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EDUCATOR GUIDE

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Introduction

By 2050, Earth's human population is estimated to reach *9.7 billion* people. This increase means we will need to feed over two billion *more* people than we do today. Producing enough food so everyone on the planet has food security — access to sufficient, safe, and healthy food — is an urgent global challenge, and one that has no easy solutions.

We all depend on farmers and farming to produce the food we eat. But at the same time, modern agriculture is a major contributor to some of Earth's most intractable environmental problems: global climate change, depletion and pollution of fresh water resources, loss of biodiversity, and soil erosion and degradation. How can we produce enough food to meet the needs of our world's growing population without overwhelming our planet's environment? How can we farm sustainably — providing both food security and preserving farmlands and the natural world?

Top Crop: Farming for the Future is an online and mobile game that puts students right in the middle of figuring out solutions to this real-world challenge. Taking on the role of a farmer-scientist, students must decide how to create the most sustainable farm, one that produces abundant crops, and at the same time, alleviates environmental impact and preserves natural ecosystems. In figuring out how to tackle the problems that face their farm, students will problem-solve, experiment, collect and analyze data, use new, advanced technologies and techniques, manage resources, and make complex decisions. By playing *Top Crop*, students will gain important insights into the critical connections among science, technology, society, and the natural world.

This Educator's Guide provides the subject matter background and vocabulary needed to use this game with students in schools, in afterschool and informal settings, and at home. The guide also provides learning objectives, facilitator tips, discussion ideas, additional activities and content resources, and connections to national curriculum standards and principles.

Quick Start
www.natgeoed.org/topcrop

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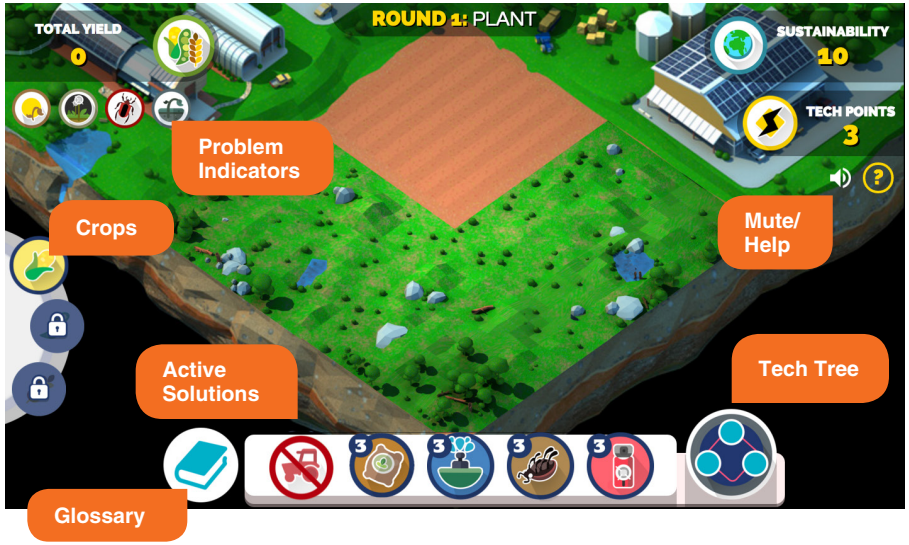
Game-Based Learning

Using interactive games to facilitate learning in educational settings has a number of recognized benefits. For most students, games are highly engaging and motivating. Games provide real-time feedback and built-in goals — such as “leveling up” or reaching a desired conclusion — that can motivate students to improve their problem-solving skills and build their content knowledge.

The use of portable technology like laptops and tablets in educational settings is a recent trend that is expected to grow, and a number of educational games, including the *Top Crop* game, can be played on both desktop computers and tablets. In fact, educational games that can be played on mobile devices like tablets benefit from the intuitive nature of these devices, which often makes it easier for students to learn and play these games. This flexibility allows for game-based learning in schools, in afterschool and informal settings, and at home.



Learning Objectives

Students will:

- Analyze information to identify problems and possible solutions
- Make informed and complex decisions that have no single right answer
- Apply a variety of technical and non-technical solutions to a problem
- Recognize the importance of sustainable agriculture in providing food safety for our world’s growing population
- Develop an understanding of how science and technology can contribute to solving critical problems facing society and the natural world

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Game Overview

Top Crop: Farming for the Future is an online and mobile farming simulation game that involves students in current and emerging scientific research, technologies, and techniques that promote sustainable farming. In *Top Crop*, the player takes on the role of a farmer-scientist. The overall goal of the game is to create the most sustainable farm, producing both abundant crops and protecting the natural environment.

The player is given four plots of farmland on which to grow up to three different food crops — wheat, corn, and soybeans. At the start of the game, only one plot is ready and available for planting. Other plots are unlocked as the game progresses. Game play cycles through four phases: Planting, Growing, Harvesting, and Scoring. The player's goal is to attain the largest possible crop yield over 10 rounds of gameplay, while simultaneously sustainably managing the farm's natural resources.

Have students read the instructions before they begin play.

The *Top Crop* Game Story

The Department of Agriculture wants to experiment with new technologies and methods in sustainable farming, and they've asked you to lead the charge! You've been given your own plot of farmland and, as long as you're able to show promising results, they'll provide new technology and equipment for you and your crew.

Your work will help our leaders figure out the best way to provide healthier food and sustainable farming techniques for the planet's growing population. It will take some experimentation, strategy, and trial and error, but if you succeed, the whole world will benefit from your discoveries.

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Planting crops may seem simple, but just like on any farm, a *Top Crop* farmer must deal with serious issues — weeds, insect pests, drought, and poor soil nutrition — that can affect crops and prevent a successful harvest. The decisions players make to solve the farm's problems will affect both the crop yield and the sustainability of the farm. It takes analysis, problem solving, and decision-making to succeed at *Top Crop*.

