Growing Corn in a Computer: The Hybrid Hybrid-Maize Simulation Model and its Application to Production Agriculture

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Growing Corn in a Computer
The Hybrid-Maize Simulation Model and its Application to Production Agriculture

Achim Dobermann
Haishun Yang
Outline

1. Definition of yield potential and yield gaps
2. Hybrid-Maize – model description and validation
3. Potential applications of Hybrid-Maize in corn management
Yield potential and yield gaps

- Yield potential
- Water-limited yield
- Actual yield

Gap 1:
- Solar radiation
- Temperature
- Genotype
- Plant density

Gap 2:
- Other limiting factors: Nutrients, Weeds, Pests, Others

Other limiting factors:
- Nutrients
- Weeds
- Pests
- Others

Yield potential: Water-limited yield: Actual yield

Yield (%)
0  20  40  60  80  100
To achieve yield potential of an environment:

- Utilize the entire growing season (= optimal planting date and variety choice)
- Optimize plant population
- Grow the crop with minimal possible abiotic and biotic stresses (nutrients, water, pests)
Hybrid-Maize model

- Corn specific. Simulates growth and development of corn driven by light interception and temperature.
- Simulates corn yield potential and water-limited attainable yield. Nitrogen component is in work.
- Sources: Ceres-Maize, INTERCOM, own components & modifications.
- Predicts date of silking based on GDD for a corn hybrid.
- Allows simulating single growing seasons or long-term climate data.
- Easy import of online weather data.

Authors: H. Yang, A. Dobermann, K. Cassman, J. Lindquist, T. Arkebauer, D. Walters (UNL).
Hybrid-Maize model

Input data

- Daily weather (solar radiation, max. and min. T, rainfall)
- Crop management (date of planting, GDD for hybrid, plant density, sowing depth)
- For simulating water-limited yield: max. rooting depth, texture class and bulk density in topsoil and subsoil)
- Optional: change model parameters (model uses default values, but those can be changed)
  - Hybrid-specific crop coefficients
  - Soil physical properties for different soil texture classes
  - General model coefficients describing crop growth and development
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High Plains Regional Climate Center
University of Nebraska
236 L.W. Chase Hall, Lincoln, NE 68583-0728
Phone: 402-472-6706, Fax: 402-472-6614

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Select a station by placing the mouse cursor over a square and clicking. Alternatively, use the table below to find a station.

Location: Move mouse over a station.
Hybrid-Maize validation

Hybrid-Maize validation

Total aboveground crop biomass growing season.
Manchester: Francis Childs farm, 2002, Pioneer 33P67, 34,000 plants/acre
Lincoln: High-yield experiment, 2002, Pioneer 33P67, 38,000 plants/acre
## Hybrid-Maize validation

<table>
<thead>
<tr>
<th>Crop model</th>
<th>Grain</th>
<th>Stover</th>
<th>Total biomass</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>13.2</td>
<td>13.2</td>
<td>26.4</td>
<td>0.50</td>
</tr>
<tr>
<td>Ceres-Maize</td>
<td>12.4</td>
<td>11.0</td>
<td>23.4</td>
<td>0.53</td>
</tr>
<tr>
<td>Muchow-Sinclair</td>
<td>11.4</td>
<td>11.4</td>
<td>22.8</td>
<td>0.50</td>
</tr>
<tr>
<td>Intercom</td>
<td>9.7</td>
<td>9.0</td>
<td>18.7</td>
<td>0.52</td>
</tr>
<tr>
<td>Hybrid-Maize</td>
<td>13.1</td>
<td>13.2</td>
<td>26.3</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Lincoln, NE, high-yield experiment, corn after soybean, 37,000 plants/acre, intensive nutrient management, averages of 1999-2001.
Hybrid-Maize validation

<table>
<thead>
<tr>
<th>Location</th>
<th>Manchester</th>
<th>Lincoln</th>
<th>Mead</th>
<th>C. Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant density (plants/acre)</td>
<td>34,000</td>
<td>38,000</td>
<td>27,000</td>
<td>33,000</td>
</tr>
<tr>
<td>Simulated grain yield (bu/acre)</td>
<td>282</td>
<td>280</td>
<td>268</td>
<td>274</td>
</tr>
<tr>
<td>Measured grain yield (bu/acre)</td>
<td>248</td>
<td>242</td>
<td>247</td>
<td>266</td>
</tr>
<tr>
<td>Simulated total dry matter (lbs/acre)</td>
<td>24400</td>
<td>24700</td>
<td>23000</td>
<td>23600</td>
</tr>
<tr>
<td>Measured total dry matter (lbs/acre)</td>
<td>23000</td>
<td>24700</td>
<td>22100</td>
<td>23900</td>
</tr>
</tbody>
</table>

Manchester: Francis Childs farm, 2002, Pioneer 33P67, rainfed
Mead: NSFP trial, 2002, Pioneer 33P67, sprinkler-irrigated
Clay Center: NSFP trial, 2002, Pioneer 33P67, furrow-irrigated
Potential applications

Using historical, long-term climate data for a site:

- Assess long-term yield potential and its variation among years (irrigated and non-irrigated).
- Assess change in yield potential due to varying planting date, hybrid choice, or plant density.
- Post-harvest analysis: what happened?

