

3.3. Analysis of Yield Determinants in Past Cropping Seasons and Cropping Systems

Data for a single year can be used to conduct an in-depth analysis of a past growing season to help identify factors that affected yield potential; to estimate the size of the yield gap in a particular field (see section 1); and to explore alternative management scenarios that might contribute to increased yield, for example, with regard to planting date and hybrid maturity. This application is also useful for analyzing research data collected in field experiments. In most cases, the hybrid grown is known and actual dates of crop emergence and silking may have been observed in the field. An exact date of when physiological maturity was reached may or may not be known. Actual irrigation schedules can be entered. Location-specific soil physical properties may have been measured and can be entered under **Settings → Parameter settings → Soil**.

Example: Investigation of potential factors that may have caused low yields in an irrigated corn field

2002 was a dry and hot year in many parts of Nebraska. In some cases, irrigation may have been insufficient to keep up with the high crop use and we wish to gain a better understanding of how much yield may have been lost due to water stress. Our site is a field on a loamy sand in Northeast Nebraska, near O’Neill. Rainfall during the growing season averages 12 inches (305 mm). Standard practices at this site include planting corn around May 1 at a 30-inch (0.76 m) row spacing and a final population of 30,000 plants/acre (74,000 plants/ha). Common hybrids grown in this environment require 2570 GDD50F (1430 GDD10C) from planting to maturity. The best weather station representing that area is located at O’Neill, NE, with daily climate data available for the 1985 to 2004 period. In a first step, we quickly compare yield potential in 2002 with that in all other years for which climate data are available. Model settings for this are:

Simulation mode: Single year, 2002, check ‘With long-term runs’
 Start from: Planting on May 1, planting depth 1.5 inches
 Maturity: GDD50F of 2570
 Plant population: 30
 Water: Optimal

O’Neill, NE, Planting date: May 1, Hybrid: 2570 GDDF50, irrigated maize, optimal conditions

Results of 2002 along with long-term runs using historical weather data from 1985 to 2004																		
Rank	Year	Gr.Y	Gr.DM	Stover	tDM	HI	vDays	rDays	V+R	tSola	Tmin	Tmax	Tmean	vTmean	rTmean	ETref	tRain	trri
Best yield	2004	292.6	6.93	5.18	12.11	0.57	81	93	174	77636	52.0	76.0	64.0	65.3	62.9	0.22	17.5	0.0
75% percentile	1996	264.5	6.26	5.26	11.52	0.54	73	87	160	73775	52.3	76.3	64.3	67.1	62.0	0.20	14.2	0.0
Median yield	1997	229.2	5.43	4.88	10.30	0.53	69	57	126	57797	58.1	81.7	69.9	68.4	71.7	0.24	8.0	0.0
25% percentile	1998	209.0	4.95	5.79	10.74	0.46	69	52	121	58429	59.6	81.7	70.6	68.4	73.6	0.21	13.5	0.0
Worst yield	1990	172.2	4.08	6.99	11.06	0.37	78	61	139	69780	49.3	81.6	65.4	66.2	64.5	0.24	12.6	0.0
Long-term mean		230.2	5.45	5.85	11.31	0.48	72	64	136	66334	55.3	80.7	68.0	67.7	68.6	0.24	12.4	0.0
Long-term CV, %		15	15	15	8	13	11	22	14	10	6	4	5	3	7	14	34	0
Task-run	2002	211.6	5.01	4.68	9.69	0.52	54	48	102	54175	61.4	87.5	74.5	73.0	76.1	0.31	7.3	0.0
Among the six years above, frost damage during grain filling occurred in:																		
1996																		
1990																		
Overall probability of frost occurrence during grain filling (%) : 40																		

Simulated yield potential in 2002 was 212 bu/acre, which was significantly below the long-term average of 230 bu/acre with similar management. Average growing season temperature in 2002 was 75 °F or 7 °F above the long-term average. Only 7.3 inches rain fell during the 2002 growing season (**tRain**), indicating high demand for irrigation. At issue is whether actual irrigation in 2002 kept up with the higher demand. The farmer at this site started irrigating on June 30. He irrigated weekly (1.2 inches each time) until late July, but stopped irrigation thereafter because some rain fell in August. He also recorded when emergence (May 20) occurred. We enter all this information on the main page and then simulated the 2002 year in more detail:

