Agriculture and Climate Change

Humans, like all animals, are driven by their food supply. The world population now exceeds 5 billion and is projected to reach 8 billion by the year 2025. The demand for food increases with population growth and results in more forests felled, more fields cleared and abandoned, more ecosystems impoverished, more soils depleted, more air and water polluted, more energy consumed, more water and fertilizers used, and more greenhouse gases released into the atmosphere.

Agriculture is a widespread and important activity, supplying food and fiber, and providing a livelihood for millions of Americans, both directly (on the farm) and indirectly (processing, transportation, marketing, service industries, etc.). One critical facet of agriculture is the production of corn, wheat and soybeans — our main food crops. Production of these three crops takes up about two-thirds of the total U.S. agricultural acreage, and their economic value is equal to that of all other crops combined. For this reason, these are the crops on which climate modeling efforts have been concentrated.

Part of the Great Lakes Region lies within the Corn Belt where corn and soybeans are primarily produced. But what is the Corn Belt? The U.S. Corn Belt is also known as the country’s “agricultural heartland,” as it is where the majority of corn, soybeans, and wheat are grown. Technically defined as including the states of Illinois, Indiana, Iowa, Missouri, and Ohio (and also parts of Wisconsin, Nebraska, Kansas, South Dakota and Michigan, North Dakota, and Minnesota), it covers over 700,000 square miles. In Ohio 57 percent of the state’s land is used for farming, while Indiana and Illinois have 69 percent and 78 percent, respectively, of their state’s land used for farms. A farm generating more than $1000 in sales is considered farmland.

Corn is the third largest crop in the world, following wheat and soybeans. In the United States, where it is the number one crop, corn is used for animal feed and processed foods such as cereals, corn syrup, corn oil, and corn starch. In other countries, it is used as a main staple in the human diet; for example, in flours and as a vegetable. Industrial uses include alcohol, adhesives, paper, linoleum, paint, soaps, and textile sizing. As corn has been bred by humans for grain production for 25,000 years, we have had a long time to become dependent on corn for many things.
Agriculture is an activity that is very sensitive to climate, because plant growth is directly dependent upon climatic conditions. If global climate changes are substantial, the predicted fluctuations in temperature and moisture conditions will move the major growing areas of the country away from their present locations. Corn crops would generally shift northward (see Figures 1 and 2) and could be replaced by crops of soybeans, cotton, canola, sorghum, barley, and oats. Several crops would also be displaced by the northward shift. These include wheat, hay, and oats.

Global climate changes would also cause a variety of other changes. A longer growing season would be likely, and this would create a need for crop geneticists to develop new plant varieties. Secondly, as insects and disease pathogen populations are expected to increase, losses of corn yield could be approximately 35 percent unless insecticide and herbicide use is correspondingly increased. Thirdly, if the amount of CO₂ in the atmosphere were to increase as most scientists predict, more carbon would be available for plants as food (carbohydrate) production. As a result, the rate of photosynthesis may increase in some species, producing higher crop yields. For example, corn and sugar cane respond very mildly to elevated levels of CO₂ while wheat, potatoes and beans may increase their growth and yield by 10 to 50 percent. Although yields may be higher with
more CO₂, food quality could deteriorate. In addition, because pests and weeds would thrive in the warmer temperatures and higher CO₂ levels, it is difficult to predict the overall total change in agricultural production in the northern Great Lakes regions.

Although global warming is likely to affect agriculture in the Corn Belt, the economic impact of global warming in the Great Lakes region is a complex issue. Farmers will not necessarily lose money, because other crops may replace current ones, resulting in more, less, or equal profit. Some regions may be harmed economically, while others actually benefit from global warming. There are many factors to consider when thinking of agriculture and global change.

Activity A: Will the Corn Belt be tightened?

Students may have heard adults speak of tightening their belts when economic times get hard. The idea applied to this activity is that there could be less to eat. Is it likely that agriculture in the Great Lakes region will be negatively impacted by global climate change?

Objectives

When students complete this activity, they should be able to:

- Describe how global climate change will affect the agricultural crops currently grown in the Great Lakes states.
- Hypothesize about the crops that could replace those currently grown in the Great Lakes states.
- Discuss the potential economic impacts of global warming on agricultural production in the corn belt.
- Analyze the potential impact of global climate change on people's occupations related to agriculture in the Great Lakes states.
- Articulate the complexity of the relationship between global warming and agriculture, and the resulting difficulty in making predictions.

Teacher's Note

Have students refer to the appendix following this activity that lists some of the possible characteristics of climate change and their effects on crop production.

Materials

For this activity you will need:

- A copy of Figures 1 and 2 for each group
- U.S. Atlas and Almanac, and state maps
- Overhead transparencies and markers
- Wall Street Journal
- Appendix: Factors to consider for brainstorming — included with this activity
1. Table 3 gives students square miles of each state and projections of area within future corn belts. Students estimate the area of each state within the present corn belt.

