A 5-year Analysis of Crop Phenologies from the United States Heartland

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Introduction

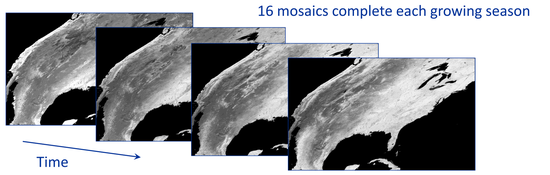
The following time-series charts describe the phenology, or seasonal life cycle, in terms of satellite observed Normalized Difference Vegetation Index (NDVI) for primary crops in the central United States (US). The temporal profiles were derived by intersecting known field location and crop type information from the Farm Service Agency (FSA) against remotely sensed imagery from the National Aeronautics and Space Administration's (NASA) Terra polar orbiting Earth observing satellite. 15 intensively cultivated states from the country's interior were each used for the study and averaged annually over the five year span from 2006 through 2010. Crops analyzed were alfalfa, barley, corn, cotton, oats, rice, sorghum, soybeans, and wheat (durum, spring, winter). These charts help objectively portray the growth and senescence of crops and may also be useful for analysis against crop progress, condition, or yield information.

Background

NDVI is a biophysical measurement related to the amount of biomass and vigor of vegetation and calculated from multispectral imagery channels as

NDVI = (near-infrared band – red band) / (near-infrared band + red band).

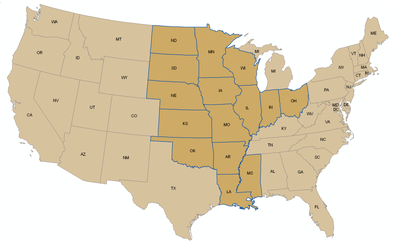
Theoretical values range from -1.0 to 1.0 but more practically 0.1 is typically close to the minimum (correlated with bare soil) while 0.9 is near the maximum (representing dense, fully leafed-out vegetation). Because NDVI is normalized it allows for consistent comparison of vegetation conditions across differing imagery dates and thus ideal for time-series analysis. The imagery data utilized was collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra satellite. Specifically analyzed was the derived 16-day composited, 250 meter resolution, NDVI layer from the "MOD13Q1" science product.



Each time step is a "best of" image mosaic derived through an algorithm which chooses the best acquisitions, from dozens possible, within set 16-day time spans. Effectively created is an image every 16 days with little contamination from atmospheric obstructions (*e.g.* clouds, haze) or ground cover anomalies (*e.g.* snow, standing water). The utilized image mosaics for this study ranged from March 22 to December 3, for a total of 16 per year, and were adequate to document both fall and spring planted crops.

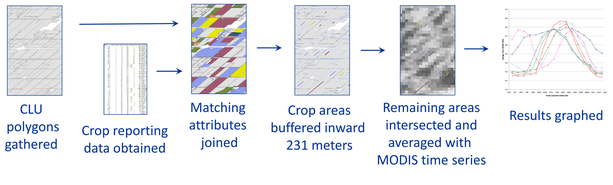
Study area

States included were Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, and Wisconsin. These represent the majority of the intensive agricultural US areas dedicated to growing commodity crops.



