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Understanding the 2016 yields and interactions between soils, crops, climate and management

Sotirios Archontoulis
Iowa State University, ewh@iastate.edu

Mark Licht
Iowa State University, lichtma@iastate.edu

Mike Castellano
Iowa State University, castelmj@iastate.edu

Ranae Dietzel
Iowa State University, rdietzel@iastate.edu

Andy Van Loocke
Iowa State University, andyvanl@iastate.edu

See next page for additional authors

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Presenter Information
Sotirios Archontoulis, Mark Licht, Mike Castellano, Ranae Dietzel, Andy Van Loocke, Raziel Ordonez, Javed Iqbal, Laila Puntel, Carolina Cordova, Kaitlin Togliatti, Rafael A. Martinez-Feria, Huber Isaiah, and Matt Helmers

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Understanding the 2016 yields and interactions between soils, crops, climate and management

Sotirios Archontoulis, assistant professor, Agronomy; Mark Licht, assistant professor, Agronomy; Mike Castellano, associate professor, Agronomy; Ranae Dietzel, postdoctoral research associate, Agronomy; Andy VanLoocke, assistant professor, Agronomy; Raziel Ordonez, postdoctoral research associate, Agronomy; Javed Iqbal, postdoctoral research associate, Agronomy; Laila Puntel, graduate student, Agronomy; Carolina Cordova, graduate student, Agronomy; Kati Togliatti, graduate student, Agronomy; Rafael Martinez-Feria, graduate student, Agronomy; Huber Isaiah, graduate student, Agronomy; Matt Helmers, professor, Agricultural and Biosystems Engineering, Iowa State University

Introduction

Several technologies to forecast crop yields and soil nutrient dynamics have emerged over the past years. These include process-based models, statistical models, machine learning, aerial images, or combinations. These technologies are viewed as promising to assist Midwestern agriculture to achieve production and environmental goals, but in general, most of these technologies are in their initial stages of implementation. In June 2016 we launched a web-tool (http://crops.extension.iastate.edu/facts/) that provided real-time information and yield predictions for 20 combinations of crops and management practices. Our project, which is called FACTS (Forecast and Assessment of Cropping sysTemS), takes a systems approach to forecast and evaluate cropping systems performance. In this paper we report FACTS yield predictions accuracy against ground-truth measurements and analyzing factors responsible for achieving 200-240 bu/acre corn yield and 55-75 bu/acre soybean yields in the FACTS plots in 2016.

Materials and Methods

The FACTS project covered 10 corn and 10 soybean experiments located in six sites across the state of Iowa. In each experiment, several soil and crop measurements were made at resolution varying from 30 minutes to 10 days. Measurements included soil water and temperature, groundwater table measurements, soil NO$_3$-N and NH$_4$-N, nitrous oxide emissions, N-fixation, in-season destructive crop sampling to estimate staging, biomass production and partitioning, tissue N concentration, leaf area index, root depth and root mass distribution. During the growing reason 10 forecasts were released bi-weekly via the FACTS website. The approach to forecasting cropping systems yield and soil nitrate/water levels included use of a) mechanistic cropping systems model (APSIM; Holzwoth et al., 2014) to simulate crop growth, soil dynamics, and soil-crop-weather interactions; b) actual, historical, and forecasted weather information from NDFD and CFS weather models.

Results

How accurate were the FACTS predictions?

On average across 10 corn and 10 soybean fields FACTS under-predicted corn yields by 2.3% and over-predicted soybean yields by 3.1% (Figure 1). In most cases the prediction error was within ± 5-10%, which is very encouraging.
Figure 1. Validation of the FACTS yield forecast (last prediction; Sept 12, 2016).

**FACTS project - 2016 Corn yields:** [http://crops.extension.iastate.edu/facts/](http://crops.extension.iastate.edu/facts/)

- Combine
- FACTS Forecast (Sept 12)

**FACTS project - 2016 Soybean yields:** [http://crops.extension.iastate.edu/facts/](http://crops.extension.iastate.edu/facts/)

- Combine
- FACTS Forecast (Sept 12)

**FACTS project - 2016 Yield Prediction Error**

- Over-prediction
- Under-prediction

Relative error (%)
The reasons for some under/over-predictions were mostly due to uncertainties about the initial soil profile moisture at the day of planting, cultivar characteristics and biotic factors. For example, in central and southeast Iowa corn yield under-predictions were because of the underestimation of groundwater table and soil moisture. In northeast Iowa, corn yield over-prediction was because corn plants experienced “biotic” stress due to excessive rain in that site, which caused ear drop to the ground and yield loss. Some of these issues (non-biotic) have already been incorporated into the model (updated results are not shown here), while other improvements in the model are underway for 2017.

The important question is how early during the growing season we can get a good prediction of the final yield. According to our results the first prediction at planting (median prediction across 35 historical years; 1980-2015) is a good proxy of the final yield (Figure 2). The prediction error is still within ±5-10% with a few exceptions. This may be hard to believe, but there is convincing evidence from this year (2016, Figure 2) as well as the previous 2015 year (Archontoulis et al., 2015) to support that. If this result is confirmed in the coming years, this might open new ways of designing and managing cropping systems.