Scoring

At the end of each round of gameplay, players receive scores for their crop's Total Yield and their farm's Sustainability.

They are also awarded Tech Points based on the yield and sustainability of their farm. Players can use their Tech Points to unlock another plot of land; or purchase another crop to grow, or a new technology or farming technique.

Tech Points

Yield

Sustainability

The tech tree holds the tools students can purchase with tech points.

The Crops

Top Crop farmers can grow up to three different crops on their farms:

Corn

Soybeans

Wheat

These three crops were selected because they are widely grown globally, and are key ingredients in many of the foods we eat. They are also found in some non-food items. Corn, soybeans, and wheat are also grown under the same environmental conditions, often on the same farm — which adds to the realism of the problems and decision making in *Top Crop*.

The Tech Tree

Using their Tech Points, players can purchase a variety of tools and farming techniques from the Tech Tree to help them solve the problems on their farm. In each round, different tools and

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techniques become available. Students can read a description of each tool and technique and how its use will affect the farm. For example, reducing the chance of drought, preventing weed growth, or attracting wildlife that are beneficial to the farm.

However, some tools and techniques have a higher sustainability penalty attached to them. Players need to use these strategically, decide if the immediate benefit is worth the longer-term risk, and consider which of the available tools and techniques will keep this penalty low, and keep the farm producing crops sustainably well into the future.

The techniques and tools available in the Tech Tree are:

Crop Rotation: Farmers sometimes swap their crops. They plant different kinds of crops each season, a technique called crop rotation. This method adds nutrients and nitrogen — a chemical that helps plants grow — to the soil. Crop rotation also helps get rid of insects and diseases that can destroy crops.

Cover Crops: Certain plants, known as cover crops, have the natural ability to smother weeds, slow erosion, and ease damage from drought. Red clover, oats, and barley are all types of cover crops.

Drainage System: A drainage system can prevent your fields from getting waterlogged during heavy rains. Drainage pumps are an example of this type of system.

Irrigation: A watering technique called surface irrigation allows water to flow across a field on the surface of the soil. Depending on the crop type, the water is either flooded onto the field or run through plowed furrows between rows of plants.

Improved Irrigation: Some farms feature a network of pipes that run along the rows of crops. The pipes drip water onto the roots of the plants. This watering method is called drip irrigation.

Improved Irrigation 2: Farmers can use a technique called sprinkler irrigation to water their crops. This involves pumping water through pipes and spraying it onto the plants with sprinklers.

Pesticides: On some farms, pesky bugs are banished with microbial pesticides. These are pest-repellant concoctions that boast microbials — or super small life forms such as a fungus or bacteria — as the main ingredient.

Improved Pesticides: Biologists have figured out how to modify a plant's DNA — the genetic code that determines characteristics such as the plant's color and size. The scientists can add in a gene (a section of DNA) that allows the plant to produce a pest-repellant substance, also called a Plant- Incorporated-Protectant.

Improved Pesticides 2: Biomedical pesticides are natural substances that protect plants from pests. For instance, scented plant extracts can be used as

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biomedical pesticides. Farmers place the extracts in traps away from the actual crops. Insects are lured by the scent into the traps, where they become stuck — and unable to harm crops.

Herbicides: Herbicides are chemicals used to control growth of unwanted plants on your farm.

Improved Herbicides: Contact herbicides are used to control the growth of unwanted plants. This herbicide only affects parts of the plant it touches directly. So if a leafy plant is sprayed with the herbicide, it will wither but the roots will remain.

Improved Herbicides 2: Systemic herbicides are substances that control the growth of unwanted plants such as weeds. A plant sprayed with this herbicide first absorbs the substance through its leaves or stem. The substance then travels throughout the plant's insides, killing it completely.

Seed Treatment — Fungicide: Your seeds have been treated with a fungicide, a substance that shields plants from harmful fungi. Treating the plant so early on may prevent the need to spray it later in its growth cycle.

No-till Farming: No-till farming is a sustainable agricultural technique that doesn't involve disturbing the ground through tillage — the digging or stirring of soil.

Conventional Plowing: Conventional plowing involves using equipment to turn over the upper layer of the soil. This buries weeds and the remains of previous crops and warms the soil for planting.

Strip Tillage: Strip-till is a farming system that uses minimum tillage, or the digging or stirring of soil. With this method, digging only occurs in the portions of soil that will contain rows of plant seeds.

Fertilizer: By using fertilizers, you can grow more plants for higher yields. However, rain can wash fertilizer out of the fields and into rivers and lakes, disturbing the environment.

Improved Fertilizer: Macronutrient fertilizer packs in as many nutrients for plants as possible, such as nitrogen, phosphorus, and potassium.

Improved Fertilizer 2: Micronutrient fertilizer is a fertilizer that contains essential micronutrients (such as boron, chlorine, or iron) but not a significant amount of macronutrients such as nitrogen, phosphorus, or calcium.

Crop Scouts: High-tech tools such as hand-held computers and GPS tracking systems make it easier for farm workers to monitor the land. Using the technology to record locations affected by harmful pests or diseases allows the workers to target problem areas quickly and efficiently. For instance, by recording the exact location of an insect infestation, farmers can spray that specific spot rather than blanketing a field with pesticides.

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Drones: Unmanned flying machines called drones will buzz around your fields, searching for problem areas. Seeing a crop from above can reveal irrigation problems or pest infestations that may not be obvious on the ground.

Infrared Satellite Images: Farmers can monitor the health of their crops with infrared satellite images, which detect levels of chemicals in plants invisible to the naked eye. For instance, healthy plants filled with chloroform (a chemical plants need to thrive) appear as a different color in infrared images than plants that lack this important ingredient.

