variability. Previous studies have shown that integrated LAI over the growing season is highly correlated with crop yield because both the magnitude and duration of photosynthetic activity is considered [1][2]. We have previously demonstrated that a LAI-based Climate-Variability Impact Index (CVII) can quantify the percentage of the climatological annual production either gained or lost due to climatic variability and that it has a potential application in crop monitoring and yield estimation [3][4]. As a continuation of this effort, in this paper we use thE LAI-based CVII to model yield forecast in two drought-stricken regions. One is for the extreme drought that occurred in 2005 over Illinois. The second is for the drought of 2006 which affected large parts of the continental US. During this year North and South Dakota were two of the most drought-stricken areas.

METHODOLOGY

A quantitative index is applied to monitor crop growth and predict agricultural yield in continental USA. The Climate-Variability Impact Index (CVII), defined as the monthly contribution to overall anomalies in growth during a given year, is derived from 1-km MODIS Leaf Area Index. The growing-season integrated CVII can provide an estimate of the fractional change in overall growth during a given year. In turn these estimates can provide fine-scale and aggregated information on yield for various crops.

Trained from historical records of crop production, a statistical model is used to produce crop yield during the growing season based upon the strong positive relationship between crop yield and the CVII

(**Figure 1**). By examining the model prediction as a function of time, it is possible to determine when the in-season predictive capability plateaus and which months provide the greatest predictive capacity.

RESULT

Case studies for Illinois and North and South Dakota demonstrate that the model is capable of quantitatively predicting changes in production before harvesting and pinpointing regions where agricultural failure is greatest. The model predictions are consistent with USDA's estimates obtained after harvesting. The CVII model can provide significant predictability (less than 10% error) at the state-average level by the middle of the growing season and at least 1-2 months earlier than the start of the harvesting. The in-season CVII model shows predictability comparable to the concurrent NASS estimates (**Figure 2**). For instance, in mid-August 2006 the CVII model predicted a corn yield of 108 bushel/acre for South Dakota, which is almost identical to the actual yield of 107 bushel/acre. In comparison, the NASS estimate released in August predicted a yield of 100 bushel/acre and in October predicted a 105 bushel/acre.

Additional findings are also provided by these two case studies. For instance, although on a continental scale the CVII maps integrated over the growing season agree with the growing season water deficit conditions represented by 6-month SPI through August, our results highlight the need for explicit monitoring of vegetation growth when estimating yield. The case study in Illinois is particular demonstrates that drought-monitoring indices based upon meteorological data alone, such as SPI, may miss important variability in vegetative production because they can both overestimate (2005) and underestimate (2002) impacts upon vegetation in drought-stricken regions (**Figure 3**). However, the CVII maps appear to have better success capturing the crop yield. The CVII model predicts a 7% decrease in 2005 corn yield in Illinois (compared to the previous 5 year average or 145 bushel/acre overall), which is almost identical to the actual state-wide corn yield from NASS released after the harvesting (8% decrease, or 143 bushel/acre).

Overall, this research has successfully shown that when properly formulated, the satellite-based CVII can be used to perform near real-time drought monitoring and famine prediction at regional and global scale; and provide earlier yield forecasts for crops in the middle of the growing season.

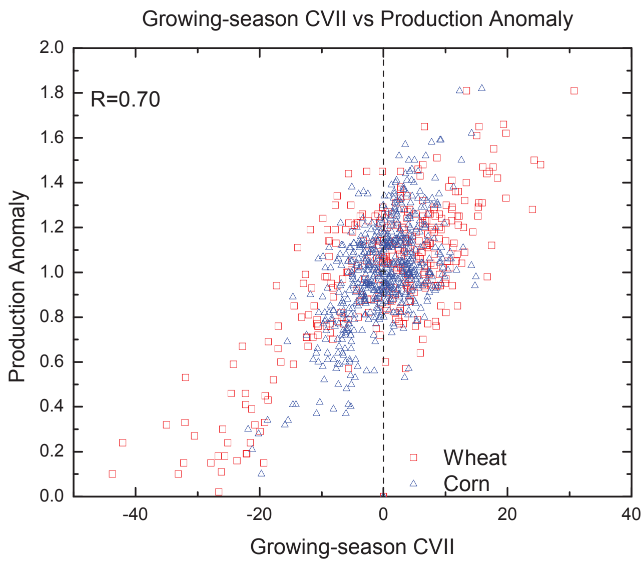

Figure 1: Relationship between growing-season (Apr-Aug) CVII and crop production over the study regions of Illinois, South Dakota and North Dakota. MODIS landcover maps are used to select the cereal crops (wheat) and broadleaf crops (corn). Red squares represent the counties where corn is the majority crop and blue triangles represent the counties where wheat is the majority crop.

