Estimating US Crop Yields
From both the NASS survey and remote sensing perspectives

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Research and Development Division
Spatial Analysis Research Section
US Yield Trends (bu./ac.)

[Graph showing historical yield trends for Corn, Soybeans, and Wheat from 1860 to 2000]

- **Corn** (blue dots)
- **Soybeans** (red squares)
- **Wheat** (green triangles)
Crop Production reports

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(NA) not available.

Crop Production 2011 Summary (January 2012)
USDA, National Agricultural Statistics Service
Agricultural Yield Survey

Agricultural Yield
The Agricultural Yield survey provides farmer reported survey data of expected crop yields used to forecast and estimate crop production levels throughout the growing season. The Agricultural Yield survey is conducted in all states except Alaska and Hawaii. Samples of farm operators are selected from the March Crops/Stocks survey (small grains) and the June Crops/Stocks survey (late season crops and tobacco). Farmers reporting acreage of at least one commodity of interest are included in the monthly data collection to forecast crop yields.

Publications
The Crop Production report is published no later than the 12th of each month. Acreage, yield, and production forecasts and estimates are prepared for the crops in season.
Objective yield

Corn - Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota, Wisconsin
Cotton - Arkansas, California, Georgia, Louisiana, Mississippi, North Carolina, Texas
Soybeans - Arkansas, Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota
Wheat - Colorado, Illinois, Kansas, Missouri, Nebraska, Oklahoma, Texas, Washington
Potatoes - Idaho, Maine, Minnesota, North Dakota, Oregon, Washington, Wisconsin

Publications
Monthly production forecasts are published in the Crop Production report. End-of-season estimates are issued in the September Small Grains Summary and in the mid-January Crop Production Summary.
Plant counts vs yield

Corn for Grain Objective Yield Data

The National Agricultural Statistics Service is conducting objective yield surveys in 10 corn-producing States during 2011. Randomly selected plots in corn for grain fields are visited monthly from August through harvest to obtain specific counts and measurements. Data in these tables are rounded actual field counts from this survey.


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<td>2008: 25,000</td>
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y = 377.67x - 728986

y = 2.9802x - 5811.7
Yield from remote sensing: MODIS-based

- Global coverage
- Daily revisit rate
- 15 acre ground sample resolution
  - from red and near-infrared bands
- “Best of” image mosaics automatically generated
  - 8 and 16-day temporal windows
- Timely
  - data usually available within a few days
- Free distribution
  - downloaded via ftp
- Robust user group
  - nearly 20,000 citations so far
- Launched in 1999 and 2002
  - 10-year plus history
- 6 year design life but still functioning fine
- Similar follow-on mission in near future
  - VIIRS
Data distribution of MODIS “standard products”

- Distributed in 10 x 10 tiles
  - lower 48 states = 14 tiles
  - Corn Belt = 4 tiles
- Sinusoidal projection
  - unusual but not a problem
- NASA HDF file format
  - some somewhere can ingest
- 2-3 Data latency
  - Improves a bit every year
NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}

NIR = near-infrared
VIS = visible
Synoptic look at NDVI over 2011 growing season
The NDVI time series viewed only with those pixels containing corn.

2011 official Speculative Region ("Cornbelt") yield = 152.5
How to establish the pixels that are only corn

FSA CLU/578 (early season)

- or -

NASS CDL (late season)

MODIS-scaled High probability sample of corn areas
Intersecting corn “mask” with MODIS data
Corn timing importance

Corn 5-year average 2006-2010

State
- Arkansas
- Illinois
- Indiana
- Iowa
- Kansas
- Louisiana
- Minnesota
- Missouri
- Mississippi
- North Dakota
- Nebraska
- Ohio
- Oklahoma
- South Dakota
- Wisconsin

Terra MODIS mean NDVI

16-day composite median date

Dates:
- 8/1
- 9/1
- 10/1

Year:
- 2006
- 2007
- 2008
- 2009
- 2010
2011 official yield = 169 (October)
This year’s data example #3

Kansas Corn

2011 official yield = 105 (October)
This year’s data example #4

2011 official yield = 154 (October)
Modeling premise

The “bigger” the NDVI curve the bigger the yield

- NDVI peak
  - Mild relationship between the peak of the NDVI vs. yield
- NDVI accumulated area
  - Good relationship between area under the curve (and over some threshold) vs. yield

Both improved by also incorporating a trend component

\[ \text{Yield} = ( f(\text{NDVI}) \times m_1 ) + ( \text{year} \times m_2 ) + b \]
Thresholding research

• Trying to understand what the best threshold is in which to integrate over

• Analogous to corn growing degree days
  – Say, where 10 degrees C is the threshold of importance for crop maturity.

• Through trial and error usually found
  – Too high, resulting model not as good
  – Too low, resulting model not as good

• Currently have been optimizing each model to maximize r-squared (and have a significant p-value)
  – Most cases are fairly similar
  – Would prefer something universal and tangible to biophysical processes
    • e.g. silking, denting, period of grain fill etc.

7000 (or 0.7 NDVI) seems like a reasonable round universal number (all things considered)
Reality check

Scene of a large hailstorm
Some conclusions

• Yield estimates should be viewed in context with phenology charts
  – A number doesn’t tell the whole story
• Models seem to amplify results on extremes
  – KS and IA as examples
• About 2/3rd of model is NDVI driven, the rest trend
  – trend is flattening now though
• 0.7 NDVI seems a good all around threshold
  – Makes sense from both a modeling and biophysical standpoint
• Remote sensing forecasting a blend of planted versus harvested yield
  – satellite “sees” the corn plants but has no inclination if it is indeed harvested for grain, silage, or abandoned
• Early season forecasts are weak but probably better than educated guess
  – Trying to ascertain if the peak has indeed been reached early on is subjective
Tangential yield research with NDVI

- Soybeans run in a similar fashion as corn
  - It’s been a struggle
  - Hard to beat an educated guess
- Wheat run in a similar fashion as corn
  - Even more of a struggle
- RMA farm level yields
  - Massive and compelling 2005-2009 data set available
  - Intersectable with CLU polygons
- NASS OY plots with GPS coordinates for 2011
  - Iowa
  - Wisconsin

Or, looking for other suggestions and priorities
Moving forward

• Establish key dates in which remote sensing estimates are useful to others in NASS
• Model with fixed threshold at 0.7 NDVI
• Emphasize Speculative region work
• Think about harmonizing state level yields to nest into Speculative region
• Only use a decades worth of historical data in current year’s forecasting model (“rolling decade”)
• See what can be learned from RMA and OY GIS data
• (Hopefully) begin looking at VIIRS NDVI data next growing season
How’s the corn looking?

The ability to assess yields with good results in near-real time via remote sensing may have finally been reached!