FIGURE SET HEADER for Set #5

Figure Set 5: Global Warming Potential – Temperate Agriculture

Purpose: To teach students that land management can affect the amount of greenhouse gas emissions from temperate agricultural production and that cessation of agriculture results in net sequestration of greenhouse gases in the soil. Students will play roles of various citizen groups to identify ways in which agricultural land management can affect a variety of different people around the world.
Teaching Approach: Citizens Argument
Cognitive Skills: (see Bloom's Taxonomy) Knowledge, interpretation, analysis, synthesis
Student Assessment: Land Management Activity

BACKGROUND for Set #5 (back5.html)

Background

Agriculture and climate change are inextricably linked, as was shown in Figure Sets 1-4. Not only will climate change affect agricultural crop production, but agriculture is a primary source of several greenhouse gases. As shown in Figure Set 1, cultivation of undisturbed soils results in the loss of soil carbon. The production of nitrogen fertilizer, burning of fossil fuels by machinery and lime applications also emit carbon dioxide to the atmosphere. Fertilized agricultural soils contribute a substantial amount of nitrous oxide to the atmosphere. Methane oxidation in soil is lower in agricultural soils compared to adjacent forested areas. All of these factors must be examined simultaneously to understand the cumulative global warming potential of agroecosystems.

Many agricultural soils in temperate regions have been cultivated for many years. In these fields, much of the carbon stored in soil has been lost to the atmosphere due to enhanced decomposition during cultivation (See Figure Set 1). Soil carbon loss eventually levels out and remains at a steady state under conventional crop management. However, soil carbon content can actually increase under certain crop management strategies, including conservation tillage, cover crop planting and perennial crop growth. Likewise, other management strategies such as reducing fertilizer applications can reduce the amount of greenhouse gases emitted during management activities. Taken together, the net global warming potential can be calculated for different agroecosystems. Negative global warming potential values indicate net decreases in atmospheric heat trapping potential and positive global warming potential values indicate net increases in atmospheric heat trapping potential.

The global warming potential (GWP) of five agroecosystems in the Long Term Ecological Research Experiment at the W.K. Kellogg Biological Station in SW Michigan were compared from 1989 1999 (Table 5). In this experiment, five ecosystems were compared from 1989 to 1999 for their total contribution to global warming. The first three ecosystems were cultivated with annual crops, in a corn-soybean-wheat rotation.

- The **"Conventional Agriculture"** ecosystem received both soil tillage and pesticides to control weeds and was fertilized to maximize crop yields.

- **"No Till Agriculture"** refers to an ecosystem in which the soil was not disturbed after the start of the experiment in 1989. Instead, weeds were controlled using pesticides.
- **"Organic Agriculture"** refers to an ecosystem that received no fertilizer or pesticides, but tillage was used to control weeds and legume (nitrogen fixing) cover crops were used as nitrogen fertilizer sources.

No-till and organic agricultural practices reduced greenhouse gas emissions compared to conventional management, but most farmers still use conventional practices. There are several reasons why farmers may not switch to using management activities that reduce greenhouse gas emissions. Farmers need to maintain a steady income to continue farming. For example, farmers may not switch to no-till agriculture because soil compaction may occur, and tillage helps to breakdown surface plant litter that may reduce germination in future planting exercises. Farmers may not use organic agriculture practices because of slightly reduced crop yields and more labor involved in organic agriculture. Fertilizers ensure that plants will have enough nutrients to grow during the growing season. Economics and sociological pressures also play a big role in farmer decisions.

Successional communities are those that are left fallow and receive minimal human induced disturbances.

- **"Early Successional"** ecosystems were last tilled in 1988, but were then left undisturbed, except for occasional burning to prevent trees from growing in the experimental plots.
- **"Late Successional Forest"** ecosystems had not been disturbed for over 100 years and were dominated by large, hardwood trees such as oaks and maples.

Three primary gases contribute to the global warming potential (GWP) of the different agroecosystems shown in Table 5. GWP refers to the relative radiative forcing (heat trapping) ability of each source. Nitrous Oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) molecules do not have the same ability to trap heat. A molecule of N_2O traps the most heat over its lifetime in the atmosphere while a molecule of CO_2 traps the least amount of heat over its lifetime. Therefore, a molecule of N_2O is given more weight in terms of GWP than the other two gases. The table already reflects this change. See IPCC (2007) for further information on greenhouse gas concentrations and relative radiative forcing.