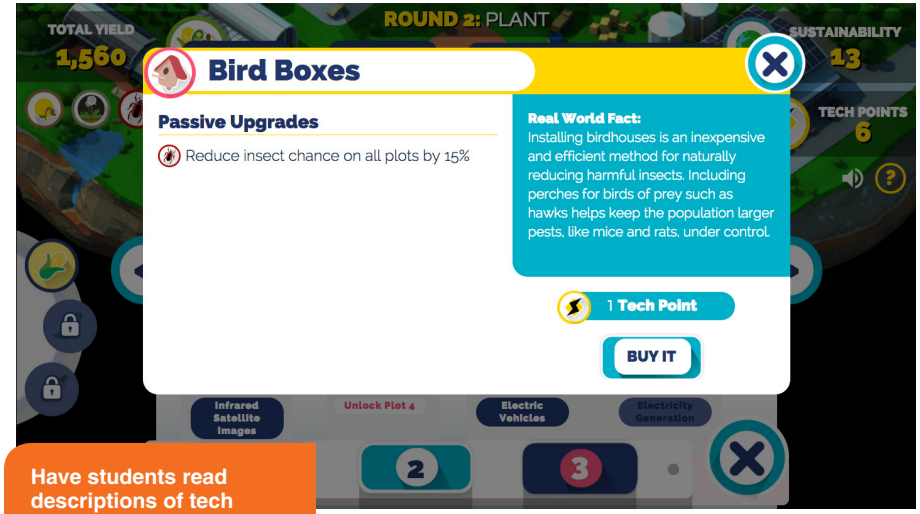
Bird Boxes: Installing birdhouses is an inexpensive and efficient method for naturally reducing harmful insects. Including perches for birds of prey such as hawks helps keep the population of larger pests, like mice and rats, under control.

GPS Precision Tools: GPS technology provides measurements for things such as water levels and nitrogen in the soil. This makes planting seeds as well as distributing water, fertilizer, and pesticides more efficient.

Electric Vehicles: Using an electric vehicle can help reduce your impact on the environment.

Wildlife Refuge: Preserving the land surrounding your farm gives animals in the area a place to thrive. And if the animals have their own living space and food supply, they may have less reason to visit your farm to feed on your crops.

Application Treatment — Insecticides: Improved machinery allows insecticides to be added to the area immediately surrounding seeds as they are planted. This lets farmers protect crops from insects in the earliest stages of their growth, while reducing the quantity of chemicals used. This measured approach reduces unneeded treatments.



Have students read descriptions of tech tools to understand their effect on crop yield and sustainability.

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Electricity Generation: Install windmills, waterwheels, or solar panels to generate power for your electric farm equipment. This will reduce your impact on the environment as well as energy costs.

Using the Game in Different Settings

Afterschool Programs

Because learning opportunities are embedded in the game, students can play the game independently, either individually or in small groups. Facilitators can check in with students and use questions to encourage thoughtful play. For a richer experience, facilitators can use the discussion questions and related resources and activities described in this guide to engage small or large groups of students. The game's built-in scoring can be used to encourage friendly competition among groups of players and can add another element of fun and challenge to the game in this setting.

Classrooms

Teachers can incorporate the *Top Crop* game into a variety of science, social studies, and geography curriculum units. Additionally, the game can be used as a hook to develop multidisciplinary lessons that bring together several different curriculum areas. Examples of curriculum topics where *Top Crop* can be used include:

- Global climate change
- Ecology and the environment
- Food and nutrition
- Science, technology, society, and the natural world
- Human population growth and the environment
- Human impact on our planet
- Cultural behavior and its impact on the environment

A major goal of *Top Crop* is to engage students in problem solving and informed decision-making. Asking questions and guiding discussions before, during, and after gameplay can reinforce critical thinking, problem solving, and decision-making.

Teachers can also take advantage of the level of engagement students generally experience with gaming to involve students in additional discussion and activities. Issues raised in *Top Crop* can be catalysts for further classroom discussion and debate; or provide jumping off points for student projects that involve research and written or oral presentations. The Extending the Learning section provides ideas and resources for further activities.

Science Centers

Science centers can make the *Top Crop* game available to visitors through computer stations on the science center floor. Play can be supported in this setting through display text and related exhibits. Science centers can also use the game as part of informal educational programs for students and families.

At Home

Students can play the *Top Crop* game independently at home. Parents or caregivers can play the role of facilitator, using questions, and guiding discussions to encourage more thoughtful problem solving and decision-making.

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Role of the Facilitator

Managing Game Play

Students play the game at their own pace. Therefore, students who begin the game at the same time may complete the gameplay rounds at different times. Facilitators should walk around the room and monitor student engagement in thoughtful analysis and problem solving. Asking questions can target or expand student thinking on possible ways to solve the problems their farm is facing. There is no one right solution to the problems facing *Top Crop* farms. Designed to encourage experimentation and solutions that will result in both a high crop yield and high sustainability score, *Top Crop* is highly re-playable.

Know Your Sources

There is a wealth of information available at our fingertips, and sometimes it is difficult to sort through it all. Topics surrounding farming, agriculture, food, food security, global climate change, and the environment are particularly popular, and information can be contradictory. Here are three tips to help make sure the information you use on these topics is valid:

1. Look at the source. Who published the information? If it is an individual, what are his or her qualifications? If it is an organization, what is their mission or goal? Do they have a bias?
2. Look at the date. How old is this information? Is more current information available?
3. Look for more sources. Are there other sources to confirm this information? Look for government or university studies to back up your sources.

Facilitating Discussion and Engagement with the Content

The *Top Crop* game offers a variety of learning opportunities in the context of game play.

Facilitators can encourage the deepest level of engagement with the content by starting the session with an introductory discussion that sets up the context of the game, provides background information, and handles any misconceptions students may have. Sample discussion questions are provided in this guide. During gameplay, facilitators can challenge students to read and ask questions about all the available information provided in the game. Facilitators can also encourage more thoughtful decision-making by posing questions for students to discuss and explore as they play the game.

