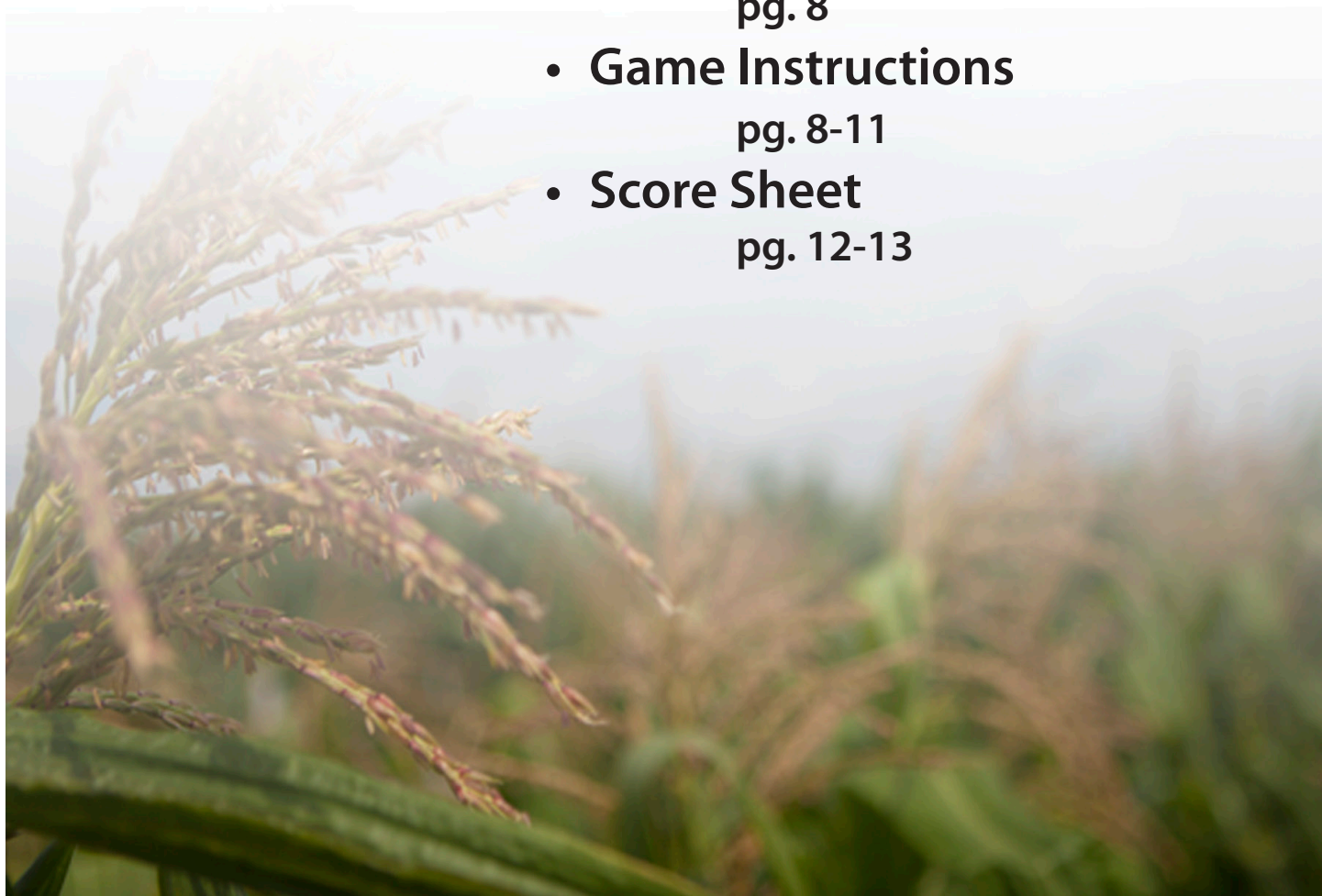




The Bioenergy Farm Game

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Activity developed by Robyn Kademan of Carginal Heights Upper Middle School, Sun Prairie, WI, with GLBRC Scientist Tim Meehan at the University of Wisconsin-Madison with funding and other support from the Great Lakes Bioenergy Research Center



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www.glbrc.org/education
education@glbrc.wisc.edu



U.S. DEPARTMENT OF
ENERGY

Introduction to Bioenergy: Farming Fuels of the Future

If you've pumped gas recently, you've probably seen these terms and phrases: "E10," "E85," "Contains 10% Ethanol," "85% Ethanol." You might be wondering, "What is ethanol and why are we putting it in our gas tanks?" (Fig.1)

What is ethanol?

Ethanol is a type of biofuel made from plants. We call ethanol a renewable fuel because plants can be grown and harvested year after year as long as care is taken to preserve soils and the environment in the process. The simplest way to turn plants into ethanol is to extract the plant's sugars and then combine those sugars with yeast that convert them into ethanol.



