Climate Change and Corn in the Corn Belt of the Midwest, USA

Richard Moore, Ohio State University
Dennis Todey, South Dakota State University

This research is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190: Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems
Project Web site: sustainablecorn.org
Today’s Topics:

1. Corn
2. Climate Change—Dennis Todey
3. Climate Change and Corn—USDA Midwest Climate Hub
4. Corn Cap grant—Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems Coordinated Agricultural Project
5. Corn and Lake Erie

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More Information on the Corn Cap grant is available from:

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November/December 2014; 69 (6)

Sustainablecorn.org
Importance of Corn

- Major cereal crop in the United States
- 75% of world caloric intake is from corn, rice, soybean and wheat
- 70% of U.S. corn crop produced in 9 CSCAP Midwest states
# Ohio Agricultural Crop Values (2012)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Planted All Purpose Acres</th>
<th>Harvested Acres</th>
<th>Yield</th>
<th>Production</th>
<th>Price per Unit</th>
<th>Value of Production in Dollars</th>
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</thead>
<tbody>
<tr>
<td><strong>CORN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Corn, Grain</td>
<td>3,650,000</td>
<td></td>
<td>123.00 BU / ACRE</td>
<td>448,950,000 BU</td>
<td>7.09 $ / BU</td>
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<tr>
<td>Corn, Silage</td>
<td>200,000</td>
<td></td>
<td>16.00 TONS / ACRE</td>
<td>3,200,000 TONS</td>
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<tr>
<td>Corn</td>
<td>3,900,000</td>
<td></td>
<td></td>
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<tr>
<td><strong>SOYBEANS</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Soybeans</td>
<td>4,600,000</td>
<td>4,590,000</td>
<td>45.00 BU / ACRE</td>
<td>206,550,000 BU</td>
<td>14.60 $ / BU</td>
<td>3,015,630,000</td>
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<tr>
<td><strong>HAY &amp; HAYLAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay &amp; Haylage</td>
<td>1,170,000</td>
<td></td>
<td>2.39 TONS / ACRE, DRY BASIS</td>
<td>2,791,000 TONS, DRY BASIS</td>
<td>537,185,000</td>
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<td>Hay &amp; Haylage, Alfalfa</td>
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<td>410,000</td>
<td>3.00 TONS / ACRE, DRY BASIS</td>
<td>1,232,000 TONS, DRY BASIS</td>
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<tr>
<td><strong>HAY</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Hay</td>
<td>1,100,000</td>
<td></td>
<td>2.12 TONS / ACRE</td>
<td>2,330,000 TONS</td>
<td>193.00 $ / TON</td>
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<tr>
<td>Hay, Alfalfa</td>
<td>350,000</td>
<td></td>
<td>2.80 TONS / ACRE</td>
<td>980,000 TONS</td>
<td>231.00 $ / TON</td>
<td>226,380,000</td>
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<td>Hay, (Excl Alfalfa)</td>
<td>750,000</td>
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<td>1.80 TONS / ACRE</td>
<td>1,350,000 TONS</td>
<td>162.00 $ / TON</td>
<td>218,700,000</td>
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<tr>
<td><strong>WHEAT</strong></td>
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<td></td>
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<tr>
<td>Wheat, Winter</td>
<td>500,000</td>
<td>450,000</td>
<td>69.00 BU / ACRE</td>
<td>31,050,000 BU</td>
<td>7.94 $ / BU</td>
<td>246,537,000</td>
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<tr>
<td>Wheat</td>
<td>500,000</td>
<td>450,000</td>
<td>69.00 BU / ACRE</td>
<td>31,050,000 BU</td>
<td>7.94 $ / BU</td>
<td>246,537,000</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Source:
http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=OHIO
Crops of the Midwest

- Corn (53,000,000 acres)
- Soybean (44,000,000 acres)
- Wheat, alfalfa, asparagus, cabbage, carrots, cucumbers, onions, peas, bell peppers, potatoes, sweet corn, tobacco, tomatoes, watermelon

- Apples, blueberries, sweet cherries, tart cherries, peaches, plums, raspberries, strawberries

- Pastureland (16,000,000 acres used for grazing and forage)

- Market value of $188,860,000,000 in 2012

Source: Jerry Hatfield PPT presentation Nov. 2014
Ohio Corn Production (2012)
Current Agriculture in the Midwest