![Figure 2. Validation of the FACTS yield forecast (first prediction at crop planting).](image)

To ensure that the model provided the right answer (grain yield) for the right reasons we also checked various processes within the APSIM model. In the FACTS website there more than 80 figures available showing predicted versus measured soil moisture and nitrate levels at different depths. In all cases, the simulation of soil water and nitrate (per layer) was adequate.

**What drove 2016 yield levels?**

To understand how weather impacted crop yields, it is important to know the weather during the growing season as well as the weather before planting, which influences the soil moisture, temperature and nitrate levels in the soil (Table 1). The first part of the growing season, May–June, was dry (precipitation deficit of 2.3 inches on average) and the second part, July–August, was wet (precipitation surplus of 3.6 inches; Table 1).
Table 1. Actual cumulative differences between 2016 and long-term (1980-2015) weather variables for different time periods across six FACTS sites in Iowa. A negative value means that 2016 was below climatology and vice versa. The time period “before” refers to November 1, 2015 to April 30, 2016 period. Central-A is Ames and Central-K is Kelly.

<table>
<thead>
<tr>
<th>Before May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Before May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation difference (inches)</td>
<td>Radiation difference (MJ/m²)</td>
<td>GDD difference (˚F-d)</td>
<td>Number heat days difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwest</td>
<td>5.2</td>
<td>-0.2</td>
<td>-2.9</td>
<td>0.1</td>
<td>-0.4</td>
<td>-91.3</td>
<td>42.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>2.2</td>
<td>-1.4</td>
<td>5.0</td>
<td>1.6</td>
<td>3.0</td>
<td>-33.9</td>
<td>25.3</td>
</tr>
<tr>
<td>Central-A</td>
<td>1.6</td>
<td>-0.9</td>
<td>-3.7</td>
<td>1.3</td>
<td>3.3</td>
<td>-108.9</td>
<td>-40.2</td>
</tr>
<tr>
<td>Central-K</td>
<td>3.2</td>
<td>-1.1</td>
<td>-3.9</td>
<td>1.4</td>
<td>2.2</td>
<td>-112.8</td>
<td>-45.0</td>
</tr>
<tr>
<td>Southeast</td>
<td>1.9</td>
<td>-1.2</td>
<td>-3.5</td>
<td>2.9</td>
<td>3.0</td>
<td>-44.2</td>
<td>27.1</td>
</tr>
<tr>
<td>Southwest</td>
<td>6.4</td>
<td>2.5</td>
<td>-2.4</td>
<td>2.2</td>
<td>1.0</td>
<td>-16.5</td>
<td>-3.5</td>
</tr>
<tr>
<td>Average</td>
<td>3.4</td>
<td>-0.4</td>
<td>-1.9</td>
<td>1.6</td>
<td>2.0</td>
<td>-67.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The dry June was accompanied by high temperatures (heat days; defined as maximum temperature above 86˚ F). About 30% of the days in June exceeded 86˚ F during the day. The combination of heat and drought in June stimulated concerns for subsequent water stress effects to crop growth and yield. However, the pre-planting rainfall accumulation in the soil profile (about 3 inches more than average; Table 1) compensated for that heat/water stress in Iowa cropping systems. These Iowa soils have a plant-available water content of about 10 inches which offers additional buffering capacity to early season water stress. The June radiation and cumulative growing degree days (GDD) were 15% above climatic average (Table 1). The higher temperature increased leaf development and soil cover and combined with the higher radiation levels, resulted in a higher light interception and therefore dry matter accumulation in June. Broadly speaking, an extra 90 MJ/m² (Table 1) in June meant four extra sunny days for plant growth.

According to our crop growth data (not shown) the above ground biomass production for soybeans in June of 2016 was higher than in 2015. However the above ground biomass for corn in June of 2016 was similar to that observed in 2015 suggesting that the additional dry matter was allocated to below ground (roots). Our root measurements across all sites (on the row and between the rows) indicated than the root profile was well developed and deep in 2016. On average the maximum root depth was similar between corn and soybean crops (on the row: 49.6 inches ± 9.2 inches; between the rows: 43.7 inches ± 10.9 inches). The deep and well developed root system was able to extract nutrients to support grain growth during the filling period. In turn, the 2016 grain harvest index (0.57) at physiological maturity for corn was about 10% higher than that observed in 2015 (0.52; data not shown).
In summary the key points for reaching the 200–240 bu/acre corn and 55–75 bu/acre soybean yields levels in 2016 were: a) higher than normal soil moisture at planting which buffered high temperatures and evapotranspiration demand early in the season; b) 15% more radiation and temperature in June, a period when crop require high levels of these weather variables to increase radiation interception, especially in the northern sites; c) excellent precipitation and temperature conditions during grain filling.

References