Figure 1: You might have seen this label on gas pumps. Ethanol is a fuel made from plants.

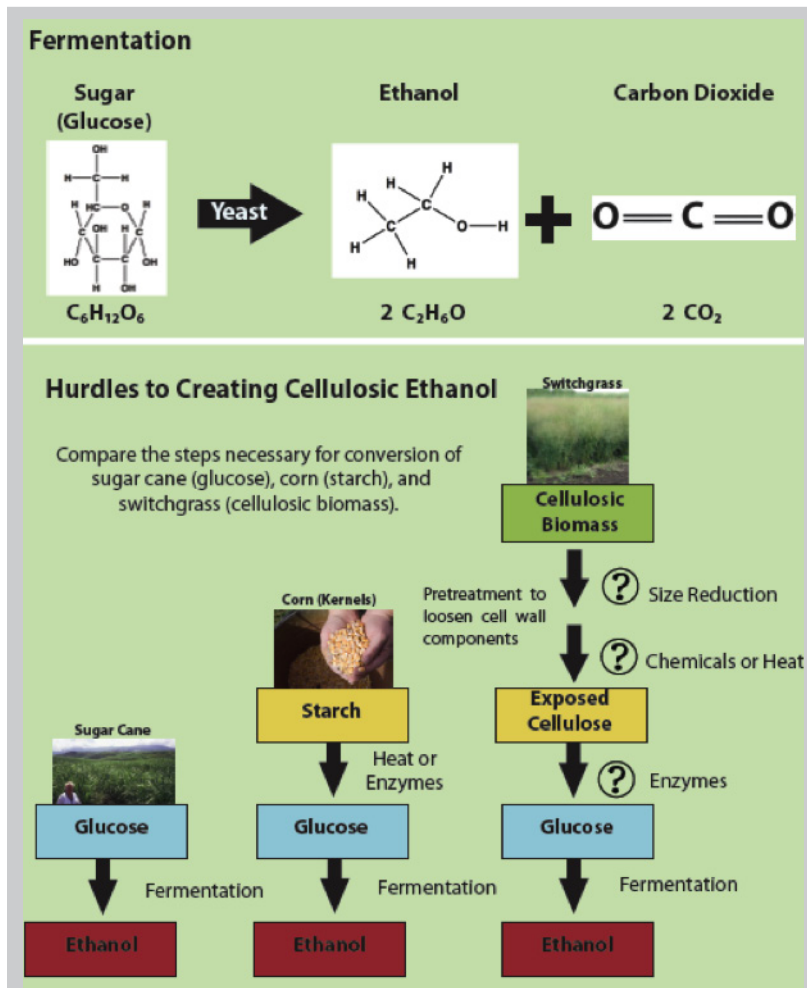


Figure 2: Comparison of how ethanol can be produced from sugar cane, corn grain, and cellulosic biomass such as switchgrass.

lead to future food shortages. Even if all of the corn grain produced were used to make ethanol, that would likely only meet a fraction of our transportation fuel needs.

The process

of converting sugars into ethanol is called fermentation (Fig. 2). The sugars from sugar cane plants – the same plant that provides us with table sugar – are converted into ethanol in this way.

In the United States almost all of the ethanol that we mix with our gasoline is made from corn grain. Using heat and chemicals, corn grain is first converted into sugars, which are then fermented into ethanol (Fig. 2). As of 2012, approximately 40% of all of the corn grown in the US is used to make ethanol. That ethanol makes up approximately 10% of the total transportation fuel for gasoline engines.¹

Issues with Corn Grain Ethanol

What are the pros and cons producing fuels from corn grain? Can we rely on corn grain to supply all of the ethanol that we will need to drive our cars and other vehicles into the future? Scientists, engineers, farmers, and policy makers have recognized that there are some significant drawbacks to relying on corn grain to meet our future renewable fuel needs. For example, using more and more of the US corn grain to produce ethanol could

¹ U.S. Energy Information Administration. *Biofuels Issues and Trends*, October 2012. Washington: U.S. Department of Energy, 2012.

Moving Beyond Corn Grain Ethanol

Currently, only the corn grain can be easily made into fuel; the rest of the plant (called the corn stover) is discarded or used for other purposes. What if we were able to convert the entire corn plant, not just the grain, into sugars and then ethanol? If this were possible, could we someday make ethanol from a variety of grasses, crops and even trees? Scientists and engineers at the Great Lakes Bioenergy Research Center (GLBRC) are researching ways to make this possible. Their goal is to move beyond corn grain ethanol to a future where we produce large quantities of biofuels made from diverse crops such as corn stover or wild grasses (Fig. 2).