- Management decisions:
  - set adequate yield goals
  - determine optimal planting date (window)
  - identify most suitable varieties/hybrids
  - determine optimal plant density
  - evaluate economics and risks of various scenarios.
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Irrigated corn at Lincoln, 114 d hybrid, Planted April 25
Lincoln, NE, based on long-term climate. At this site, high night temperatures during grain filling may cause early maturity of corn. Delaying planting or choosing a longer season hybrid could move grain filling into a period with lower night temperatures.
Can we exploit more yield potential at this site by shifting the grain filling to a cooler period?

→ plant a full-season hybrid 2-3 weeks later than normal
Irrigated corn at Lincoln, 119 d hybrid, Planted May 15
Irrigated corn at Lincoln, 119 d hybrid, Planted May 15
Irrigated corn at Lincoln, 119 d hybrid, Planted May 15
Irrigated corn at Lincoln, 119 d hybrid, Planted May 15
Simulated corn yield potential at Lincoln, NE
40,000 plants/acre, 1986-2002

Pioneer 31N28
119 CRM, 2860 GDU to maturity

Pioneer 33P67
114 CRM, 2760 GDU to maturity
**El Lincoln, NE: 2003 Yields**

<table>
<thead>
<tr>
<th></th>
<th>Predicted</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silking date</td>
<td>23-Jul</td>
<td>22-Jul</td>
</tr>
<tr>
<td>Grain yield (bu/acre)</td>
<td>287.2</td>
<td>285.3</td>
</tr>
</tbody>
</table>

Lincoln, NE, 2003
Treatment: CS-P2-M2
Hybrid: 31N28 (119 d)
Plant density: 35,000 plants/acre
Planting: 13-May
Emergence: 22-May
Maturity: 25-Sep
Irrigated corn at Lincoln, 2003, Pioneer 31N28, Planted May 13
Irrigated corn at Lincoln, 2003, Pioneer 31N28, Planted May 13
Irrigated corn at Lincoln, 2003, Pioneer 31N28, Planted May 13
What determines spatial variation in corn yield potential in Nebraska?

Mean Annual Growing Degree-Days (frost to frost)

Mean Annual Precipitation (in)
What determines spatial variation in corn yield potential in Nebraska?

Maximum Irrigated Corn Yield (grain) (1997 - 2001)

Maximum Rainfed Corn Yield (grain) (1997 - 2001)

Data is from the National Agricultural Statistics Service (USDA NASS).

M. Milner (11-18-02)
Simulated attainable corn yields in different regions of Nebraska

<table>
<thead>
<tr>
<th>Region</th>
<th>Planting date</th>
<th>GDD (F)</th>
<th>Irrigated corn (bu/acre)</th>
<th>Dryland corn (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>@30,000 plants/acre</td>
<td>@25,000 plants/acre</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Common range</td>
</tr>
<tr>
<td>Southeast-East</td>
<td>5-May</td>
<td>2650</td>
<td>245</td>
<td>230-270</td>
</tr>
<tr>
<td>Central</td>
<td>6-May</td>
<td>2600</td>
<td>250</td>
<td>235-270</td>
</tr>
<tr>
<td>South-Central</td>
<td>3-May</td>
<td>2650</td>
<td>255</td>
<td>240-275</td>
</tr>
<tr>
<td>Southwest</td>
<td>8-May</td>
<td>2550</td>
<td>235</td>
<td>220-260</td>
</tr>
<tr>
<td>Northeast</td>
<td>9-May</td>
<td>2550</td>
<td>240</td>
<td>220-260</td>
</tr>
<tr>
<td>North-Central</td>
<td>10-May</td>
<td>2400</td>
<td>220</td>
<td>200-245</td>
</tr>
<tr>
<td>Northwest</td>
<td>7-May</td>
<td>2250</td>
<td>205</td>
<td>195-225</td>
</tr>
</tbody>
</table>

Simulations based on weather data collected during the past 20 years at multiple locations in each district (High Plains Regional Climate Center online database). Assumes currently widespread cropping practices (planting date, hybrid maturity, plant density) as reported by NASS.
To achieve full climatic site yield potential, management requires:

- Identify optimal growing season duration: Hybrid-Maize model searches for optimal planting data and the date when grain filling stops.
- Select a corn hybrid that fully utilizes the optimal growing season duration (GDD).
- Use very high plant population (40,000 plants/acre).
- Grow under stress-free conditions.
Average irrigated corn yield in Nebraska by crop reporting district in the NASS database (1998-2002) and corresponding simulation of yield potential by the Hybrid-Maize model. Simulation is based on the current reported cropping practices (reported planting and maturity dates, 30,000 plants/acre).
Optimal management: *gain in season length*