Hybrid-Maize Nebraska Lincoln

Input | Results | Chart | Growth | Weather | Water

General Input

Weather file...: O'Neill, NE, wth
Available data: 1/1/1985 - 12/31/2005

Simulation mode

Current season prediction
 Include yield trend

Long-term runs
 with long-term runs

Start from: m/d
 Emergence: 5 / 20
 Planting: 5 / 1
 Seed depth (inch): 1.5

Seed brand: Generic

Maturity

GDD50F: 2570
 Date (m/d):
 Relative maturity (days):

Optional:

Date of silking (m/d):
 GDD50F to silking: 1316
 * Generic estimate

Population (x1000/acre): 30

Water

Optimal
 Estimate irrigation water requirement

Rainfed / Irrigated
 Assume no water stress in prediction phase

Irrigation schedule

Month	Day	Amount (Inch)
6	30	1.2
7	6	1.2
7	11	1.2
7	17	1.2
7	22	1.2
7	28	1.2

Reset entries

Nitrogen

Optimal
 Last season residues Incorporation: Type:
 Quantity (Mg/ha):
 Date: / /
 Soil N/min at planting (lb/acre):
 Soil organic C (%):
 Fertilizer N (lb N/acre):

Soil

Max rooting depth (inch): 40

Top-soil (1 ft): Texture: Loam, Initial moisture status: Wet (100% FC), Bulk density: 1.3 (g/cm3)
 Sub-soil: Loam, Wet (100% FC)

English units

Run...

This run is coded: O'Neill, NE, 2002 | Weather folder = C:\Program Files\Hybrid-Maize\2002\Weather data\

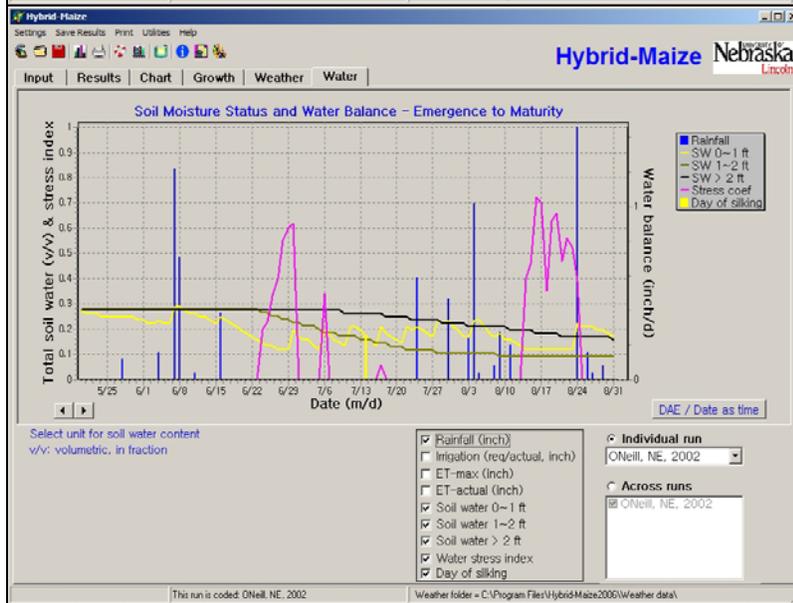
Run 1: Detailed model inputs for the 2002 growing season. Note how the date of emergence, the irrigation schedule, and soil properties were entered and that the option ‘with long-term runs’ is unchecked because we are only interested in evaluating the 2002 year.

Predicted values:

Grain yield: 183 bu/acre

Total aboveground dry matter: 8.7 short tons/acre

Harvest index: 0.5



Run 1: Rainfall and irrigation events and their effect on predicted dynamics of soil moisture in three depths and the water stress coefficient. Note the long period with no rainfall from June 17 to July 24 and the occurrence of crop water stress (pink line) during early growth in late June and during grain filling in late August.