In addition to looking for ways to efficiently convert crops into ethanol, researchers are investigating the best ways to

grow potential bioenergy crops such as corn, switchgrass, miscanthus, and native grasses. Scientists collect data on certain characteristics such as ability to grow in different conditions, ability to produce energy, and environmental impacts (Figure 3). Each potential crop has strengths and weaknesses.



Figure 3: Scientists at GLBRC are growing a variety of bioenergy crops and collecting data on a range of characteristics, including yield (energy production) and environmental impacts (biodiversity, greenhouse gas emissions).

Some produce more energy but have higher costs and greater environmental impacts. Others produce less energy, but have lower costs and supporting beneficial environmental services such as providing habitat for wildlife or taking more CO₂ out of the atmosphere.

What future bioenergy farms and landscapes will look like will depend upon what is important to farmers, communities and society as a whole. For instance, is it most important to produce as much energy and money as possible despite the environmental impacts? Or should we grow more crops that benefit the environment and provide opportunities for recreation, but make less energy and money? Or is there a compromise that can meet multiple goals and values?

In this game you will take on the role of a bioenergy crop farmer in the not too distant future. Like real bioenergy farmers, your task will be to plant and manage your farm so as to make money and create positive environmental impacts. At the same time, you should choose crops and make farm management decisions that reflect your values and goals. The information contained in this game guide, such as the characteristics of each crop, should inform your decisions. As you play the game, use the score sheet to record how each crop field is gaining or losing income and environmental points. Use your field and whole-farm scores to evaluate how well you are meeting your goals as a farmer.

Guide to Bioenergy Crops

Use these pages to learn about bioenergy crops. Use this information, along with your values and goals, to decide which crops and how many fields of each crop you will plant.



Each of the following pages features one of the four bioenergy crop options: corn, switchgrass, miscanthus or native grassland. For each crop, the guide includes an overview of the crop's important features and a table for reference on how well each crop performs in ten different categories. These categories are:

- **Yield:** the amount (i.e. weight or mass) of a crop produced in an area such as a 1-acre field. Sample measure: pounds/acre.
- **Profits:** the total amount of money a farmer makes after harvesting and selling a crop.
- **Costs:** the total amount of money a farmer must spend in order to grow and harvest a crop.
- **Fertilizer Use:** how much fertilizer is typically required to grow a crop.
- **Pesticide Use:** the amount of pesticides (insecticides, herbicides, etc.) typically required to protect a crop from various insect and weed pests.
- **Erosion/Nutrient Runoff:** how much soil erosion and fertilizer runoff into streams, rivers, lakes and groundwater occurs when growing a crop.
- **Resilience:** the ability of a system such as an ecosystem to recover from a disturbance such as drought, floods and pest outbreaks.
- **Biodiversity:** the number of different species of plants, animals, and insects in a field that live with a given crop.
- **Carbon Dioxide Emissions:** the amount of carbon dioxide (CO_2) that is released when planting, maintaining, and harvesting the crop. Emissions are offset by the CO_2 that the crop takes out of the atmosphere as it grows.
- **Recreation Value:** the value that a crop would have for various outdoor recreational activities, such as bird watching, canoeing, hunting, hiking, etc. This characteristic is more subjective than the others and depends on how a community wants to use the farmland.

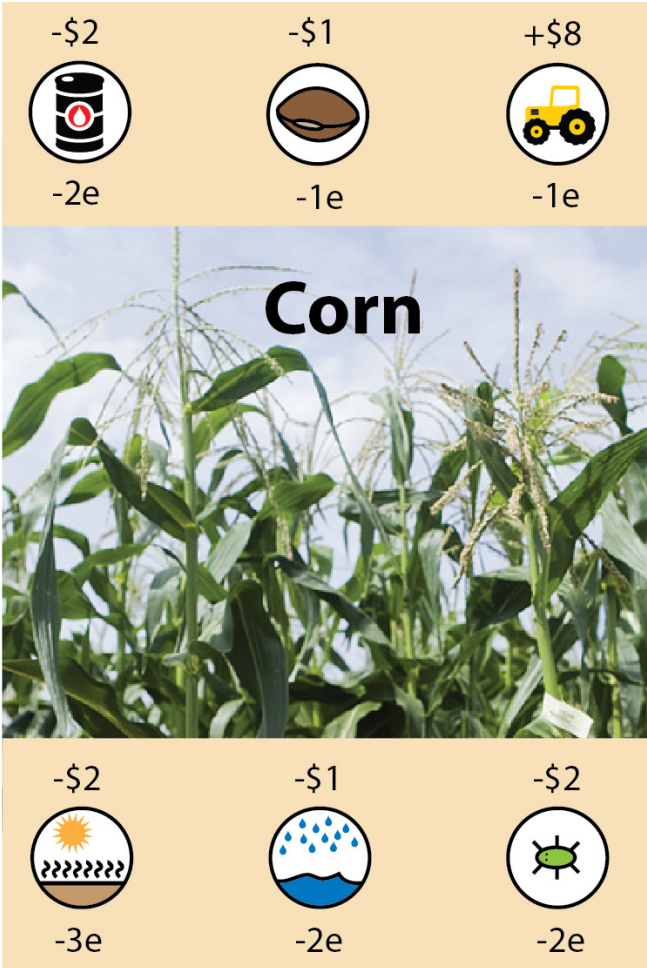
Corn (Zea mays)