2. The seasonal precipitation fluctuation removes North and South Dakota and much of the Great Lakes shoreline resulting in a smaller Corn Belt. This suggests that the timing of rainfall is very important in the growth cycle of a corn plant. Rains in July and August are important for the reproductive stage of the plant’s life — tasseling, pollination, and formation of the ear. Harvests would be smaller with the lower rain unless the crops were irrigated. Given the costs of irrigation, lower rains during these critical months could affect crop growth in the northern regions.

3. Figure 2a appears to encompass more land area than 2b suggesting that changes in both precipitation and temperature would affect the new corn belt. The approximate area of the corn belt based on 2a is 300,777. Scenario 2b has an area of 248,015.

4. Students may assume that the state will suffer economically, but some states could increase crop yields and profits.

5. Use “Factors to Consider for Brainstorming” at the end of the activity to examine possible effects of climate change on agricultural crops.

6. See the Teacher’s Note accompanying the Extensions and the important factors listed at the end of this activity.

7. Students should see a county agent regarding crops suitable to their area. If new environmental conditions are as predicted, corn crops could be replaced by soybeans, cotton, canola, sorghum, barley, and oats. Crops that would be displaced by a northward shift are wheat, hay and oats.

8. Students will work in groups of four to six to do the following:

1. On a map of the U.S. (Figure 1), note the outline of the present Corn Belt. Using information from an atlas, calculate the approximate area in square miles of the Corn Belt.

2. In Figure 2, each scenario is based upon a 3°C temperature increase. Scenario B is also based on a projection of an 8 cm yearly increase in precipitation; however, this includes a 0.6 cm decrease from July-August. Compare the two models. How does this seasonal precipitation fluctuation affect the range of the Corn Belt?

3. Using either of the Scenarios in Figure 2 and an atlas for reference, what is the estimated approximate area of the projected future Corn Belt?

4. Choose one Great Lakes state and do research to find out the agricultural crops grown there. Consult an almanac or Farm Bureau reference for information about each Great Lakes state. If crops change with global warming, how will the state’s economy be affected? Do you think the overall agricultural yield will go up or down?

5. What will be the impact of global change on agriculture? Will the nature of food supply change in the Great Lakes?

6. Do all crops provide equal income to farmers? Using Tables 1 and 2, students should brainstorm possibilities and support their conclusions.

7. What other crops can replace corn? What crops would be displaced by a northward shift of corn?

8. Choose a way in which to present your research to the class. You may use any visual means of your choice (video, computer, slides, overhead transparencies, chalkboard, posters, etc.). Explain which model you used (Figure 2) and why you chose it. Explain your estimates of loss or gain in production, and your predictions of the effects of global climate change on agriculture in one Great Lakes state based on the model you chose, and the information you found. Develop and present a brief summary to the class.
Figure 2a. Geographic shift of the Corn Belt projected with a 3°C temperature increase evenly distributed over the year and with no change in precipitation (adapted from Blasing and Solomon, 1983).

Figure 2b. Geographic shift of the Corn Belt projected for a 3°C temperature increase evenly distributed over the year and an 8 cm increase in annual precipitation, but with July-August precipitation 0.6 cm less than current values (adapted from Blasing and Solomon, 1983).

Table 1. Comparison of grain prices (Wall Street Journal, November 11, 1993)

<table>
<thead>
<tr>
<th>Grain</th>
<th>Month (1994)</th>
<th>Settle Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORN (CBT) 5,000 bu.; cents per bu.</td>
<td>March</td>
<td>285 1/4</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>287 3/4</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>287 3/4</td>
</tr>
<tr>
<td>SOYBEANS (CBT) 5,000 bu.; cents per bu.</td>
<td>March</td>
<td>688 1/2</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>690 3/4</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>692 1/2</td>
</tr>
<tr>
<td>WHEAT (CBT) 5,000 bu.; cents per bu.</td>
<td>March</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>329 1/4</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>321 1/2</td>
</tr>
<tr>
<td>OATS (CBT) 5,000 bu.; cents per bu.</td>
<td>March</td>
<td>143 3/4</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>146 3/4</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>149</td>
</tr>
</tbody>
</table>

The settle prices are read as cents per bushel, for example, a price for wheat of 340 translates to $3.40 per bushel when bushels are sold in groups of 5,000 (a bushel is equivalent to 8 pounds of grain). Grain buyers and sellers make contracts on future grain prices based on predictions. The news issue is from 1993, but prices reflect projections for 1994. Students can obtain more current commodity price information in The Wall Street Journal Commodity Section.
Table 2. Acreage of crops grown in the Great Lakes states [data in 1,000s of acres (1989 Census Data)]