- 11 – 19 d
- 20 – 29 d
- 30 – 38 d
Simulated full-season corn yield potential across Nebraska in comparison with actual average yields of irrigated corn (means of 1998-2002). Simulation assumes full utilization of the available growing season (optimal planting and choice of corn hybrid, 40,000 plants/acre).
Full season maize yield potential simulated by Hybrid-Maize compared to the yield of Nebraska yield contest winners (irrigated corn category).
## Corn yield potential in 2003

<table>
<thead>
<tr>
<th>Station</th>
<th>Mead</th>
<th>Beatrice</th>
<th>Concord</th>
<th>G. Island</th>
<th>C. Center</th>
<th>N. Platte</th>
<th>Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid GDD(F)</td>
<td>2750</td>
<td>2750</td>
<td>2600</td>
<td>2750</td>
<td>2750</td>
<td>2650</td>
<td>2300</td>
</tr>
</tbody>
</table>

### Simulated yield potential @ 32,000 plants/acre (bu/acre)

<table>
<thead>
<tr>
<th></th>
<th>Mead</th>
<th>Beatrice</th>
<th>Concord</th>
<th>G. Island</th>
<th>C. Center</th>
<th>N. Platte</th>
<th>Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term maximum</td>
<td>323</td>
<td>321</td>
<td>309</td>
<td>312</td>
<td>327</td>
<td>331</td>
<td>276</td>
</tr>
<tr>
<td>Long-term median</td>
<td>263</td>
<td>256</td>
<td>265</td>
<td>270</td>
<td>271</td>
<td>265</td>
<td>233</td>
</tr>
<tr>
<td>Long-term minimum</td>
<td>225</td>
<td>240</td>
<td>151</td>
<td>231</td>
<td>197</td>
<td>166</td>
<td>162</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Mead</th>
<th>Beatrice</th>
<th>Concord</th>
<th>G. Island</th>
<th>C. Center</th>
<th>N. Platte</th>
<th>Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>245</td>
<td>243</td>
<td>266</td>
<td>261</td>
<td>267</td>
<td>265</td>
<td>207</td>
</tr>
<tr>
<td>2002</td>
<td>250</td>
<td>240</td>
<td>254</td>
<td>268</td>
<td>246</td>
<td>251</td>
<td>237</td>
</tr>
<tr>
<td>2003</td>
<td><strong>273</strong></td>
<td><strong>256</strong></td>
<td><strong>285</strong></td>
<td><strong>312</strong></td>
<td><strong>325</strong></td>
<td><strong>302</strong></td>
<td><strong>262</strong></td>
</tr>
</tbody>
</table>
Potential applications

Using real-time climate data for a growing season:

- Estimate actual yield potential and water-limited attainable yield based on daily records of solar radiation, temperature, rainfall, and irrigation.

- Management decisions:
  - adjust yield goal during the season and make subsequent adjustments in fertilizer amounts (sidedress, fertigation)
  - evaluate moisture status and make decisions on irrigation.
  - evaluate actual plant growth and soil moisture dynamics in comparison with normal years/other years.
  - make decisions for next year.
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Irrigated corn, Pioneer 31N28, Lincoln 2003, actual weather until July 22
Real-time yield potential forecast at Lincoln, NE, 2003. Corn (Pioneer 31N28) was planted on May 13 @ 37,000 plants/acre. Beginning May 18, yield forecasts were made with Hybrid-Maize every 5 days. The red line shows the final yield measured (285 bu/acre).

**Irrigated corn, Lincoln 2003**
Dryland corn, Pioneer 33B51, Mead 2003, actual weather until August 16
Dryland corn, Pioneer 33B51, Mead 2003, actual weather until August 16
Dryland corn, Pioneer 33B51, Mead 2003, actual weather until August 16
Dryland corn, Mead 2003, actual weather until August 16
Dryland corn, Mead 2003, actual weather until August 16
Real-time yield potential forecast at Mead, NE, 2003. Dryland corn (Pioneer 33B51) was planted on May 13 @ final stand of 24,000 plants/acre. Beginning May 18, yield forecasts were made with Hybrid-Maize every 5 days. The red line shows the final yield measured (127 bu/acre).

**Dryland corn, Mead 2003**
Summary

- Models are not perfect representations of the real world. They represent the current scientific understanding in relatively simple mathematical terms.
- Hybrid-Maize is a robust model for estimating corn yield potential under non-limiting and water limiting conditions.
- Model estimates allow evaluating different options for crop management.
- Hybrid-Maize has promising potential for in-season management decisions.
Outlook

- Do more validation at other sites and for dryland corn.
- Write user’s manual and release software in early 2004.
- More testing in real-time field management.
- Incorporate nitrogen management module.