Based on the actual irrigation management, the predicted grain yield is 183 bu/acre. However, a short period of moisture stress affected late vegetative growth in June and a more significant yield reduction may have occurred due to lack of irrigation in mid to late August because the assumption that rainfall in the first half of August was sufficient to match crop needs until maturity was not correct. We test this hypothesis by conducting two more runs of the 2002 data: first we add an earlier irrigation event on June 22 (**Run 2**), and then we add an additional, late irrigation in August (**Run 3**).

Hybrid-Maize Nebraska Lincoln

Input | Results | Chart | Growth | Weather | Water

General Input

Weather file...: O'Neill, NE, wth
Available data: 1/1/1985 - 12/31/2005

Simulation mode

Current season prediction
 Include yield trend

Long-term runs

Single year
 with long-term runs

Year: 2002

Start from

Emergence
 Planting

Start date: 5/20
Seed depth (inch): 1.5

Seed brand: Generic

Maturity

GDD50F: 2570
 Date (m/d)
 Relative maturity (days)

Optional:

Date of silking (m/d)
 GDD50F to silking: 1316
* Generic estimate

Population (x1000/acre): 30

Water

Optimal
 Estimate irrigation water requirement

Rainfed / Irrigated
 Assume no water stress in prediction phase

Irrigation schedule

Month	Day	Amount (inch)
6	30	1.2
7	6	1.2
7	11	1.2
7	17	1.2
7	22	1.2
7	28	1.2
6	22	1.2

Nitrogen

Optimal

Last season residues Incorporation Type: []

Quantity (Mg/ha): []

Date: [] [] []

Soil N/min at planting (lb/acre): []

Soil organic C (%): []

Fertilizer N (lb N/acre): []

Soil

Max rooting depth (inch): 40

Top-soil (1 ft): Texture: Loam, Initial moisture status: Wet (100% FC), Bulk density: 1.3 (g/cm3)

Sub-soil: Texture: Loam, Initial moisture status: Wet (100% FC)

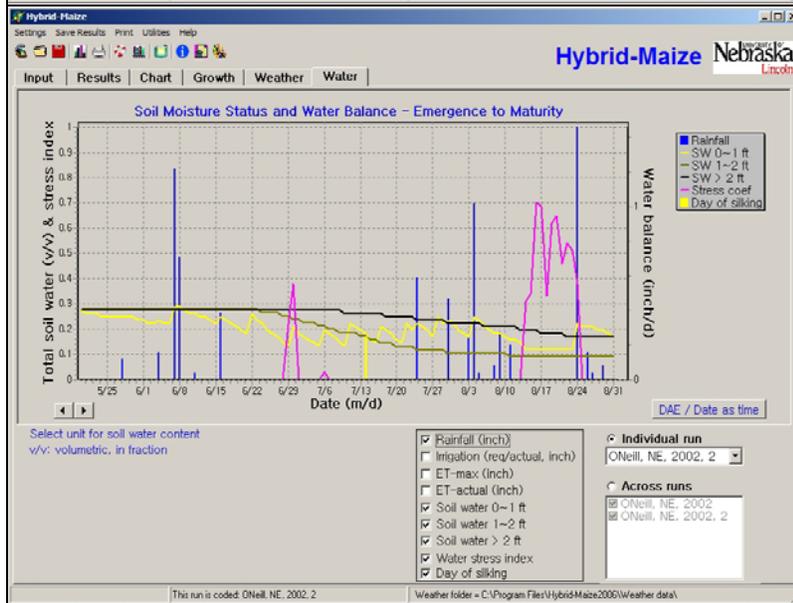
English units

Run...