<table>
<thead>
<tr>
<th></th>
<th>Soybeans/Beans</th>
<th>Corn/Grain</th>
<th>Hay</th>
<th>Wheat/Grain</th>
<th>Oats/Grain</th>
<th>Corn/Silage</th>
<th>Misc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>8800</td>
<td>9000</td>
<td>1000</td>
<td>1000</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Indiana</td>
<td>4400</td>
<td>4900</td>
<td>700</td>
<td>600</td>
<td>70</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Michigan</td>
<td>1000</td>
<td>2000</td>
<td>1400</td>
<td>400</td>
<td>700</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Minnesota</td>
<td>4400</td>
<td>4800</td>
<td>2400</td>
<td>2400</td>
<td>200</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>New York</td>
<td>600</td>
<td>2300</td>
<td></td>
<td></td>
<td>800</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Ohio</td>
<td>3700</td>
<td>3100</td>
<td>1300</td>
<td>800</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>1070</td>
<td>1915</td>
<td>186</td>
<td>243</td>
<td>438</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>29997</td>
<td>2788</td>
<td>4784</td>
<td></td>
<td>679</td>
<td>667</td>
<td>329</td>
</tr>
</tbody>
</table>

1993 State of Ohio Average Yields

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>52 bushels/acre</td>
</tr>
<tr>
<td>Soybeans</td>
<td>40 bushels/acre</td>
</tr>
<tr>
<td>Corn</td>
<td>140 bushels/acre</td>
</tr>
</tbody>
</table>

Ohio State Extension, Franklin County, OH.

“Success in adapting to possible future climate change will depend on a better definition of what changes will occur where, and on prudent investments, made in timely fashion, in adaptation strategies”
(Rosenzweig and Hillel, 1995).

Answers to Review Questions

1. Difference in climate could move growing areas for corn, soybeans, and wheat away from present locations, causing farming communities to switch to other crops that would be more suitable to the new climate.
2. Genetically engineered plant varieties might require less water. Increase in pesticide use could offset larger insect populations, and irrigation could compensate for drier conditions.
3. Have students look in Wall Street Journal for current cost prices.
4. Students should think broadly, to include chemical company jobs, farm machinery repairs, crop storage, insurance, telecommunications, farming-supported industries, laboratory scientists, etc. They should also consider loss of forests in Minnesota, Wisconsin, Michigan which could be cleared for crops.

Review Questions

1. What could global climate change do to the three major food crops produced in the U.S.?
2. How might advances of agriculture and technology curb crop loss?
3. Evaluate possible replacement crops for those currently grown in the Great Lakes states. What is the comparative economic analysis of these current agricultural crops with the replacement crops (will the new crops result in economic gain)?
4. How might global climate change affect the vocations of those living in the Great Lakes states? What occupations and/or careers would be gained or lost if global warming caused a decrease in corn production?
Extensions

These extensions can be done individually or in a group.

1. Using the information in Table 1, consider the following:
   a. How do you think this chart would look 50 years from now? 100 years from now?
   b. If less land is available for irrigation, i.e. less cropland, how will this affect prices?
   c. How will farmers' incomes change? How will they have to change their operations, equipment, seed costs, labor, and other costs of doing business?

2. Do “grocery store research” and bring in food products made with corn (meal, flour, syrup, oil, etc.). Find similar products in which other items are substituted for corn. Compare the alternatives on cost, shelf life, and uses.

3. Find some recipes that use corn products. Experiment with other recipes, or create your own, that substitute other ingredients for corn. How do they compare in taste, availability of ingredients, cost and ease of preparation?

4. Imagine you own a 200 acre farm in any one of the Great Lakes states, and you currently raise corn and soybeans there. Describe your farm or draw a diagram showing the current production of crops. Then decide how you will meet changing climate conditions by: a) irrigating, b) changing crops, c) making no changes, etc. Describe your farm-in-the-future or make a new diagram of your farm showing these changes. Transparencies can be used as overlays to illustrate changes.

Teacher’s Note

It is difficult to address the question of economics. Different crops have different input costs, which makes it challenging to try to compare one to another. The most profitable crops are not necessarily those with the highest price per bushel. A suggestion would be to assume equal input costs and compare which crops would be most profitable. Then in review it would be important to discuss that in reality these costs vary from crop to crop. Of course, the number of bushels per acre for any crop depends on the crop and the growing conditions. As an extension, the students could consider what would happen if crops replacing corn were not grains, but things such as cotton. Allow students to brainstorm possibilities, while supporting their conclusions. Additional information useful to discussions is included under “Factors to consider for brainstorming.”

