MICHIGAN STATE UNIVERSITY | Extension

Climate Change and Agriculture Fact Sheet Series **E3149** April 2011

FIELD CROP AGRICULTURE AND CLIMATE CHANGE

Julie E. Doll[1] and Marci Baranski [1,2] [1]W.K. Kellogg Biological Station, Michigan State University, [2]Michigan State University Extension

How are greenhouse gases related to agriculture?
Greenhouse gases such as carbon dioxide occur naturally in the atmosphere and keep the Earth warm, allowing us to survive on Earth. Over the last 200 years, the amount of greenhouse gases in the atmosphere has increased as a result of burning fossil fuels and other human activities[1]. The majority of scientists agree that increased greenhouse gas levels are causing Earth's average global temperature to rise. Consequently, we experience changes in climate at the local level (see MSU Extension E3148).

Field crop agriculture both emits and consumes greenhouse gases that affect climate – so agricultural management and policies can help combat climate change.

Two of the most important greenhouse gases are related to field crop agriculture: carbon dioxide (CO_2) and nitrous oxide (N_2O). Field crop agricultural practices both emit these gases and remove them from the atmosphere. For example, through photosynthesis crops remove carbon dioxide from the atmosphere and use it to build plant tissue. Some of this carbon can be stored in the soil as soil organic matter. However, when soil is tilled, microbes are stimulated to more quickly convert organic carbon to carbon dioxide, which escapes into the atmosphere. In most farmed soils, tillage has caused the release of 40–60% of original soil carbon[2]. Soil microbes can also emit nitrous oxide, especially when there is excess nitrogen that plants do not use.

Ultimately, the way we farm the land can directly affect the amount of important greenhouse gases in the atmosphere.

In 2008, agriculture contributed about 7% of human-based greenhouse gas emissions in the United States[3]. Much of this impact comes from the more potent greenhouse gases (see MSU Extension E3148): methane largely from animal agriculture and nitrous oxide largely from field crop agriculture. Agricultural soil management was responsible for 68% of total nitrous oxide emissions; these emissions are greatly influenced by the amount of nitrogen fertilizer applied, the crop grown, and the weather patterns[3]. Figure 1 shows the relative contribution of major agricultural greenhouse gas sources in the United States.

How will climate change affect Michigan field crop agriculture?
Global warming is likely to bring local shifts in temperature and in the amount and seasonal distribution of precipitation. It is also likely to result in more extreme weather such as droughts and periods of heavy precipitation. Such changes can affect plant growth, the spread of pests and diseases, and water availability in both positive and negative ways (Table 1).

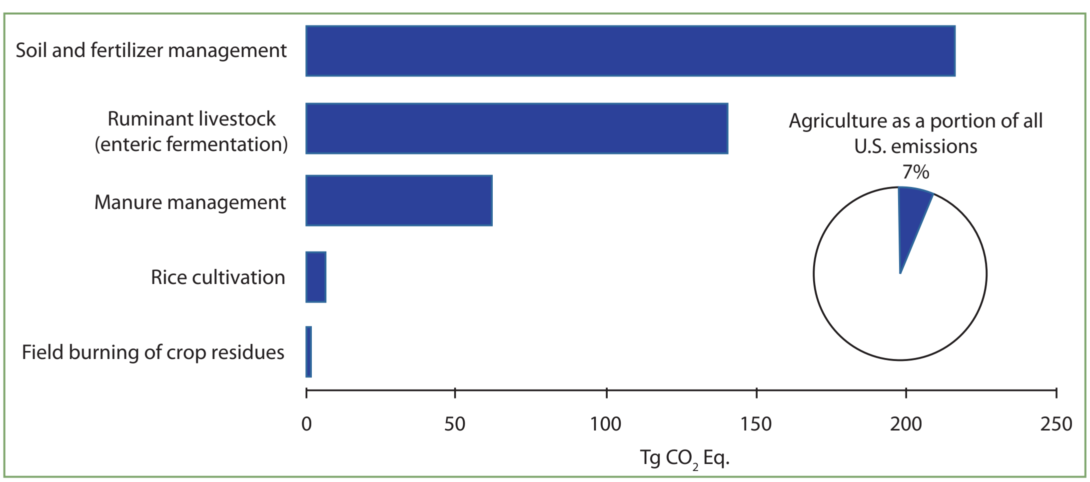


Figure 1: Relative contributions of agriculture to greenhouse gas emissions in 2008 (expressed in the unit CO_2-equivalents). Total emissions increased by 16% from 1990–2008 from the U.S. agricultural sector. (Figure adapted from EPA 2010[3].)