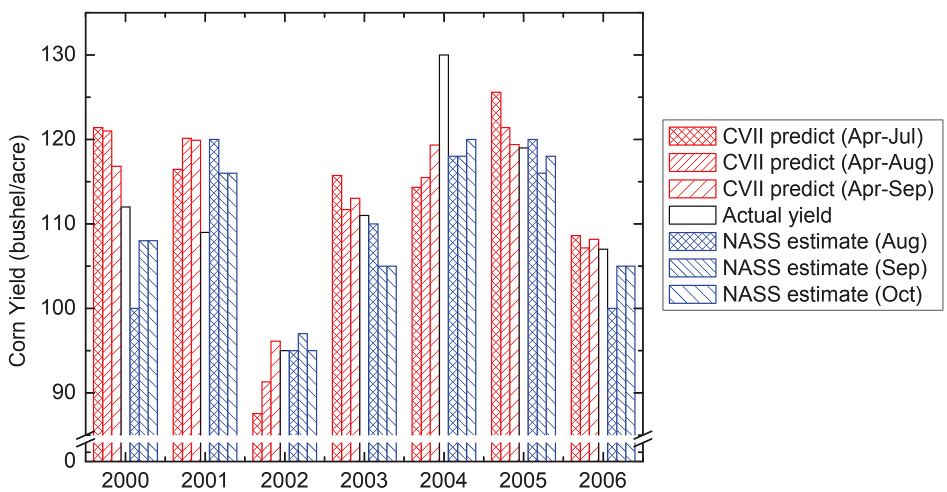

Figure 2: The actual corn yield and the estimated yield in South Dakota made by NASS and CVII model over the course of the growing season. The NASS estimates (blue bars) are released in August, September and October for each year. The CVII model predictions (red bars) are based upon the CVII values at the end of July, August, and September. The model predictions based on integrated CVII have a typical lag of approximately 2 week so that the April-July/August/September integrated CVII

predictions are concurrent with the NASS estimates released in August/September/October respectively. The actual yield is observed by NASS after harvesting.

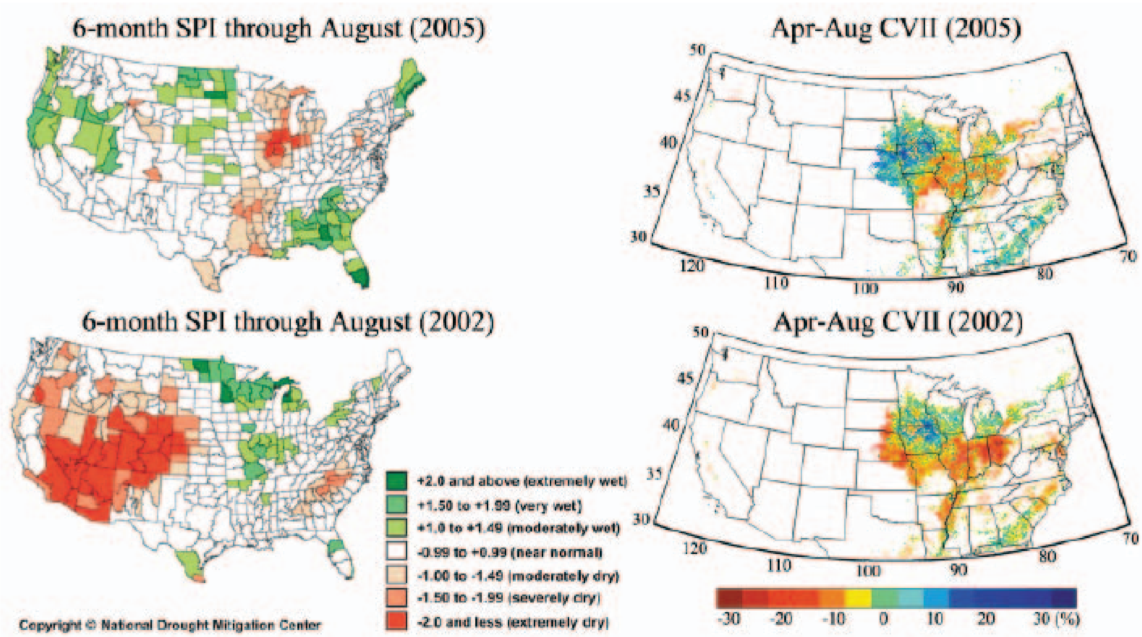

Figure 3: 6-month Standardized Precipitation Index (SPI) vs. the growing-season Climate-Variability Impact Index (CVII) in 2002 and 2005. Six-month SPI maps are produced by National Drought Mitigation Center (http://www.drought.unl.edu/monitor/spi.htm). CVII values represent fractional loss (red) or gain (blue) of vegetation growth during the growing season (April-August), compared with the 2000-2004 mean. Only Broadleaf crops are shown.

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