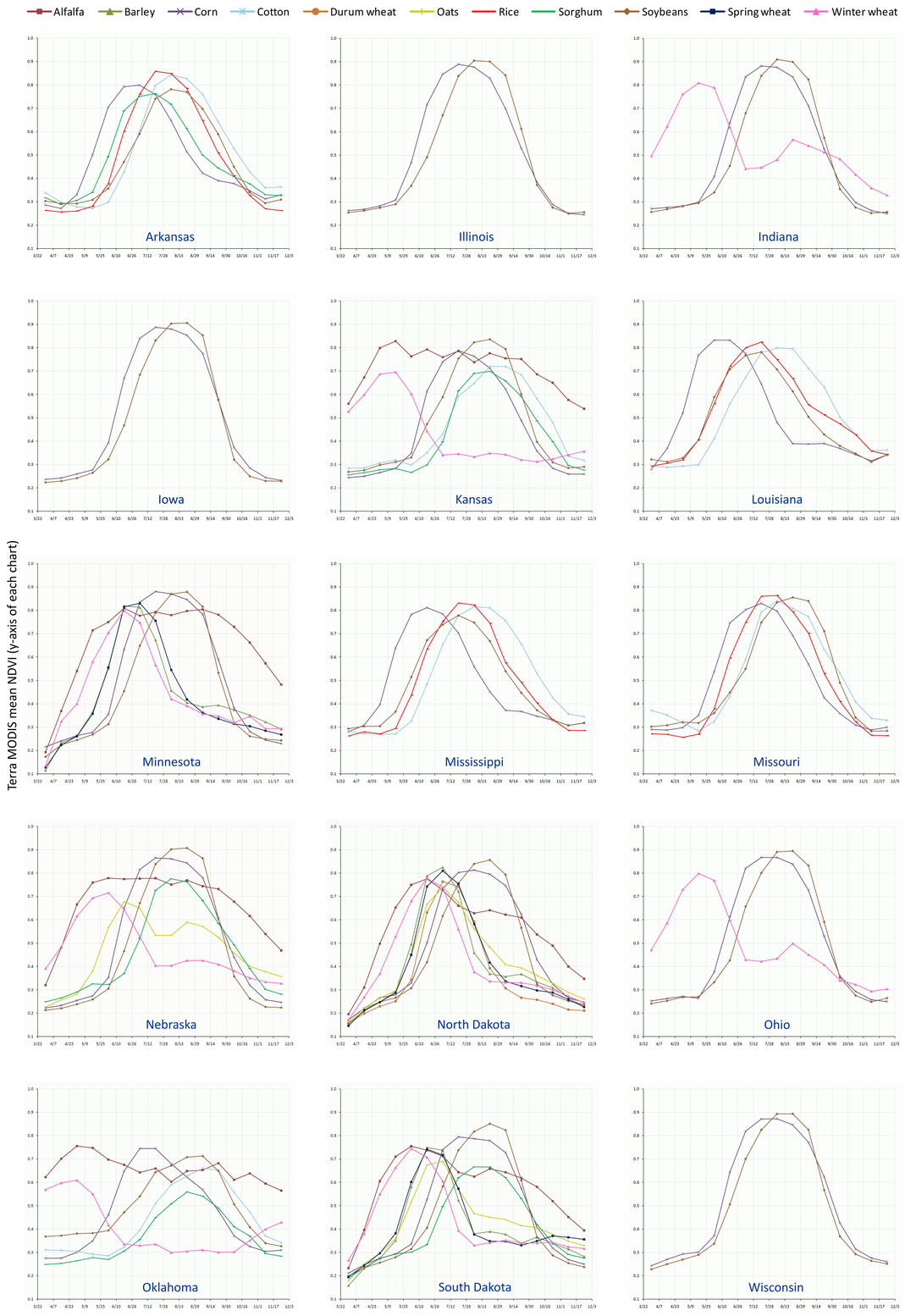
Methodology

Ground information needed to ascertain which pixels of the MODIS images pertained to what crops was gathered from the FSA. Their "form 578" farmer crop reporting data was matched with FSA's Common Land Unit (CLU) polygon based geographic information system (GIS) data. Next, the matching GIS records were spatially "buffered" inward by 231 meters (the MODIS pixel size) to assure that no field edge pixels, which likely contain mixed cover types, were included. The remaining buffered FSA areas were then intersected with the MODIS time series and averaged for each crop by state to provide the representative phenological curve. All analysis was performed within the MODIS sinusoidal projection to preserve full radiometric and spatial fidelity of the data. Crops found in more abundance (particularly corn and soybeans) had more samples going into the mean and were thought to be the most accurate. Any crop that did not contain at least ten FSA samples within a state, for each of the five years, was excluded to reduce the likelihood of unrepresentative or noisy phenology profiles being shown.