Carbon dioxide is produced through several agricultural processes. Tillage often leads to the loss of soil carbon due to enhanced decomposition of organic matter. Nitrogen fertilizer production is

atmosphere and transport it to fields. Lime is often applied to fields to increase the soil pH, which can lead to net emissions of carbon dioxide in certain circumstances. Fuel is needed to power tractors and other equipment used to complete various agricultural activities, such as planting, tilling, spraying pesticides and harvesting.

Nitrous oxide (N_2O) is a gas that is produced during nitrification and denitrification processes. Nitrification is the process by which certain types of bacteria convert ammonium (NH_4^+) to nitrate (NO_3^-). Denitrification occurs when no oxygen is available. Anaerobic bacteria utilize nitrate as an electron donor for the oxidation of organic matter, which leads to the production of

N_2 and N_2O gases. High levels of soil nitrogen due to fertilization can lead to increased levels of N_2O production (McSwiney and Robertson 2005).

Methane (CH_4) is also produced under anaerobic conditions. Microbes that thrive in these oxygen poor environments produce methane as a byproduct of carbon mineralization (Segers 1998). However, some soil organisms are able to oxidize methane, effectively removing it from the atmosphere and producing carbon dioxide (Roslev et al. 1997).

FIGURES for Set #5 (figure5.html)

Table

Ecosystem Management	CO_2				N_2O	CH_4	Net GWP
	Soil C	N Fertilizer	Lime	Fuel			
Conventional Agriculture	0	27	23	16	52	-4	**114**
No-Till Agriculture	-110	27	34	12	56	-5	**14**
Organic Agriculture	-29	0	0	19	56	-5	**41**
Early Successional	-220	0	0	0	15	-6	**-211**
Late Successional Forest	0	0	0	0	21	-25	**-4**

Legend

Table 5. Global warming potential (GWP), by greenhouse gas and by specific source of CO_2, is shown for five different experimental ecosystems in a long-term ecological research (LTER) experiment in southwest Michigan. Each Ecosystem Management treatment was replicated six times on randomly selected one hectare plots. Positive numbers indicate net increase in global warming potential while negative numbers indicate a decrease in global warming potential. Annual crops were harvested for agricultural production while successional communities were left undisturbed, except for occasional burning of the Early Successional plots. This table is

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STUDENT INSTRUCTIONS for Set #5 (students5.html)

Student Instructions

Familiarize yourself with the Figure Set 5 Background and Table 5 before coming to class.

Class Activity - State of Michigan Hearing

The State of Michigan is considering passing a law that requires farmers to become GWP-neutral, which means that they no longer can be a net emitter of greenhouse gases. To do this, they would need to change their agricultural practices to no-till or organic methods and/or set aside some of their land in conservation areas (e.g. Early Successional), where greenhouse gases are sequestered in the soil.

You will be assigned to one of six stakeholder groups that have a chance to testify in front of the Michigan Legislature. In your group, you will construct a statement and will have three minutes to address the State of Michigan Legislature, presenting your argument. A seventh group of Michigan Legislators will also be formed from students. The six interest groups are:

1. Michigan corn farmers, who need to cultivate as much land as possible to maintain income levels, and make sure that they get enough use out of expensive equipment.
2. Landowners along the Florida coast that would lose their property with only a 1 meter rise in sea level if global warming continues. Global warming will cause thermal expansion of water and the melting of ice sheets on land in northern and southern areas, resulting in more water in the sea.
3. The Pheasants Forever organization. Pheasants thrive in conservation areas that are planted to prairie grasses and forbs.
4. The ethanol industry, which is increasing dramatically in size, and utilizes corn grain for ethanol production. Biomass from trees, grasses and crops are also being considered for use in the synthesis of ethanol. Ethanol can be partially substituted for gasoline.
5. The Sierra Club, which promotes conservation of prairie habitat and biological diversity.
6. The Food Industry, which uses corn to make many food items that are consumed in large quantities by the public.

After all arguments are presented, the State of Michigan Legislature group will decide whether or not to vote in favor of the law.

Figure Set 5 Notes to Faculty:

section for any details about the figure. The suggested student active approach for Figure Set 5 is

perspective of various citizen groups, and to make arguments that are grounded scientifically, yet represent their point of view. This activity was tested in a small high school classroom, and there were some outstanding statements from students.