Further Investigation

One of the important considerations of agricultural production is a plant’s characteristics. Plant species conduct photosynthesis differently. Students could do an investigation of photosynthesis to understand the difference between C3 and C4 plants. These values help describe the number of carbon atoms involved in the first step of photosynthesis. C4 plants, such as corn, use CO2 more economically than C3 plants, such as wheat and soybeans. Increased levels of CO2 change the competition between these plants, however, making the C3 plants able to better utilize the higher gas levels, as predicted for a changing climate. The following article offers an explanation of this and other related concepts.

Factors to Consider for Brainstorming

**Effects of Higher CO₂**
- Higher levels of atmospheric CO₂ may increase plant growth, resulting in increased yields of corn, soybeans, and wheat.
- Plants may adapt to the gradual change in CO₂ over time, and therefore not alter current production levels.
- Soybeans and wheat tend to respond better to higher CO₂ levels than do corn and sugar cane.
- Corn crops would generally shift northward (see Figures 1 and 2) and could be replaced by crops of soybeans, cotton, canola, sorghum, barley, and oats.

**Thermal Changes**
- Increased yields may occur in the northern latitudes where warmer temperatures result in a longer growing season.
- Decreased yields may occur in mid-latitudes as higher temperatures shorten a crop’s life cycle (shorter time for grain to develop).
- A northward shift of growth zones is expected. Hotter temperatures harm certain crops, such as corn, and they will grow better further north (see Figures 1 and 2).
- Crops, such as soybeans, if they can tolerate heat more easily, may outcompete the corn where it grows now.
- High daily maximum temperatures may affect crops. Hot night temperatures are also bad for corn.

**Hydrological Change**
- Rainfall patterns will change, which might expand crop irrigation requirements in certain regions. Along with a reduction in water supplies, the extra water demand may require some land to be removed from irrigation. Water resources are already tight in some areas because of urban demands.
- With less precipitation, drier soil is likely.
- Dry periods may be particularly harmful during grain-filling stages of plant growth.
- It may be necessary to breed crop varieties that are drought resistant as well as heat resistant.

**Climate Variability**
- Extreme events are possible — droughts, extremely high or low temperatures, and storms.
- Variations may push crops over their temperature tolerance.

**Pests and Diseases**
- Global warming may change the ranges and populations of agricultural pests. New approaches to pest control may be needed.
- With warmer temperatures, insects may survive the winter and have longer reproductive cycles, resulting in larger populations.
- Predators of insects may also have longer reproductive cycles.
- Warmer temperatures may favor some plant diseases that would normally occur in the subtropical region but could flourish in the new climate of temperate zones.

**Soils**
- Warmer temperatures may mean increased decomposition by microorganisms and decreased fertility, thus less nutrients in the soil.
- More fertilizers may be needed.
- Soils may be drier and more prone to wind and rain erosion, particularly during storms.

What can you hypothesize about crop production in the Great Lakes region based on these possibilities?
Table 3. Total area of states and two scenarios of geographic shift

<table>
<thead>
<tr>
<th>State</th>
<th>Total Sq. miles</th>
<th>Total Corn Belt Sq. miles</th>
<th>2a Sq. miles</th>
<th>2b Sq. miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>56,345</td>
<td>56,345</td>
<td>21,580</td>
<td>25,500</td>
</tr>
<tr>
<td>Indiana</td>
<td>36,185</td>
<td>36,185</td>
<td>20,300</td>
<td>36,185</td>
</tr>
<tr>
<td>Iowa</td>
<td>56,275</td>
<td>56,275</td>
<td>20,000</td>
<td>25,000</td>
</tr>
<tr>
<td>Kansas</td>
<td>82,277</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Michigan</td>
<td>58,527</td>
<td></td>
<td>58,527</td>
<td>0</td>
</tr>
<tr>
<td>Minnesota</td>
<td>84,402</td>
<td></td>
<td>73,000</td>
<td>64,860</td>
</tr>
<tr>
<td>Missouri</td>
<td>69,697</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nebraska</td>
<td>77,355</td>
<td></td>
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<td>0</td>
</tr>
<tr>
<td>North Dakota</td>
<td>70,702</td>
<td>0</td>
<td>21,750</td>
<td>0</td>
</tr>
<tr>
<td>Ohio</td>
<td>41,330</td>
<td>41,330</td>
<td>25,080</td>
<td>41,330</td>
</tr>
<tr>
<td>South Dakota</td>
<td>77,116</td>
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<td>4,500</td>
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<td>Wisconsin</td>
<td>56,153</td>
<td></td>
<td>56,040</td>
<td>55,140</td>
</tr>
<tr>
<td>Totals</td>
<td>766,364</td>
<td></td>
<td>300,777</td>
<td>248,015</td>
</tr>
</tbody>
</table>

Selected data taken from the 1994 World Almanac.

REFERENCES


DATA SOURCES

Amherst, MA: Massachusetts Agricultural Experiment Station.

Whitmore, Susan C. 1991. *Global Climate Change and Agriculture. A Summary of Global Change Information Resources*