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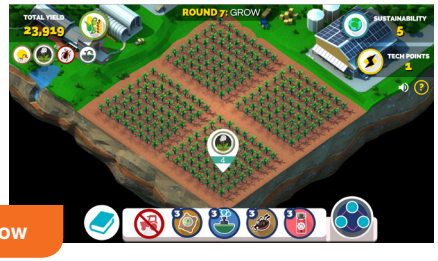
Handling Students' Misconceptions

Students — especially those from urban and suburban communities — may have little or no knowledge about modern farming or where the food they eat actually comes from. They may not be aware of the importance of agriculture in our world. Many students will base their understanding of agriculture on depictions of farms and farming in books, media, television, films, and games. Many students may not understand that farming today takes place in cities as well as rural areas; and that urban farming is critically important in providing food security to many communities worldwide. The *Top Crop* game also emphasizes the critical role of science and technology in agriculture, another concept that may be new to students.

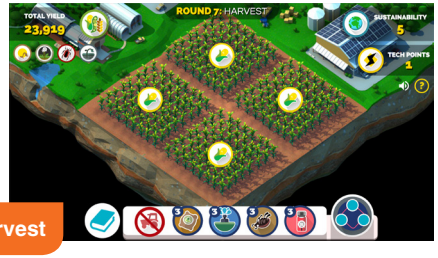
Beyond general misconceptions about modern agriculture, topics such as organic agriculture, the genetic modification of seeds, and urban agriculture remain objects of heated debates. It is important to understand that these debates can be highly opinionated or polarizing, and careful selection of resources is advised.

The Background Information section will assist facilitators in guiding students through the content and issues presented in the game. The Extending the Learning section lists additional resources and activities that can be used with the *Top Crop* game.

1. Plant



2. Grow



3. Harvest

Background Information

Overview of Modern Farming

Farming exists in almost every region of the globe from very cold areas such as Iceland and Greenland, to tropical rainforests and dry desert areas. Farms and farming methods vary widely from small subsistence farms, to large-scale mechanized agriculture, to high tech hydroponics and greenhouses. Although we often think of farms in rural settings, urban agriculture is widespread and expanding in cities around the world. Each of these different places and ways of farming has specific challenges and constraints that affect the type and amount of crops produced. Different farming methods also have very different impacts on the natural environment, including global climate change.

Botanists estimate that there are over 400,000 plant species. But the majority of the world's daily nutrition comes from only

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15 different crops. These crops account for approximately 90% of the global caloric intake, excluding meat, according to the Food and Agriculture Organization. Corn, rice, and wheat are the most widely grown crops in the world. Other important staple food crops are potatoes, cassava, soybeans, barley, sweet potatoes, sorghum, and yams.

Science and technology have always been integral to farming. Research into new technologies and new methods of farming are critical to solving the problems of food security, and the need to create sustainable farming.

Refer students to the appropriate key vocabulary terms.

Agriculture is a complex and dynamic endeavor. Around the world, farmers are continually adapting and responding to:

- Community food preferences and the need for food security
- Local and global markets for food crops
- Global climate change
- The availability of new technologies and techniques emerging from agricultural research
- Increased awareness of the need to farm sustainably and preserve farmlands and the natural world for future generations

Local and Global Farming Connections

A farmer's decision to grow certain crops involves a wide array of factors. The geographic location of the farm and its environment, soil types and nutrition, growing season temperatures, and timing and amount of water availability, affect both the type of crops that can be grown and when these crops can be grown. For example, in areas of cold winter temperatures, farmers typically plant, grow, and harvest crops on a spring-summer-fall schedule. In the tropics, crops can be grown all year round in some areas, or farming is limited by the cycle of rainy or dry seasons.

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The use of technologies, such as irrigation, greenhouses, and hydroponics, alters the geographic and environmental constraints faced by farmers. Irrigation has expanded farming to dry lands and deserts that would not naturally support it. Greenhouses provide year-round food production in cold climates. Hydroponic technologies allow food crops to be grown without soil. Continued research has the potential to considerably impact how and where we can grow food.

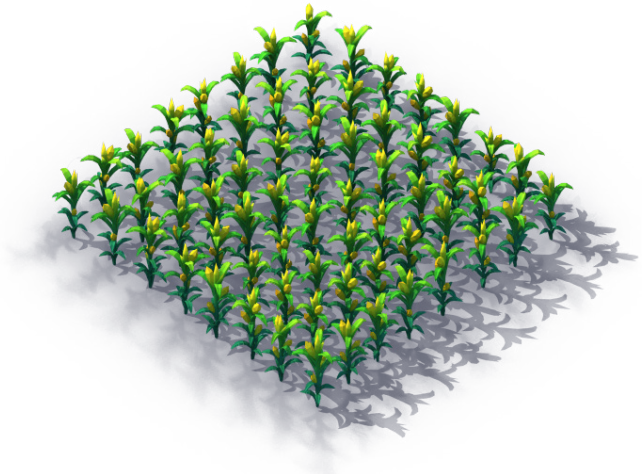
Local food needs and preferences are also important considerations for many farmers. Different communities around the world have very different food needs and value different food crops. In addition to considerations of the food needs of their families and community, farmers also consider the prices they can get for certain crops. A crop that is worth more means more income to the farming family.

Examples from urban agriculture — farming in cities — demonstrate how local food security and food preferences can shape the decisions made by individual farmers about what crops to plant. In developing countries, widespread, small-scale urban farms grow everything from vegetables and fruit to livestock, poultry, and fish. These very small farms provide the urban farming family with income, and are critical sources of food for the local community.

In developed countries, urban agriculture is expanding dramatically because of the consumer preference for fresh foods that are grown locally, with less environmental impact. In most large cities today there are numerous farms that range from small plots of land to high tech greenhouses that produce crops that are sold locally to stores, restaurants, and consumers.