Corn is the most commonly planted crop in the United States. The grain is widely used to produce both biofuels, such as ethanol, and food for livestock and people. Scientists have recently discovered new ways to produce biofuels from rest of the corn plant called corn stover. Using corn stover to produce biofuels is an attractive idea because the stover is already being produced in great quantities and, unlike corn grain, is not used directly to feed people.

Because corn has been grown and bred for thousands of years, farmers have developed sophisticated methods for producing high yields of the crop under a wide range of conditions. There are also very good markets for both corn grain and stover, which are important ingredients for food, fuel and other products. For this reason, corn is currently the most profitable bioenergy crop.

However, there are also some drawbacks to planting corn. Corn is an annual crop. This means that farmers need to replant it every year, which can be expensive, takes time and has negative environmental impacts. Replanting, tilling the soil, fertilizing and harvesting every year can have negative impacts on soil health and produces more carbon dioxide (CO₂) emissions from tractors. Also, like most annual crops, corn does not have very deep roots. When the plant is harvested, the remaining roots do not restore very much carbon to the soil as they decompose. Shallow roots do less to prevent water and wind erosion.

In addition, corn needs large additions of fertilizers, pesticides, and water to grow well. This can be both expensive for the farmer and can harm wildlife and groundwater. Corn is a grown as a monoculture (only one crop type in the whole field). These conditions make it a poor habitat for insects, birds and wildlife.



Summary of how corn measures up:

Yield (high) M L H	Profits (high) M L H	Costs (high) M L H	Fertilizer Use (high) M L H	Pesticide Use (high) M L H
Erosion/Nutrient Runoff (high) M L H	Resilience (low) M L H	Biodiversity (low) M L H	CO₂ Emissions (high) M L H	Recreation Value (low) M L H

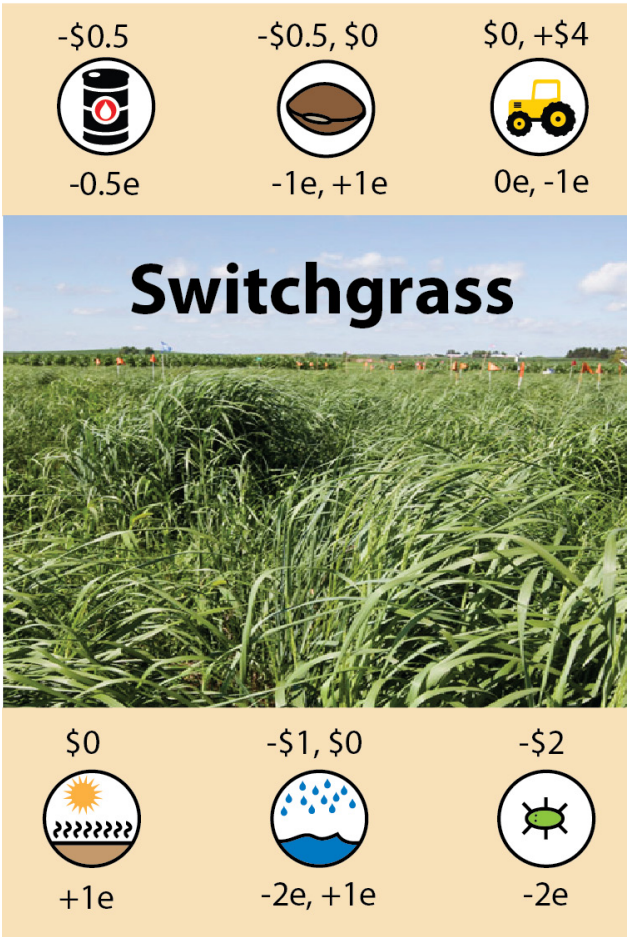
Switchgrass (*Panicum virgatum*)

Switchgrass is native to the United States and has been growing wild in the country’s grasslands for thousands of years. It is a hardy plant that grows well in a range of conditions thriving in upper midwest, central and southeastern U.S. In particular, switchgrass can grow well on soils that are too poor to support a healthy corn crop. It has received a great deal of attention recently as a potential bioenergy crop because it can produce good yields in poor soils with little water and fertilizer inputs.