This run is coded: O'Neill, NE, 2002, 2 | Weather folder = C:\Program Files\Hybrid-Maize\2005\Weather\data

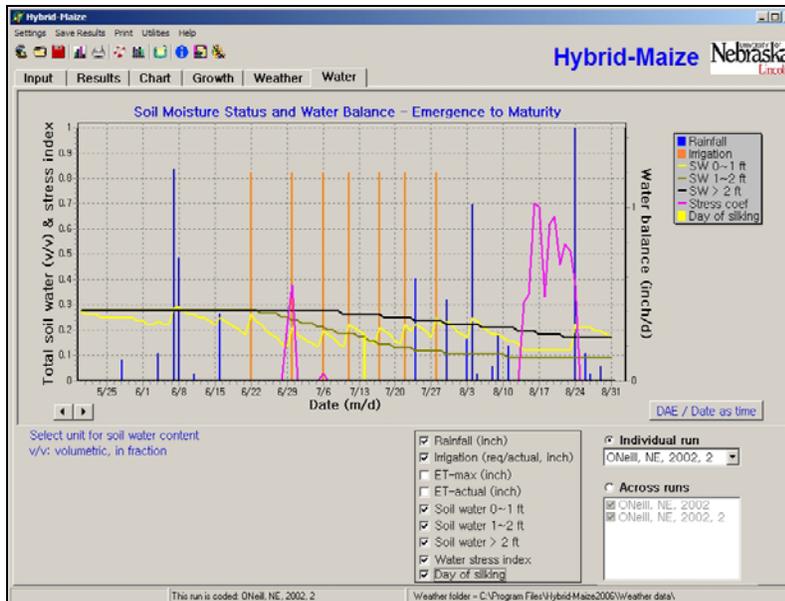
Run 2: Detailed model inputs for the 2002 growing season. Note how an additional irrigation event has been entered on June 22.

Predicted values:
 Grain yield: 184 bu/acre
 Total aboveground dry matter: 8.9 short tons/acre
 Harvest index: 0.49



Run 2: Rainfall and irrigation events and their effect on predicted dynamics of soil moisture in three depths and the water stress coefficient.

Starting the irrigation one week earlier in June increased crop biomass from 8.7 to 8.9 short tons/acre, but had no significant effect on grain yield (184 vs. 183 bu/acre). Note how nearly all water stress during vegetative growth was avoided by starting to irrigate on June 22, but the drought stress in late August remained and was the most likely cause of yield loss. Thus, we add one more irrigation event on August 15 and obtain:

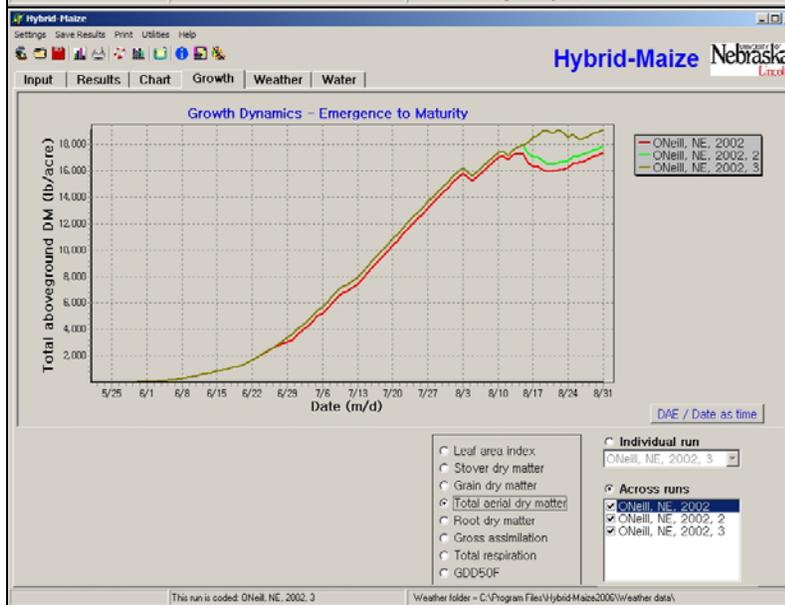


Run 3: Rainfall and irrigation events and their effect on predicated dynamics of soil moisture in three depths and the water stress coefficient. An additional irrigation event was entered on August 15.