Agriculture is global, connecting countries around the world. Countries depend on each other for the food they need. For example, cassava is an important food staple for many communities, particularly in tropical regions. In many tropical areas, cassava is both grown and eaten locally. But cassava is also a major export crop for farmers in Nigeria, Thailand, Costa Rica, Vietnam, and Indonesia. Cassava from farms in these countries is sold to consumers around the world.

Agriculture is dynamic. Demand for certain food crops in one part of the world can change farming practices in other parts of the globe. Take the case of soybeans; soybeans are grown for both human consumption,



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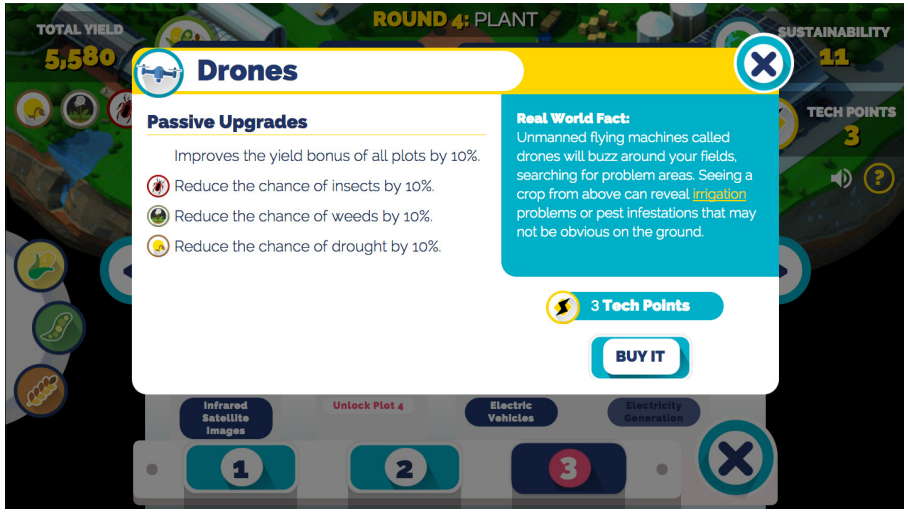
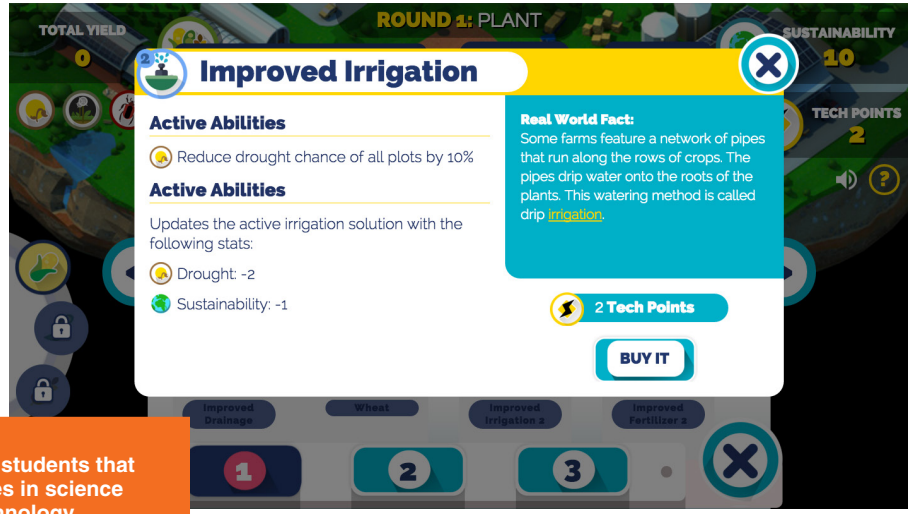
and for processing into animal feed. China has a tremendous need for protein-rich foods, such as meat, fish, and eggs. But China does not produce enough soybeans to meet the needs of its livestock, poultry, and fish farms. Huge quantities of soybeans are imported by China then used, in the form of animal feed, by farmers to raise animals for food. In response to this new market for soybeans, many farmers around the world changed the crops they grow. For example, in the United States, farmers increased their soybean production and now raise less wheat. Farmers in Brazil turned areas of forest and savannah into soybean farms.





Global Climate Change and Agriculture – Mitigation and Adaption

Is farming always ecologically friendly? Unfortunately farming is not very green. Agriculture is one of the major contributors to global climate change. Common farming practices release three of the five major greenhouse gases that cause climate change — carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Carbon dioxide is released when forests are cut down or land is burned to create croplands. The use of fertilizers also releases nitrous oxide.

Remind students that advances in science and technology continue to influence sustainable agriculture.

Agriculture is the major source of methane, which is released through the intensive farming of animals for food, and by the artificial wetlands created when rice is grown. Even the common practices of conventional plowing or mechanical tilling,

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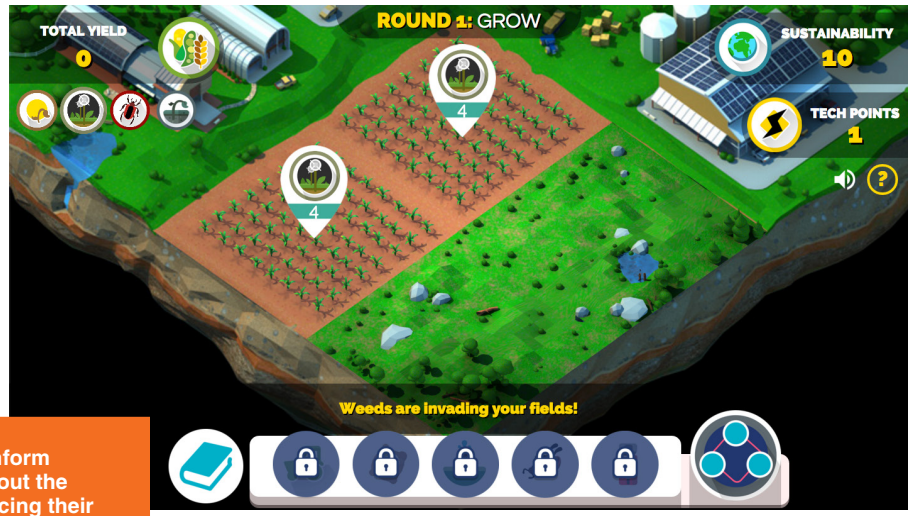
which are used by farmers to prepare fields for planting, release significant amounts of nitrous oxide by burying crop residues and weeds under the soil.