There are feedbacks so the issue is consequently complicated. For example, while greater rainfall and a longer growing season can enhance crop growth, they can also lead to more plant disease and different and perhaps more virulent pests. Furthermore, if the greater precipitation occurs in winter rather than summer, then the longer growing season will not enhance rainfed yields and may delay springtime soil drying. If, on the other hand, the greater precipitation occurs in summer but in more intense storms, the benefit may be offset by nitrogen loss, erosion, and other fertility problems.

For now, the takeaway message is uncertainty. The climate is changing, and changes are likely to happen more rapidly in the future. We do not know exactly how climate change will affect Michigan field crops, but we know there will be change, and the better we are prepared for it the more we can use it to our benefit. Agriculture's ability to be nimble in adapting, as well as having good information about changes and adaptive measures is key[4]. Below we discuss how documented and predicted changes in climate have the potential to affect field crop agriculture. See MSU Extension E3152 and E3153 for a detailed description of crop adaptation and soil management in response to changes in climate.

Table 1: Representation of positive and negative impacts of climate change on field crop agriculture

Good or Bad for Ag?	Good	Bad
Increased CO_2 concentrations	✓	✓
Warmer temperatures	✓	✓
Greater weather variability		✓
Crops more vulnerable to pests		✓
Longer growing season	✓	
More precipitation	✓	✓

Increased carbon dioxide concentrations in the atmosphere (carbon fertilization): Almost all plants utilize one of two types of photosynthesis, C3 or C4. The difference between these types is how the plant uses carbon dioxide in the growth process. Michigan C3 crops include soybeans and wheat while corn is a C4 plant. In general, crop yields are enhanced by more carbon dioxide, with C3 plants responding more strongly than C4 plants, so long as other factors such as water availability are not limiting their growth[5]. However, estimates of increased yield from elevated carbon dioxide may be overestimated as most of these experiments have been conducted in enclosures that fail to represent field conditions and do not account for interacting factors such as weeds, nutrients, soil water, and decreased air quality[5,6].

Warmer temperatures: The general warming trend of the Midwestern United States could allow varieties of crops typically planted in more southern climates to be planted further north[7,8]. While warmer temperatures can increase crop productivity[1], there is an optimum temperature for reproductive growth. Once this maximum is exceeded, plant and seed growth is diminished. This can reduce yields[9]. Water availability also can become more limited as higher temperatures increase plant water use.

More precipitation: While more rainfall during the growing season could benefit plants, the likely increases in winter and spring precipitation, heavy downpours, and summer evaporation can lead to more times of floods and water deficits[8]. These predicted changes in precipitation and subsequent excesses or deficits of water in the Midwest would negatively affect field crop agriculture[7,8].

Greater weather variability: Though winters may be shorter due to warming temperatures, weather variability can pose an obstacle to some field crops. Unpredictable occurrences like the spring freeze in 2007 or extensive water logging of fields by excessive rainfall could become more common, harming crops[7].

Crops more vulnerable to pests: Plant pathogens are highly responsive to increased rainfall. Similarly, insect abundance increases with temperatures[9]. Invasive weeds, insects, and pathogens from warmer climates may colonize northern soils, creating new, major pest problems for field crop farmers[7]. Much more research is needed to understand changes in production due to climate-induced shifts in diseases and weed and insect pests[5].

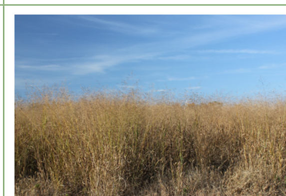
Longer growing season: The Upper Midwest stands to benefit from a longer growing season associated with warmer temperatures[7]. Longer growing seasons provide more management flexibility, reduce the risk of early frost, and allow longer-season varieties to be planted.

What can agriculture do about climate change?

Although agriculture contributes to excess greenhouse gases in the atmosphere, it is possible to reduce emissions and even remove carbon dioxide from the atmosphere through specific land management practices. There are three main concepts central to interactions between climate change and agriculture:

1) **Mitigation:** intervention to reduce the *sources* or enhance the *sinks* of greenhouse gases[1].
2) **Sequestration:** the removal of carbon dioxide from the atmosphere and subsequent storage in carbon sinks (such as oceans, forests, or soils) through physical or biological processes, most notably through photosynthesis[10].
3) **Adaptation:** Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects[1].