Unlike corn, switchgrass has been grown and bred by farmers as a crop only recently, primarily as a forage crop for livestock. Farmers and scientists have had less time to figure out the best way to grow and harvest this crop under a range of field conditions, but researchers are working hard to improve techniques for switchgrass cultivation. Switchgrass yields per acre are lower than those of corn, but the costs of production are also lower. Unlike corn, switchgrass does not have the same strong, well-established markets for both food and fuel. Farmers growing switchgrass can expect modest profits in comparison to corn. However, it can be an appealing option to farmers because it can grow well on land not suitable for corn.

Switchgrass is a perennial plant that grows back year after year from its extensive root system. Therefore farmers can spend less time and money on replanting. Less time spent running tractors for tilling and planting also means less CO₂ released into the atmosphere. Switchgrass’s very deep root system helps take CO₂ out of the atmosphere and store it in the soil. Deep roots also prevent soil erosion, chemical runoff and help the crop tolerate droughts.

Like corn, switchgrass is grown as a monoculture. But because switchgrass is a native perennial, it provides more reliable habitat for birds, insects and other wildlife that have depended on the plant for thousands of years. Scattered weeds often grow in switchgrass fields, which also contributes to supporting biodiversity.



Summary of how switchgrass measures up:

Yield (medium) M L H	Profits (medium) M L H	Costs (low) M L H	Fertilizer Use (low) M L H	Pesticide Use (low) M L H
Erosion/Nutrient Runoff (low) M L H	Resilience (medium) M L H	Biodiversity (medium) M L H	CO₂ Emissions (low) M L H	Recreation Value (medium) M L H

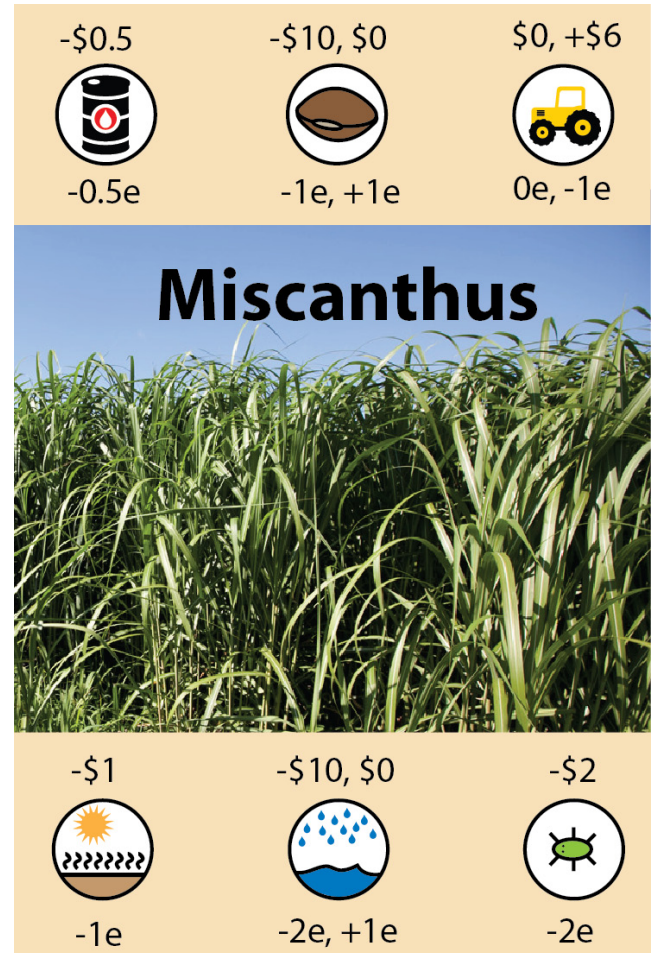
Miscanthus (*Miscanthus x giganteus*)

Miscanthus is a perennial grass native to Asia that recently has been introduced to Europe and North America for use as a bioenergy crop. Miscanthus is very productive with yields that often exceed those of corn and switchgrass. Like switchgrass, miscanthus can grow well in poor soils not suitable to crops like corn. Because miscanthus is so productive, even in poor soils, some scientists are concerned that the grass could spread aggressively outside of crop fields and become a problematic invasive species. Scientists and farmers are still experimenting to determine the best methods for growing miscanthus as a bioenergy crop.

Currently the initial planting cost for miscanthus is very high compared to other bioenergy crops. Farmers must purchase and plant miscanthus rhizomes (live root cuttings) directly in their fields, which is expensive and time consuming compared to spreading seeds. The money made in future years from harvesting large yields can help farmers to recover the initial costs. Also, because Miscanthus grows well with little water, fertilizer and pesticides, farmers can save money, cut CO_2 emissions from tractors, and reduce water pollution from chemical runoff from fields. Even so, miscanthus currently is not quite as profitable as corn.

Miscanthus is a perennial grass with deep roots that take CO_2 out of the atmosphere and store it in the soil. The deep root system also helps prevent soil erosion, chemical runoff and allows miscanthus to grow well in dry conditions.