Many individual farmers recognize these problems and are working to mitigate their role in global climate change. They are reducing their farm's greenhouse gas emissions by modifying the way they farm. For example, fields can be planted without tilling and disturbing the soil. Using a no-till technique substantially reduces nitrous oxide emissions, and has the benefits of preventing soil erosion and conserving soil moisture. Precision use of fertilizer and rotating certain crops, such as corn and soybeans, also reduces nitrous oxide emissions.

Farmers in many regions are already seeing the effects of global climate change and these effects are mostly negative. Global climate change will affect all aspects of farming: where we can farm; what crops can be grown; crop yields; the impact of agricultural pests and diseases; and water availability. Farmers need to find ways to adapt to a range of new conditions — increased temperatures, changes in rainfall patterns, flooding, droughts, more extreme weather events, sea level rise, and increased atmospheric carbon dioxide. For example, sea level rise is bringing salt water further inland. This increased salinity is causing problems for coastal rice growers in Vietnam and other Asian countries.

Rising global temperatures can expand farming to areas that today are not suitable for agriculture; it could also expand where certain crops can be grown. However, many food crops will do very poorly as temperatures rise. As a result, farmers will need to change what crops they grow.

With warming temperatures agricultural pests can expand their ranges and cause damage to crops grown in areas that were previously unaffected by these pests. Plant diseases may also thrive in warmer conditions. Changes in rainfall patterns affect the timing, frequency, and amount of rain. Some farming regions will see more, and longer, periods of drought; other areas will receive



The alerts inform students about the problems facing their farm.

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excessive rainfall or rain at the wrong times during the growing season.

Global climate change seriously impacts our ability to grow the food we need to provide food security. Current and future farmers need to reduce greenhouse gases emissions and adapt to the changing conditions caused by global climate change.

Science, Technology, and Farming

To feed nine billion people in the year 2050 we need to increase the amount of crops we grow by between 70 and 100 percent. At the same time, we must decrease agriculture's impact on global climate change and the natural world.

From the very beginning of farming, science and technology have always been essential to agriculture. Farmers have used irrigation for thousands of years to bring water to thirsty crops. For millennia, people bred crop plants to have specific beneficial traits and increased yields, long before there was an understanding of genetics.

Modern genetics and other critical scientific and technological developments led to the Green Revolution of the last century, which transformed agriculture in many countries and had a profound effect on the global food supply. For example, new varieties of wheat and rice were developed that produced more grain per acre than older varieties. This breakthrough alone helped alleviate hunger for billions of people.

More recently, plant geneticists have developed genetically modified (GM) seeds. Starting in the 1990s, farmers began growing crops from GM seeds that were more drought-tolerant and resistant to agricultural pests and diseases. Such crops need less water and pesticides. In the United States as well as in Asia and Latin America, GM crops are widely grown. In many countries in Europe and Africa, GM crops have not been accepted because of environmental concerns, although some countries are now beginning to plant GM crops.

Changes in crop plants are not the only way in which science and technology contribute to agriculture. Working in collaboration, farmers, researchers at universities, government agencies, and corporations have developed new technologies and adapted older methods to make agriculture both more productive and sustainable. The *Top Crop* game introduces some of these new technologies and methods including:

- Improved irrigation technologies that use less water
- No-till cultivation
- GPS monitoring systems
- Infrared satellite systems to monitor plant health

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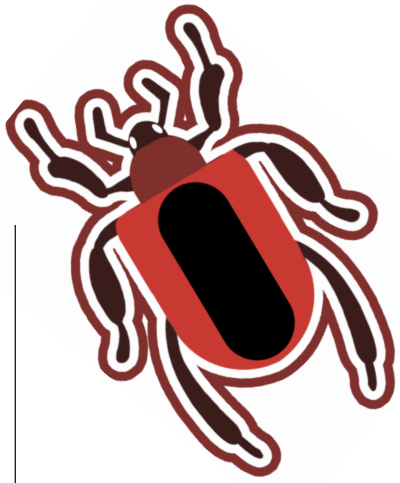
Discussion Questions

Questioning strategies applied during game play, as well as discussion and reflection questions following game play sessions, can greatly enhance student engagement and learning.



DURING PLAY

- What problems (drought, weeds, insects, and soil nutrient depletion) are facing your farm?
- Which problem(s) are the most important ones for you to solve on your farm right now? Why?
- What are your available options?
- What are some pros and cons of each choice?
- How will your choice affect the yield of your crop?
- What are some environmental and sustainability consequences of this choice?
- What are some alternatives to your choice?

AFTER PLAY

- What is your Total Yield score? What is the Sustainability score of your farm?
- Will your farm be able to contribute to the world's food safety? Do you think your farm is sustainable into the future?
- What were your most important decisions? How did they affect your farm?
- Do you feel you successfully solved your farm's problems during this session? Why or why not?
- What would you most like to improve on your farm? Why?
- Did any of the technologies that you used in the game today surprise you? Why?