**Midwest Corn Grain Production**


Yield (kg ha⁻¹): 0, 2000, 4000, 6000, 8000, 10000, 12000

- Michigan
- Iowa

**Midwest Soybean Production**


Yield (kg ha⁻¹): 0, 500, 1000, 1500, 2000, 2500, 3000, 3500

- Illinois
- Indiana

**Midwest Sweet Corn Production**


Yield (kg ha⁻¹): 1000, 1500, 2000, 2500, 3000, 3500

- Minnesota
- Wisconsin

**Midwest Potato Production**


Yield (kg ha⁻¹): 0, 2000, 4000, 6000, 8000, 10000

- Michigan
- Wisconsin
Domestication of Corn

- Corn, or maize (Zea mays ssp. Mays), was domesticated from a wild grass called teosinte over 6300 years ago in Mexico.

70-80 day corn varieties were common for the native Americans. Today 120 day corn is common.
USA GROWING STRATEGY
Rotation of Corn and Soybean Fields

Corn

Soybeans

No-till Soybeans after Corn
TYPICAL CORN SOYBEAN LANDSCAPE BY PARCEL JUST WEST OF COLUMBUS, OHIO

Source: USDA 2012 land use maps
Native American Growing Strategy: THREE SISTERS

- **CORN**
- **BEANS**
- **SQUASH**
“Cornstalk” and “Cornplanter”

• Chief Cornstalk of the Shawnees was born "Keigh-tugh-qu'a," meaning maize plant—and became leader of the northern confederacy of Indian tribes, composed of the Shawnees, Delawares, Mingoes, Wyandottes. He was defeated at Point Pleasant in 1774.

Cornplanter (right) was a Seneca tribal leader who supported the movement to adopt agriculture and small farms, while also emphasizing the need for moral and religious order among his people.

Credits: Moore and Long 2012 Stone Lab
Climate Change and Impact for Agriculture

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Greenhouse gases

- Carbon dioxide (CO$_2$)
- Water (H$_2$O)
- Ozone (O$_3$)
- Methane (CH$_4$)
- Chloro-florocarbons (CFCs)
- Nitrous oxide (N$_2$O)
Derived from

• http://nca2014.globalchange.gov/
Figure 2.3. Observed global average changes (black line), model simulations using only changes in natural factors (solar and volcanic) in green, and model simulations with the addition of human-induced emissions (blue). Climate changes since 1950 cannot be explained by natural factors or variability, and can only be explained by human factors. (Figure source: adapted from Huber and Knutti.)
Figure 2.10. The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in many U.S. regions during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC / CICS-NC).

Figure 2.11. The maps show projected increases in frost-free season length for the last three decades of this century (2070-2099 as compared to 1971-2000) under two emissions scenarios, one in which heat-trapping gas emissions continue to grow (A2) and one in which emissions peak in 2050 (B1). Increases in the frost-free season correspond to similar increases in the growing season. White areas are projected to experience no freezes for 2070-2099, and gray areas are projected to experience more than 10 frost-free years during the same period. (Figure source: NOAA NCDC / CICS-NC).
Figure 2.18. The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. These trends are larger than natural variations for the Northeast, Midwest, Puerto Rico, Southeast, Great Plains, and Alaska. The trends are not larger than natural variations for the Southwest, Hawai‘i, and the Northwest. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: updated from Karl et al. 2009³).
Figure 2.21. Trend magnitude (triangle size) and direction (green = increasing trend, brown = decreasing trend) of annual flood magnitude from the 1920s through 2008. Local areas can be affected by land-use change (such as dams). Most significant are the increasing trend for floods in the Midwest and Northeast and the decreasing trend in the Southwest. (Figure source: Peterson et al. 2013).
Climate Change and Corn

- USDA Midwest Regional Climate Hub (Jerry Hatfield)
  - http://climatehubs.oce.usda.gov/
  - http://climatehubs.oce.usda.gov/midwest-hub
Impacts on Production

• Excessive precipitation in the spring, delaying planting and field operations
• Variable precipitation in the growing season causes the variation in production
• Extreme temperatures during the growing season affect plant growth and yield and livestock production
• Warm temperatures during the winter causes early flowering of perennials and risk of frost damage (2012 tart cherry in Michigan)
• Expanded ranges and intensity of insects and diseases

Source: Jerry Hatfield, USDA Midwest Climate Hub 2014
Weather Trend: Unusual combinations of spring and summer rainfall are occurring more often