Table 2: Mitigation and sequestration strategies for field crop agriculture[11,12]

Goal	Practice	Additional benefit to farmers	
Reduce fossil fuel consumption	Renewable energy sources, improved efficiency equipment, biofuel crop substitution	Saves money, potential new biofuel crops and markets.	
Restore (sequester) soil carbon: increase carbon inputs to soil	Crop diversity through cover crops and rotations; increase crop residue quantity in no-till; manure and compost additions	Improves soil and water quality. Reduces erosion.	
Restore (sequester) soil carbon: reduce carbon loss from soil	Permanent no-till, retain crop residue, perennial crops	Improves soil, water, and air quality. Reduces soil erosion and fuel use.	
Reduce nitrous oxide emissions	Better manage nitrogen fertilizer use	Improves water quality. Saves expenses, time, and labor.	

Photos courtesy of KBS LTER - MSU

Table 2 indicates some of the many specific strategies related to agriculture. For example, research in Michigan demonstrated the ability to manage nitrogen fertilizer in a way that maintains yields while reducing nitrous oxide emissions[13]. Likewise, Michigan State University scientists documented how no-till farming restores carbon in the soil[14]. Many of the management practices aimed at reducing greenhouse gas emissions have positive impacts on the environment[12], such as improved air, soil, and water quality (Table 2). These environmental benefits can also boost agricultural yields and may help agriculture adapt to changing environmental conditions.

A single mitigation practice such as carbon sequestration alone will not be enough. Table 2 highlights the need for a *portfolio approach*—a combination of management techniques combined with strategies such as alternative energy, reduced energy use, and more energy-efficient equipment (lower emissions). Policy and markets could help provide incentives for farmers though payments and other programs to increase carbon storage and reduce nitrous oxide emissions[12,15].

References:

[1]IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

[2]Lal (2004). Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science. 304:1623-1626.

[3]U.S. Environmental Protection Agency (2010). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008. EPA 430-R-10-006. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

[4]The National Academies (2009). Ecological Impacts of Climate Change. Accessed Feb 2011 at http://dels-old.nas.edu/dels/rpt_briefs/ecological_impacts.pdf. Booklet based on Ecological Impacts of Climate Change Report (2008) by the Committee on Ecological Impacts of Climate Change, National Research Council.

[5]Tubiello FN, Soussana J-F, and Howden SM (2007). Crop and pasture response to climate change. Proceedings of the National Academy of Sciences 104: 19686-19690.

[6]Long SP, Ainsworth EA, Leakey ADB, Nösberger J, and Ort DR (2006). Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO2 Concentrations . Science 312:1918-1921.

[7]U.S. Global Change Research Program (2009). Global Climate Change Impacts in the United States: Agriculture. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/climate-change-impacts-by-sector/agriculture

[8]U.S. Global Change Research Program (2009). Regional Climate Impacts: Midwest. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/midwest

[9]The U.S. Climate Change Science Program (CCSP). 2008. The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States. http://www.climatescience.gov/Library/sap/sap4-3/final-report/sap4-3-final-exec-summary.pdf

[10]Pirog R and Rasmussen R (2009). Understanding Common Terms Used in Discussions about Climate Change and Agriculture. Leopold Center for Sustainable Agriculture, Ames. IA. http://www.leopold.iastate.edu/research/marketing_files/glossary.pdf

[11]U.S. Environmental Protection Agency (2010). Agricultural Practices that Sequester Carbon and/or Reduce Emissions of Other Greenhouse Gases. http://www.epa.gov/sequestration/ag.html

[12]U.S. Department of Agriculture (2006). Opportunities for Managing Carbon Sequestration and Greenhouse Gas Emissions in Agricultural System. http://www.nrcs.usda.gov/feature/outlook/Carbon.pdf

[13]Hoben JP, Gehl RJ, Millar N, Grace PR, and Robertson GP (2011). Non-linear nitrous oxide (N2O) response to nitrogen fertilizer in on-farm corn crops of the US Midwest. Global Change Biology 17: 1140–1152.

[14]Syswerda SP, Corbin AT, Mokma DL, Kravchenko AN, and Robertson GP (2010). Agricultural management and soil carbon storage in surface vs. deep layers. Soil Science Society of America Journal 75: 92-101.

[15]Millar N, Robertson GP, Grace PR, Gehl RJ, and Hoben JP (2010). Nitrogen fertilizer management for nitrous oxide (N2O) mitigation in intensive corn (Maize) production: An emissions reduction protocol for US Midwest agriculture. Mitigation and Adaptation of Strategies for Global Change 15:185-204.