Predicted values:
Grain yield: 207 bu/acre

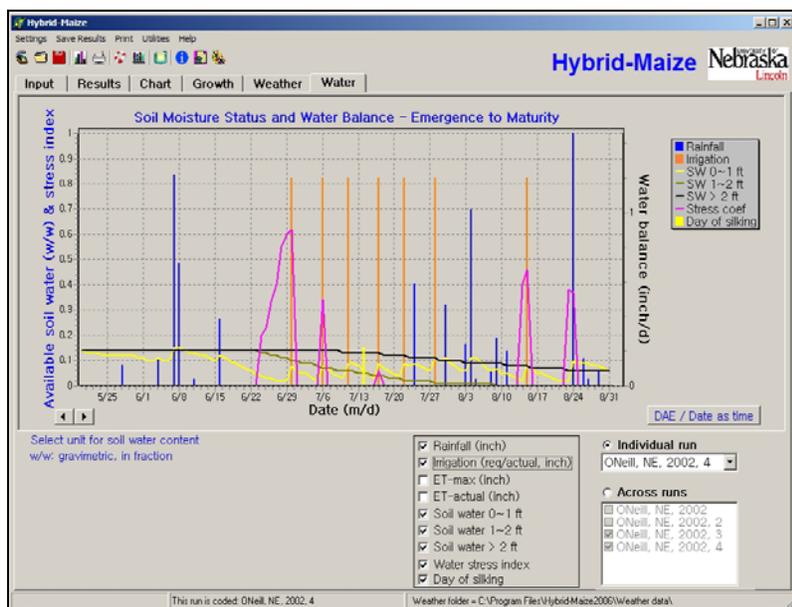
Total aboveground dry matter:
9.5 short tons/acre

Harvest index: 0.51



Runs 1, 2 and 3: Simulated total aboveground biomass for all three runs. Note how the late irrigation in run 3 increased biomass accumulation (grain filling) during the last two weeks of grain filling, resulting in significant yield increase as compared to runs 1 and 2.

An additional late irrigation on August 15 increased grain yield from 184 to 207 bu/acre, which is equivalent to the simulated yield potential under optimal conditions for that year. Nearly all water stress during vegetative and reproductive growth was avoided. Since Run 3 included the June 22 irrigation, the question arises whether this early irrigation was really necessary. To test this hypothesis, we conduct another run in which the June 22 irrigation is deleted, but the August 15 irrigation is kept:



Run 4: Rainfall and irrigation events and their effect on predicated dynamics of soil moisture in three depths and the water stress coefficient. No irrigation on June 22, but late irrigation on August 15 was kept.

Predicted values:

Grain yield: 206 bu/acre

Total aboveground dry matter: 9.3 short tons/acre

Harvest index: 0.53

Although the delay of irrigation until June 30 caused a brief period of water stress in late June, this had almost no impact on the simulated yield, which was 206 bu/acre.

This example demonstrates how important it is to monitor soil moisture or predict crop water needs throughout the entire growing season. It also shows that irrigating more than what was done in Run 3 would have been inefficient because no further yield increase was possible, as confirmed by the simulated results of an extra run with only additional August 15 irrigation but without the June 22 irrigation. Over irrigation would incur extra costs and may increase the risk of nitrate leaching on this soil, which could cause N deficiency and yield loss. The table below provides a comparison of corn yield and irrigation water use efficiency (IWUE) under different irrigation schemes in each run. IWUE is calculated as the yield gain per unit of irrigation water compared with rainfed conditions.

Irrigation scheme	Water input (inch)			Yield (bu/acre)	IWUE (bu/inch)
	rainfall	irrigation	total		
Rainfed	7.3	0	7.3	125	
Farmer irrigation (Run 1)	7.3	6.0	13.3	183	9.7
Additional 6/22 irrigation (Run 2)	7.3	7.2	14.5	184	8.2
Additional 6/22 and 8/15 irrigations (Run 3)	7.3	8.4	15.7	207	9.8
Additional 8/15 irrigation (Run 4)	7.3	7.2	14.5	206	11.3

Because water needs are difficult to predict, we recommend monitoring rainfall and soil moisture and using other established methods (Eisenhauer and Fischbach, 1984; Klocke et al., 1991; Yonts and Klocke, 1997; Benham, 1998) in combination with a model such as Hybrid-Maize for making decisions on irrigation scheduling.