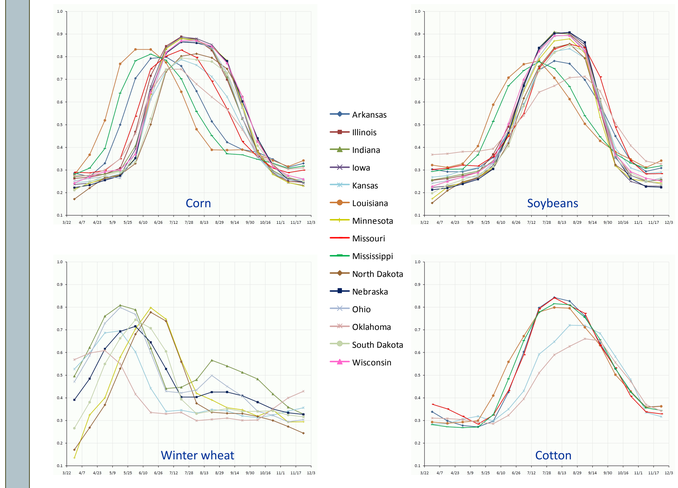
State-level 2006-2010 average results

The average crop phenology for each of the study area states are depicted. The x-axis describes the median date of 16-day composite period while the y-axis is the mean NDVI. Only crops having adequate samples in a given states are shown. States with more time-series curves were those with greater crop diversity. Corn was present in all states and NDVI peaked highest in the core states like Iowa and Illinois. Soybeans were also always present and tended to lag other crops while having a high peak. Cotton was a later crop as well but had a lesser amplitude. Winter planted wheat peaked earliest of all crops. Alfalfa tended to stay high throughout the growing season. Rice was relatively high when it existed and peaked mid-season. Sorghum exhibited a low NDVI amplitude relative to the other crops.



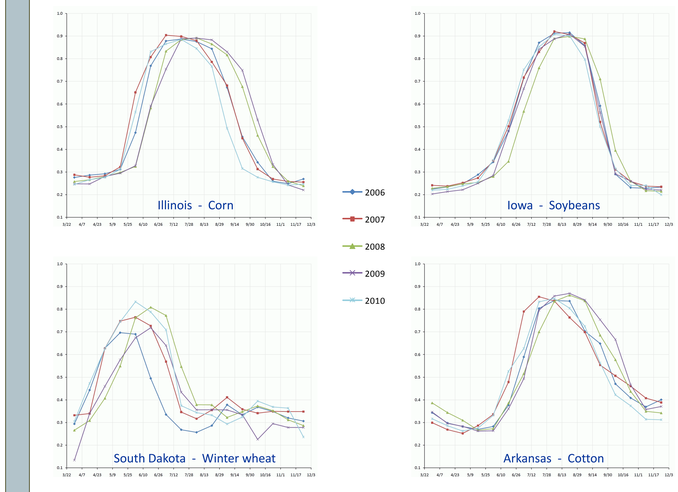
Interstate example results

To better describe the differences in phenology based on geographic region, examples of corn, soybean, winter wheat, and cotton plotted by state are shown. In general, more southerly states had lower and earlier peak NDVI. Timing could vary up to two month for all crops. The central corn and soybean states like Iowa, Illinois, and Indiana had very similar phenologies in terms of both amplitude and phase.



Interyear example results

The following charts illustrate how the phenology for the same crop type could vary across years. For example, soybeans in Iowa were quite similar for all years except 2008 when it was delayed. Illinois corn was variable in timing for all years with up to a month difference. Arkansas cotton was very early in 2007 and showed less uniformity between all curves. Winter wheat in South Dakota was quite variable for all years in both timing and height.



References and related

MODIS NDVI Data. The imagery used for this study were obtained from the NASA Land Process Distributed Active Archive Center (LPDAAC). Specifically utilized was the NDVI layer from the 16-Day L3 250m Collection 5 product obtained via FTP at *lpdaac.usgs.gov/lpdaac/products/modis_products_table/vegetation_indices/16_day_l3_global_250m/mod13q1* .

Field Crops: Usual planting and harvesting dates handbook. A recently updated guide detailing when and where common crops are planted and harvested within the US. The document can be downloaded at *usda.mannlib.cornell.edu/usda/current/planting/planting-10-29-2010.pdf* .

Crop progress. Charts highlighting the seasonal growth progress and condition of common US crops at the state-level. Current and historical charts, dating back to 2005, are obtainable at *www.nass.usda.gov/Charts_and_Maps/Crop_Progress_&_Condition/index.asp* .
Tabular crop progress reports beginning in 1995 are available at *http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1048* .

Vegetative condition from the Advanced Very High Resolution Radiometer (AVHRR). US maps based on AVHRR NDVI which are continually updated throughout each growing season. The time-series dates back to 1995. The images are available for download at *www.nass.usda.gov/research/avhrr/avhrrmnu.htm* .