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Activities

BEFORE INITIAL PLAY

Activate students' prior knowledge, and unearth misconceptions, by asking them to share what they know about food, farms, and agriculture. Sample questions to prompt discussion include:

- Where does the food we eat really come from?
- Where do you find farms? Can a farm be in a city?
- Has anyone ever visited a farm? What was that experience like?
- Does anyone know of any farms in our community? What crops do they grow?

Have students research the food crops grown in Top Crop — corn, soybeans, and wheat. Keeping food sensitivities in mind, have students read lists of ingredients on a variety of foods (and non-foods) to see where corn, wheat, and soybeans are used as ingredients. What was the most common crop used as an ingredient in the foods they looked at? In non-foods? What was the most unusual use of corn, soybeans, and wheat as an ingredient?

Have students set up their "lab notebooks" to use during the gameplay. Just like scientists (and most farmers) do in real life, as they play *Top Crop*, students can document what crops they grew, the problems they encountered, the pros and cons of the tools and techniques available to solve the problem, what decision they made and why, and what happened. Note taking will reinforce the problem solving and decision-making in game; and provide opportunities for students to discuss their results and share strategies to improve both crop yield and sustainability.

Use the information in the Game Overview section of this guide to introduce the game.

DURING PLAY

Provide additional support to students on the use of different technologies in agriculture. Watch *Precision in the Fields* (https://www.nationalgeographic.org/video/precision-in-the-fields/), a short animated explanation of the technologies used by farmers to increase yield and reduce production costs. Technologies discussed in the animation include drones, remote sensing, mobile weather apps, variable rate dispensation of fertilizers and pesticides, and soil maps, among others. Or have students read the article "Precision Farming" (http://earthobservatory.nasa.gov/Features/PrecisionFarming/).

Hold mini-strategy sessions on the problems they are

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facing on their farms and the decisions they need to make.

Some strategies to help students with *Top Crop* decision-making include:

- Identifying the problem(s) with their farm
- Understanding their options. What tools and techniques are available to them? How will each improve crop yield and/or sustainability?
- Identifying the benefits and drawbacks of each of their choices
- Encourage students to write down their choices and why they made these choices in their notebooks

AFTER PLAY

After each session of game play, discuss the session as a whole group. Use the sample discussion questions as a starting point.

At the end of the game, did students feel they met the challenges of increasing both crop yield and sustainability? Why or why not? What strategies did they find most successful?

Extending the Learning

Extending the learning in the *Top Crop* game can take a number of directions. Students can further explore the impact of agriculture on global climate change, urban agriculture, food and global food security, and agriculture and the natural environment, including pollution, soils, and water resources. Educators can also bring agriculture and farming directly into their classrooms or other learning environments. The National Geographic Education website has a wide variety of activities, lesson plans, interactives, videos, articles, profiles of researchers, and other content resources to extend the learning of the *Top Crop* game (see Appendix).

Decision-Making Activities

The issues raised in *Top Crop* create excellent opportunities for additional decision-making activities that integrate science and other curriculum content. In particular, these decision-making activities can support a number of the Next Generation Science Standards: Science and Engineering Practices (see Sidebar).

Relevant NGSS Science and Engineering Practices

- Asking questions (for science) and defining problems (for engineering)
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

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Decision-making activities involve students in asking questions, defining issues, finding and evaluating evidence, constructing an argument backed by evidence, and communicating. Some ideas for decision-making activities include:

- **Pick a viewpoint and find evidence to support it.** Many people believe that organic farming is the best solution to creating more sustainable agriculture; others don't think that organic farming is sustainable or can provide the food security the world's growing population needs.

- **Pick a viewpoint and find evidence to support it.** Genetically modified (GM) crops are increasingly grown around the world. Many people believe they are an important way of increasing both crop yield and improving sustainability. Others think that the potential risks of GM crops outweigh the possible benefits.

- **Design a solution to increase global food security** and improve the sustainability of agriculture. Why do you think your idea will be effective in solving these major problems? Explain why. Provide at least three supporting reasons based on evidence or facts.

The Future of Farming: Promising Innovations

This a critical time for farming, and but also a very exciting one. Scientists, including several National Geographic Explorers, are doing research that could change farming as we know it. Their stories demonstrate some of the promising innovations that might be the future of farming. Have students read their stories. What are the pros and cons of each innovation in terms of growing more food and sustainability?

Vertical Farming
Caleb Harper, a researcher at MIT's Media Lab, and a National Geographic Emerging Explorer, is an Urban Agriculturist. Caleb's goal is to design innovative technologies that will bring farming into cities. Urban agriculture is already important, but Caleb's ideas take it well beyond anything that exists today. Adapting aeroponics, a form of irrigation first developed by NASA for the Mir space station, Caleb envisions vertical urban farms, many stories tall. All environmental conditions, from light to nutrients, would be closely monitored and controlled by computers and optimized for plant growth. Students can read more about Caleb's work at http://www.nationalgeographic.com/explorers/bios/2015/caleb-harper/.

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Perennial Crop Plants
Jerry Glover is an Agroecologist and Soil Scientist and a National Geographic Emerging Explorer. Most crop plants are annual plants, which require replanting from seeds every year. These annual plants typically have shallow roots and require more water and fertilizers than perennial plants. Perennial plants have other beneficial traits that would make them ideal crop plants. They do not need replanting, have deep roots that hold soils, and hinder weed growth. Jerry is collaborating with other researchers to breed perennial varieties of the common crop plants, wheat, rice, and sorghum. Students can read more about Jerry's work at http://education.nationalgeographic.com/news/real-world-geography-dr-jerry-glover/.