Miscanthus is planted as a monoculture. The grass grows in such dense patches that few other plants can grow in the field with it. Because the grass is native to Asia, fewer birds, insects and other types of wildlife have adapted to using the plant as food and habitat. Overall, miscanthus provides little biodiversity for the farm and landscape.



Summary of how miscanthus measures up:

Yield (high) M L H	Profits (medium) M L H	Costs (medium) M L H	Fertilizer Use (low) M L H	Pesticide Use (low) M L H
Erosion/Nutrient Runoff (low) M L H	Resilience (medium) M L H	Biodiversity (low) M L H	CO₂ Emissions (low) M L H	Recreation Value (low) M L H

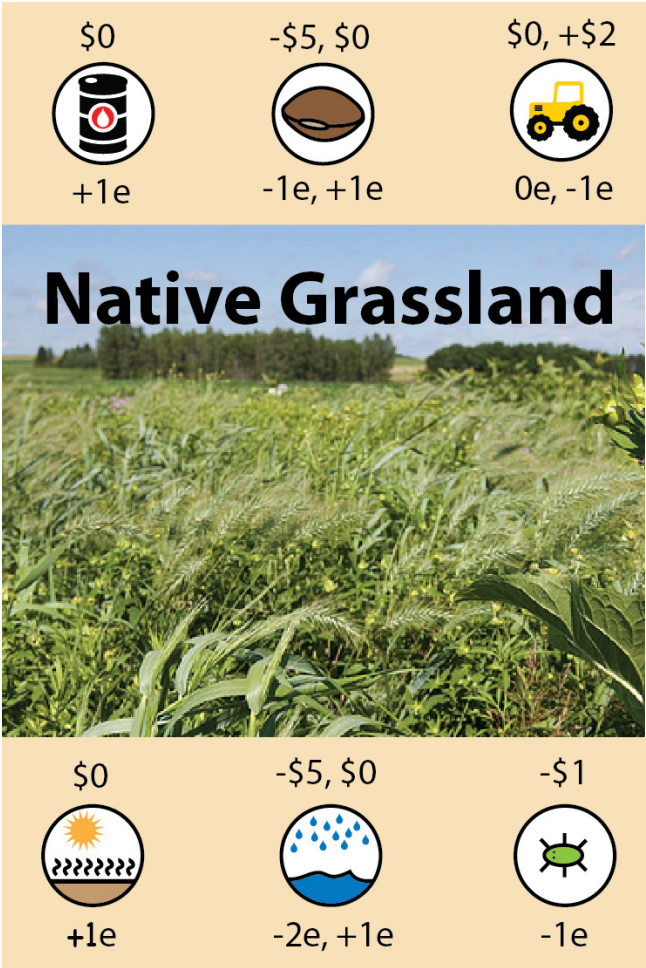
Native Grassland Planting (Various species)

The native grassland planting is a mixture of native perennial grasses and wildflowers. To some extent, this planting mimics the wild grasslands found in natural areas around the farm. In the upper Midwest, the native grassland would include many of the grasses and wildflowers found in the tallgrass prairie, including big bluestem, indian grass, switchgrass, compass plant and goldenrod. The native grassland grows well in poor soils otherwise not suited planting food crops. Once planted and established, this crop requires little or no maintenance. Native grassland provides excellent habitat for birds, insects, wildlife and other plants.

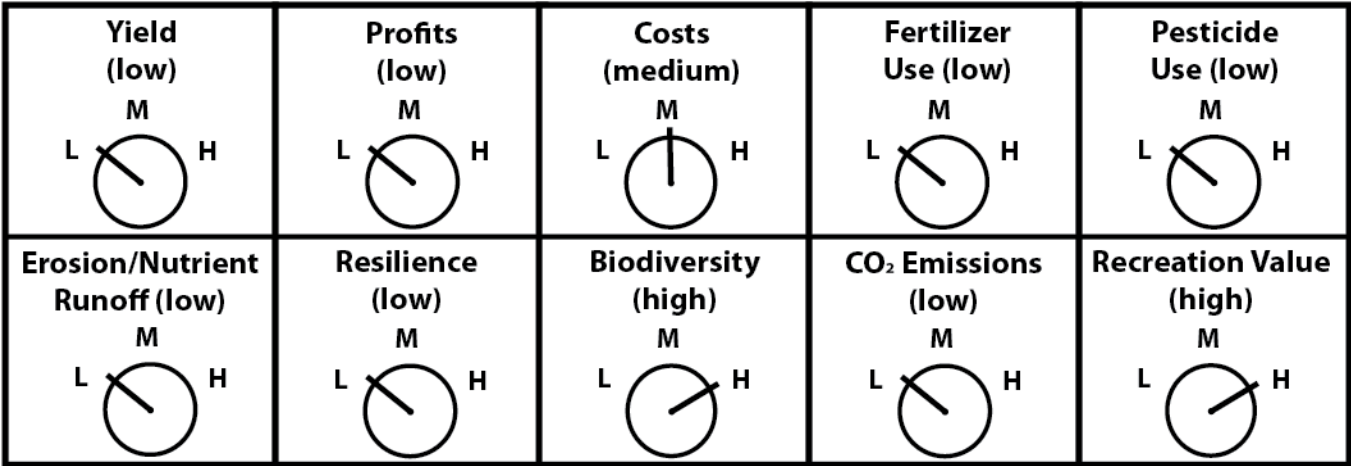
With the exception of switchgrass, none of the plants in the grassland mixture have a history for use as crops. Therefore farmers have less information or experience to guide farming this bioenergy crop. The plants have not yet been bred to have high yields and the initial cost of planting and establishing the grassland is high. For these reasons, the grassland is likely to be the least profitable cropping option in the near future.