Spring and Summer Rainfall In Iowa (1893-2013)
1-in-20-yr return in 1893-1980 has 1-in-4-yr return in 1981-2013

Data Source: State of Iowa Climatologist
Erosion: How much is tolerable?
Agriculture and Climate

• Climate scientists agree that long-term weather patterns will continue to change; however, there is great uncertainty and little research regarding how these global climate changes will impact local and regional cropping systems.
Climate and Agriculture in the Midwest

- Longer growing season - shifted frost dates
- Warmer winters
- Warmer nights
- More frequent severe precipitation events
- Greater annual stream flows
- Increased humidity within canopy
Climate & Corn-based Cropping Systems CAP Vision

• To create new science and educational opportunities as a transdisciplinary team
• To develop science-based knowledge that addresses climate mitigation and adaptation, informs policy development, and guides on-farm, watershed level and public decision making in corn-based cropping systems
Team’s research, extension, and education goals directed to specifically:

**CARBON**
Retain more soil carbon resulting in improved soil quality and sustainability

**NITROGEN**
Limit the loss of nitrogen during seasonal peaks observed within Midwestern systems that have naturally rich soils and fertilizer applications

**WATER**
Stabilize soil and nutrients during periods of saturated and flooded conditions while improving water availability and efficiency for crop use during moisture stress conditions

**SYSTEMS**
Build system resilience by integrating productivity and environmental goals through field, farm, watershed and landscape level management in the face of changing climate

**STAKEHOLDERS**
Transfer knowledge and findings through science-driven, experiential learning opportunities to equip and educate farmers and teachers
A transdisciplinary project integrates the knowledge of many specializations to make a quantum leap beyond disciplinary sciences to create new collaborative knowledge, leading to new understanding of difficult and complex problems.

• 140-person team of scientists, graduate students and topic-based specialists
• More than 19 disciplines
• 10 Land Grant Universities & USDA-ARS
• 35 field research sites in 8 states
• 20 dedicated extension educators
• 35 graduate students
• 20 advisory board members
Organized into Six Objectives

1. Develop standardized methodologies and perform baseline monitoring of carbon, nitrogen and water footprints at agricultural test sites across the Midwest.

2. Evaluate how crop management practices impact carbon, nitrogen and water footprints at test sites.

3. Apply models to research data and climate scenarios to identify impacts and outcomes that could affect the sustainability and economic vitality of corn-based cropping systems.

4. Gain knowledge of farmer beliefs and concerns about climate change, attitudes toward adaptive and mitigative strategies and practices, and decision support needs to inform the development of tools and practices that support long-term sustainability of crop production.

5. Promote extension, outreach and stakeholder learning and participation across all aspects of the program.

6. Train the next generation of scientists, develop science education curricula and promote learning opportunities for high school teachers.
(1) Develop standardized methodologies and perform baseline monitoring of carbon, nitrogen and water footprints at agricultural test sites across the Midwest.
(2) Evaluate how crop management practices impact carbon, nitrogen and water footprints at test sites
Field Research Network & Treatments

- Corn-Soybean Rotation
- Cover Crops within a Corn-Soybean Rotation
- Extended Crop Rotations
- Organic Cropping System
- Drainage Water Management
- Nitrogen Fertilizer Management
- Tillage Management
- Landscape Position
President Obama announced on June 2, 2014, that the US Environmental Protection Agency would cut carbon (C) emissions from the US power sector by up to 30% and soot and smog pollution by 25% by 2030 relative to 2005 levels (Kintisch 2014). There will also be an additional water demand of 40% by 2030, in which soil-water storage (e.g., green water) will play a crucial role (Rosegrant et al. 2002).

Source: Rattan Lal’s article in the Special Issue of the Journal of Soil and Water Conservation Nov.-Dec 2014
Nsalambi Nkongolo, Lincoln University
Example of Objective 2 Research:
Warren Dick—Ohio State University
Long-term No-till Corn-Soybean Plots (OARDC, Wooster)

Waren Dick
Introduction

• Methane (CH$_4$) is a potent greenhouse gas found at lower concentrations in the atmosphere than CO$_2$. However, methane’s global warming potential is 23x greater than that of CO$_2$.

• Methanotrophs, or methane-oxidizing bacteria (MOB):
  – are present in aerobic soils
  – oxidize methane and use it as sole source of carbon and energy
  – serve as the only known biological sink of atmospheric methane.
  – are divided into two main groups based on carbon assimilation pathway

• Land-use practices (e.g. no-tillage) impact rates of methane oxidation in soil
Hypothesis

Variation in methane-oxidation rates in soils under different land-use practices is indicative of methane-oxidizing bacterial diversity in those soils.