After giving the students some time to read the instructions and look over the table, divide them into seven different groups and assign them to either the Michigan State Legislature or one of the six interest groups. You may need to assign the students to groups a few days before class, so that they can familiarize themselves with the interest group that they will be representing. Give them 10-15 minutes to prepare their argument. There are many other interest groups that could be formed so feel free to modify the activity.

Each group has 3 minutes to present their argument to the legislature, which is a total of 18 minutes. Give the legislature a few minutes to think about how they want to vote, and then have each member of the legislature vote for or against the GWP-neutral farm law. After the legislature vote, hold a final class discussion about the outcome.

While the students are planning in their groups, they can come and talk to you or ask questions about the figure. This is a good time to make any clarifications. Remember to remind them that positive GWP numbers on the table mean that greenhouse gases are being emitted while negative

numbers mean greenhouse gases are being sequestered. You may also point out that these numbers are for southwest Michigan, and may vary with the landscape.

The activity as written will work best in small classrooms, but could be adapted to larger

where one student represents the legislature while the other six argue for one of the six interest groups. After providing the students with ample time to discuss, the legislator for each group can report back to the entire class regarding their decision, and why they decided to support or disapprove of the law.

Give the students the Land Management Activity as a homework assignment. This assignment requires them to consider both environmental and economic reasons for implementing certain farm practices. Of course there are other reasons that are factors, such as quality of life and labor requirements, but economics and environmental impact are two of the largest factors. When asked to produce the most grain possible while maintaining GWP neutral status, students should plan their farm to include no-till acres and early successional acres. To maximize profit, students may want to use a mixture of organic, no-till and early successional acres, depending on how they want their farm to look. Students should also include pictures of streams, ditches, etc.. in their pictures to depict a real scenario.

Assessment - Land Management Activity

Data from the W.K. Kellogg Biological Station Long Term Ecological Research Experiment (KBS-LTER) has shown that the global warming potential (GWP) impact of different agricultural activities could be mitigated considerably by changing management strategies. Adopting specific strategies (e.g., early successional) that minimize GWP seems straightforward; however, in reality these decisions are complex due to the broader social and economic issues. In an agricultural setting, a farmer strives to maximize his profits, so allowing all of his/her land to revert to early successional fields is not an economically viable strategy. Likewise, this strategy would not be suitable in a social context either, because societies like to maximize food production.

In this activity, you will assume the role of a farmer that needs to develop a management plan for his/her **1000 acre farm**. However, assume that a recent mandate by the government states that all farms in the United States must be GWP-neutral (0 lbs CO_2/acre /yr). Therefore, the farmer needs to develop a management plan that uses different proportions of various cropping methods (conventional vs. no till vs. organic vs. early successional) to be certified as a GWP-neutral farm under two different scenarios:

(1) maximization of farmer profit
(2) maximization of food production

Use the table below, generated using data from the Kellogg Biological Station Long Term Ecological Research (LTER) experiment, to develop **two** farm management plans.

1. Maximize grain production while maintaining GWP Neutral Status
2. Maximize profit while maintaining GWP Neutral Status.

Create your farm management plans on two separate sheets of paper. For each of the two plans, **include the following**:

1. A drawing of your fictional farm with plots of land labeled based on cropping method (Remember to consider that most farmland is not flat and some areas work better for agriculture than others)
2. The total amount of acres for each cropping method
3. The total annual grain yield from your farm
4. The total gross profit from your farm

Cropping Method	**Global Warming Potential (lbs CO_2 equivalents / acre)**[#]	**Average Annual Grain Yield (bushels / acre)***	**Average Annual Gross Profit (dollars / acre)**[+]
Conventional	1014.6	55.2	$254.91
No-Till	124.6	56.9	$263.82
Organic	364.9	41.6	$336.06
Early Successional	-1877.9	0	0

[#] Positive values mean that greenhouse gases are being emitted into the atmosphere while negative values indicate that greenhouse gases are being sequestered by the cropping system.
[*] The average grain yield in bushels per acre includes all three crops (corn, soybeans, wheat) grown in the KBS LTER experiment. These three crops are grown in a three year rotation, so that each crop is grown every third year.
[+] The gross profit values are based on conventional and organic grain markets in Chicago for the week of April 17th, 2007.