On the other hand, the native grassland is a beneficial crop from an environmental perspective. The tough, perennial plants grow well without fertilizers, pesticides or irrigation. This helps save money and reduce CO₂-emissions from running tractors and eliminates water pollution. These native plants have very deep roots that are able store a large amounts of carbon in the soil.

Unlike the other crops, the native grassland is planted as a polyculture (many types of plants in the same field). This helps make the grassland resilient to environmental changes and disturbances such as droughts, floods and pest outbreaks. If any on type of plant has a bad year, others will likely grow in to take its place helping to keep the farmer's yield from falling. Native grassland supports the most biodiversity including a variety of plants, birds, insects and wildlife.



Summary of how native grassland measures up:



Glossary of Key Terms

Annual plant: a plant that lives for only one year. An annual crop, such as corn, must be replanted every year.

Biodiversity: the number of different types of plants, animals, birds, insects and other wildlife (i.e. the number of species) growing in an area.

Biofuel: fuels made from biomass such as plant material.

Biomass: organic materials such as plant matter or corn grain that can be used as fuel.

Carbon dioxide (CO₂): a greenhouse gas produced by burning fossil fuels. CO₂ is taken out of the atmosphere by plants as they grow through the process of photosynthesis.

Fertilizer: a chemical or natural substance added to the soil to increase fertility and help crops grow. Examples include nitrates, phosphates or manure.

Habitat: natural home of plants, animals or other organisms.

Monoculture: growing only one type of crop in a field.

Native plant: a plant growing in the same area where it evolved or has grown naturally in the wild for thousands or more years.

Perennial plant: a plant that lives for more than two years. A perennial crop, such as switchgrass, can re-grow from roots year after year.

Pesticides: substances used to destroy pests such as weeds and unwanted insects that harm crops.

Photosynthesis: the process whereby plants use the sun's energy to combine CO₂ and water into sugars that are then used by the plant as food to live and grow.

Polyculture: growing more than one type of crop in the same field.

Profits: the amount of money you make.

Resilience: the ability of a system such as an ecosystem to recover from a disturbance such as drought, floods and pest outbreaks.

Yield: the amount (i.e. weight or mass) of a crop produced in an area such as a 1-acre field. Sample measure: pounds/acre.

Game Instructions

Overview: Let's grow some energy!

In this game, players take on the role of bioenergy crop farmers working to make a decent living (earning income points) while protecting their environment (earning e-points). Players choose crops based upon their goals and values. In the course of the game, players move around the board through the seasons, managing their farms (planting, harvesting, etc) and responding to unexpected events such as droughts, pest outbreaks, and floods. Because each crop is affected differently by these events, either losing or gaining points, players must use their knowledge of crop characteristics to develop a successful strategy.

How to win: Play the game for 2-4 years (i.e. 2-4 trips around the board). The standard way to win is to earn the greatest number of combined income and e-points. Alternative versions are described below.

Materials included:

- Game Manual
- Gameboard
- Farm board
- Crop Cards
- Wild Cards
- Scoresheet
- Paper game pieces

Additional Materials needed:

- One die per gameboard

Optional Materials:

- Game pieces of your choice to replace printable paper pieces
- Poker chips or similar items to use in order visualize income points and e-points

How to play the game:

1. Basics: Up to 8 players can play on a game board. Four players is preferred to keep things moving. Play as individuals or in pairs.
2. Choosing Crops: Each player has a Farm Board with five fields to plant. Decide what crops you want to plant based upon your values and goals of the game. Use the information in the Guide to Bioenergy Crops to help choose your crops. On your score sheet, record the crop names and number of fields of each crop that you're choosing to plant. Pick up the appropriate number of crop cards.
3. Playing: Roll the die to move clockwise around the board.
4. Earning/Losing Points: For each square you land on, record all income points and e-points on your score sheets. See notes below for "Required task squares (blue)," "Catastrophe squares (yellow)," and Wild Card squares (black).
 - Note that you must stop at blue required task squares, and may not continue on until your next turn.
5. Completing a Round: One lap of the board equals 1 year or growing season. After reaching the "Winter Vacation" circle, wait for the other players to finish their trip through the year. Begin tallying your yearly and running point totals on your scoresheet as other players continue.