Figure 1. Scheme of methane consumption and emission in soil (Adapted from Wetlands Research, 2009)
Conclusions

• Long-term no-tillage soils have higher methane oxidation rates (Jacinthe et al., 2014) than tilled soils and are a sink for this greenhouse gas.

• Methane-oxidizing bacteria comprise less than 6% of the entire bacterial community.

• This work has identified those methane-oxidizing bacteria that we must manage to improve no-tillage soils as sinks for methane.

• The graduate student on this project has become skilled in bioinformatics to analyze large DNA databases. This is an important skill that is highly valued.
Drainage – USDA ARS (Norm Fausey)
In general, plots under no-till with subsurface drainage produced lower emissions compared to those under chisel till. Subsurface drainage lowered the emissions compared to those under no drainage. Results from this study concluded that subsurface drainage in poorly drained soils with long-term no-till practice can be beneficial for the environment by emitting lower GHG fluxes compared to tilled soils with no drainage.

Source: S.Kumar, T. Nakajima, A.Kodono, R. Lal, and N. Fausey 2014 Special Issue Journal of Soil and Water Conservation
Central Database

- Field Research Trials
- Watershed Based Survey Data
- Farmer Interview Data
(3) Systems Analysis & Predictive Modeling

- Apply models to research data and climate scenarios to identify impacts and outcomes that could affect the sustainability and economic vitality of corn-based cropping systems.

- Determine the optimal targeting of cover crops, drainage management, and other conservation practices within a corn-based cropping system for a variety of possible environmental goals and under most likely future climate scenario.
(3) Systems Analysis & Predictive Modeling

- **Kling & Gassman**
  - Landscape-scale modeling of environmental impacts of management practices driven by policy scenarios and economic constraints (i.e., least cost achievement of policy goals).

- **Anex**
  - Life cycle assessment: Life cycle environment & resource impacts of management scenarios at regional scale under future climate scenarios.

- **Basso**
  - SALUS modeling of climate / management impacts on yield.
  - Statistical power analysis.

- **Rafique & Anex**
  - Regional soil modeling to extrapolate GHG emissions in time and space.
  - Quantify net GHG emissions (and assoc. uncertainty).

- **Bowling**
  - Drainage water management: Water table dynamics impact on trade-offs between GHG & nitrate.

- **Miguez**
  - Cover crop GHG meta-analysis.
  - Resiliency analysis.
  - Corn yield predictions.

- **Owens**
  - Predictive Soil Mapping.

- **Hydrologic Data**
  - Watershed water quality and quantity.

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**SUSTAINABLE CORN.ORG**

United States Department of Agriculture
National Institute of Food and Agriculture
(4) Social & Economic Research

• Gain knowledge of farmer beliefs and concerns about climate change, attitudes toward adaptative and mitigative strategies and practices, and decision support needs to inform the development of tools and practices that support long-term sustainability of crop production.

• Survey of nearly 20,000 farmers in top 22 corn-producing HUC6 watersheds in the upper Midwest.

• Co-produced by CSCAP and U2U project
Corn Farmers’ Attitudes about Climate Change--water

Corn Farmers’ Attitudes about Climate Change--rain

Concerns about Excess Water Issues (percent concerned or very concerned)

- More frequent extreme rains
  - CC occurring, mostly human causes: 59%
  - CC occurring, equally natural and human causes: 47%
  - CC occurring, mostly natural causes: 43%
  - Insufficient evidence: 24%
  - CC not occurring: 26%
  - All farmers: 57%

- Increases in saturated soils/ponding
  - CC occurring, mostly human causes: 50%
  - CC occurring, equally natural and human causes: 46%
  - CC occurring, mostly natural causes: 39%
  - Insufficient evidence: 36%
  - CC not occurring: 26%
  - All farmers: 41%

Source: J.Arbuckle ASA presentation October 24, 2012
Support for Collective and Individual Mitigation
(percent agree or strongly agree)

Government should do more to reduce GHG emissions

- CC occurring, mostly human causes: 60%
- CC occurring, equally natural and human causes: 30%
- CC occurring, mostly natural causes: 15%
- Insufficient evidence: 13%
- CC not occurring: 15%
- All farmers: 6%

I should reduce GHG emissions from my farm operation

- CC occurring, mostly human causes: 44%
- CC occurring, equally natural and human causes: 31%
- CC occurring, mostly natural causes: 17%
- Insufficient evidence: 15%
- CC not occurring: 7%
- All farmers: 23%

Source: J. Arbuckle ASA presentation October 24, 2012
USA CORN BELT FARMERS ATTITUDES ABOUT CLIMATE CHANGE: “Insufficient Evidence to know with certainty whether climate change is occurring or not”.

## Farmers’ Attitudes about Climate Change (2012)

<table>
<thead>
<tr>
<th>Perception</th>
<th>Corn Belt</th>
<th>SC Non Amish</th>
<th>SC Amish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>7.80%</td>
<td>14.29%</td>
<td>8.33%</td>
</tr>
<tr>
<td>Human Natural Combo</td>
<td>33.10%</td>
<td>4.76%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Natural</td>
<td>24.60%</td>
<td>33.33%</td>
<td>8.33%</td>
</tr>
<tr>
<td>Insufficient Evidence</td>
<td>30.90%</td>
<td>33.33%</td>
<td><strong>83.33%</strong></td>
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<tr>
<td>Not Occurring</td>
<td>3.50%</td>
<td>0.00%</td>
<td>0.00%</td>
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</tbody>
</table>
Summer Interns’ Hypothesis:

Individuals, who chose "insufficient data" as an answer to the 2012 survey about agreeing or disagreeing about climate change, would have a wide range of specific reasons.
The broad answers to these questions would be based on their own farming experience and that these reasons were based on their local experiences.
On Saturday, July 19, R. Moore’s intern team conducted surveys at a Family Farm Day event in Dundee. The remaining surveys were selected at random from about 3,000 farms in the Sugarcreek Watershed.
Unique Stories:

- Keeping Animals in the barn/feeding more
- Blocked up windows
- Thawed pipes with hair dryers
- Waited to plant
- Wrapping the barn/beehives in plastic/black cardboard/tarp
- Feed bags for insulation
One Amish female noted that though she does not believe flooding is occurring, she believes *climate change* is occurring.
(5) Extension: Promote extension, outreach and stakeholder learning and participation across all aspects of the program
(6) Education: Train the next generation of scientists, develop science education curricula & promote learning opportunities for HS teachers
Lake Erie Algal Bloom/hypoxia in Sandusky Bay
National Council for Science and the Environment  CAMEL Project

CAMEL CLIMATE CHANGE EDUCATION
A free, comprehensive, interdisciplinary, multimedia resource for educators / Learn more / Join

Agriculture

Vine-ripened tomato. Agriculture is the major anthropogenic source of methane and nitrous oxide emissions.

Continued (climate) changes by mid-century and beyond are expected to have generally detrimental effects on most crops and livestock. As temperatures increase, crop production areas may shift to follow the temperature range for optimal growth and yield, though production in any given location will be more influenced by available soil water during the growing season. Weed control costs total more than $1.1 billion a year in the U.S.; those costs are expected to rise with increasing temperatures and carbon dioxide concentrations.

Changing climate will also influence livestock production. Heat stress for any specific type of livestock can damage performance, production, and fertility, limiting the production of meat, milk, or eggs. Changes in forage type and nutrient content will likely influence grazing management needs. Insect and disease prevalence are expected to increase under warmer and more humid conditions, diminishing animal health and productivity, United States Department of Agriculture (USDA).

Articles and teaching materials on climate and agriculture

http://www.camelclimatechange.org/
Undergraduate & Graduate Students: Climate Camps at Iowa State U. and Lincoln U.
Some factors to consider for Lake Erie Corn Farms

- **Rising temperature**
  - Increasing growing season lengths
- **Greater variability of temperature**
  - Higher night time lows
  - Extreme swings over short time periods
  - Periods of extreme heat, cold
  - Timing of frost events

Source: Dennis Todey
Some factors to consider for Lake Erie Corn Farms

- Changes of precipitation *patterns*
  - Some places drier, others wetter
  - Decreased snowfall
- Greater *variability* of precipitation
  - More short, intense events
  - Shift of timing
- More severe weather events
  - Hail, storms, wind, etc.
Some factors to consider for Lake Erie Corn Farms

• Flexibility of production—more varieties, shorter season varieties, different crops
• Cover crops and less tillage=less GHG
• Build a resilient system to withstand the increased number and intensity of weather events
OH IO

THANK YOU