6. **Bowling:** For each turn that you wait for other players to finish the year, you may “bowl” for income points. To do so, roll the die once during each turn that you have while in the winter vacation circle. Even numbers earn you 1 income point, and odd numbers earn you 0.5 income points.
7. **Tracking Points:** After each year, total the number of e-points and income points you have collected for that year and record in the appropriate spots at the bottom of the score sheet.
8. **Re-planting:** After each trip around the board, players have the option to choose different crops. Remember that perennial crops do not earn income until the second year after planting!
9. **Completing the Game:** Play the game for 2-4 years depending on time. Tally your final total e-points and income points. The player with the most combined income and e-cards is considered the winner.

Required Task Squares: Stop! (Buying Chemicals, Planting, Harvest)

You must stop at every blue shaded square (i.e. buying chemicals, planting, and harvesting) and follow the instructions. You may not continue from that square until your next turn. For each of these mandatory tasks, refer to your crop cards for the specific costs in e-points and income points. See crop card guide below. Record costs and earnings on your score sheet.

**Note that some crops have different costs for year 1 and years 2-4. Farmers only earn harvest income after the first year for perennial crops such as switchgrass.

Catastrophe squares: Droughts, Floods, Pests!

When you land on one of these squares, refer to the information on your crop cards to determine what the cost or benefit is to your farm in income and e-points. Tally the results on your score sheet. Note that a catastrophe only affects the farm of the player who lands on that square.

Wildcards: Say what?

Pick up a wildcard when you land on one of these squares and follow the instructions. Some of wildcard events affect only the player who lands on the square; some affect all players. Feel free to make up your own wildcards once you are comfortable with the game!

Alternate versions and extensions:

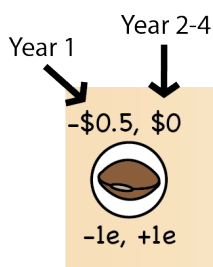
There is plenty of flexibility for players to choose their own goals for this game. Some examples include:

- Play to maximize only income, e-cards or a combined total
- Set a goal score (income and/or e-cards). The first player to this score wins.
- Set a minimum goal score for e-cards and/or income cards to be earned over four years. Everyone who meets the goal wins. A reasonable goal might be to earn at least 20 income points and net positive e-points.
- Fill out blank wild cards with new scenarios, such as crop subsidies, new prices, carbon taxes, or high fuel prices (increased planting costs) and see how that changes the game strategy and outcomes.
- Make up your own!

Guide to your crop cards:

Your crop cards have a wealth of information about how many income and e-points you spend or gain at chemical application, planting, harvest and catastrophes. The icons and numbers also indicate how your crop is affected by catastrophes such as droughts, floods and pest outbreaks. The guide below helps you interpret the information on your crop cards.

INTERPRETING CARDS



Example: If you land on a "Planting" space, refer to your crop card to determine how many Income (\$) pints or environment (e) points you gain or lose for year 1 or years 2-4.

For the example at left, you lose 1 environment point in year 1, but gain 1 e-point in years 2-4.

CARD KEY

- Chemical
- Planting
- Harvest
- Drought
- Flood
- Corn/Grass Pest

Summary Table of How Crops Measure up by Category: See Guide to Bioenergy Crops for more detailed information.

	Corn	Switchgrass	Miscanthus	Native Grassland
Yield	high	medium	high	low
Profits	high	medium	medium	low
Costs	high	low	medium	medium
Fertilizer Use	high	low	low	low
Pesticide Use	high	low	low	low
Erosion/Nutrient Runoff	high	low	low	low
Resilience	low	medium	medium	low
Biodiversity	low	medium	low	high
CO₂ Emissions	high	low	low	low
Recreation Value	low	medium	low	high

Farmer(s): _____ Date: _____

Date: _____

Crop:		Corn			
Number of Fields:		2			
Expense/Income Description		Income		e-Points	
Year 1	Chemicals	+	-	+	-
	Planting	-	1	-	1
	Harvest	8	-	-	1
	Sub-Total	8	3	0	4

Yearly Totals	Income	e-Points
Year 1	10	-8

$$2^*(0-4)$$
[illegible]

Running Total

[illegible]

Years 3-4

Farmer(s): _____ Date: _____

Crop:		Corn				Switchgrass				Native Grassland				Miscanthus				Farm-Wide			
Number of Fields:																		Income/Expenses			
Expense/Income		Income		e-Points		Income		e-Points		Income		e-Points		Income		e-Points		Income		e-Points	
Description		+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Chemicals																					
Planting																					
Harvest																					
Year 3																					
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