Solar Irrigation for Subsistence Farmers
Jennifer Burney is an Environmental Scientist and a National Geographic Emerging Explorer who works with small-scale subsistence farmers in sub-Saharan Africa. Living on incomes of about a dollar a day, these very poor farmers rely on rainfall to provide water for their crops. No rain means hunger for their families and their communities. Jennifer is working with the NGO Solar Electric Light Fund to bring solar-powered drip irrigation systems to these farms. Combined with solar-powered water pumps, these systems require no fuel, are simple to use, provide water to both crops and the community. Students can read more about Jennifer's work at http://www.nationalgeographic.com/explorers/bios/jennifer-burney/.

Have students compare final score cards and discuss results.

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Appendix

Vocabulary

Agriculture: The art and science of cultivating the land for growing crops or raising livestock

Drought: A period of greatly reduced precipitation

Fertilizer: Nutrient-rich chemical substance (natural or manmade) applied to soil to encourage plant growth

Food Security: The access a person, family, or community has to healthy foods

Global Positioning System (GPS): A system of satellites and receiving devices used to determine the location of something on Earth

Herbicide: Natural or manufactured substance used to kill plants

Industrial Agriculture: Modern farming methods that include mechanical, chemical, engineering, and technological methods on a large scale

Irrigation: Watering land, usually for agriculture, by artificial means

Nutrient: The substance an organism needs for energy, growth, and life; nitrogen, phosphorus, and potassium are particularly important nutrients needed for healthy plants

Pesticide: A natural or manufactured substance used to kill organisms that threaten agriculture; types of pesticides include fungicides (which kill harmful fungi), insecticides (which kill harmful insects), herbicides (which kill harmful plants), and rodenticides (which kill harmful rodents)

Runoff: Water from precipitation that flows from land into streams and is not absorbed. Runoff from a farm or industrial factory often contains natural or artificial chemicals

Soil Health: The ability of soil to host an ecosystem (or a community of living things) that sustains plants, animals, and humans

Sustainability: Use of resources in such a manner that they will never be exhausted

Sustainability (Alternate Definition): Use and management of resources to continually support human and natural systems and reduce impact on the environment

Sustainable Agriculture: Processes for growing crops and raising livestock that makes the most efficient use of resources; sustainable agriculture aims to cultivate the land so it may be used by future generations

Till: To prepare the land for the planting and cultivation of crops. Intensive soil tillage may increase soil erosion, nutrient runoff, and the release of greenhouse gases. Conservation tillage techniques such as no-till or strip-till can reduce those effects and help retain moisture

Urban Agriculture: The process of growing, harvesting, processing, and distributing food in a city or town

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Connections to National Standards and Principles

Top Crop and the Extending the Learning activities can be used as part of curriculum units in support of the following National Standards and Principles:

Next Generation Science Standards

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

MS-LS2-1
Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4
Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5
Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3 Earth and Human Activity

MS-ESS3-3
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Common Core State Standards: ELA/Literacy

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

WHST.6-8.7
Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

WHST.6-8.1
Write arguments focused on discipline content.

WHST.6-8.7
Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related,

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focused questions that allow for multiple avenues of exploration.

WHST.6-8.8
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

WHST.6-8.9
Draw evidence from informational texts to support analysis, reflection, and research.

21st Century Skills

- Problem Solving
- Critical Thinking
- Collaboration
- Communication

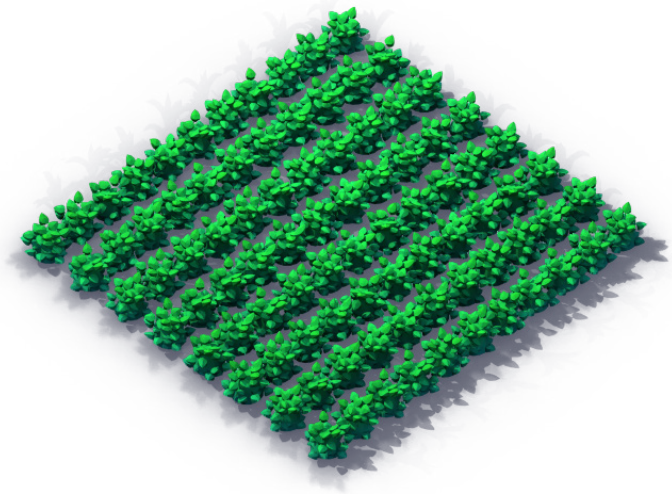
National Educational Technology Standards for Students (NETS*S)

Standard 2: Communication and Collaboration

Standard 4: Critical Thinking, Problem Solving, and Decision Making

Standard 6: Technology Operations and Concepts

National Geography Standards
Standard 14: How human actions modify the physical environment



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National Geographic Resources on Agriculture and Related Issues

Lessons and Background Information on Agriculture

Collection about Agriculture
Collection of lesson plans, interactives, articles, and photos on agriculture from National Geographic Education. http://education.nationalgeographic.com/topics/agriculture/

Agriculture
A detailed description of the history of agriculture with a discussion of more recent technologies such as aquaponics and genetically modified seeds. http://education.nationalgeographic.com/encyclopedia/agriculture/

Bringing Agriculture to the Classroom

Roots of Sustainability
This article discusses alternative and sustainable methods of farming, such as CSAs, becoming a "locavore," and urban agriculture. It describes the impact of our food choices on our landscapes and, more broadly, on global climate change. http://education.nationalgeographic.com/news/Roots-of-sustainability/

Green Scene
This article explains how St. Phillips Academy in Newark, NJ is working to incorporate urban agriculture into its educational model. The EcoSPACES program is designed to give students a better understanding of sustainability through direct experience with growing their own food on the school's rooftop garden and experimenting with the "indoor agricultural machine." http://education.nationalgeographic.com/education/news/green-scene/?ar_a=1

Food for the City
A short video that explains the growth of farmers' markets and urban agriculture in the past decade. http://education.nationalgeographic.com/education/video/food-for-the-city/?ar_a=1

Cultivating Life in the Sonoran Desert
An article showing how educators are using small-scale organic farming and new agricultural methods like aquaponics to provide students with outdoor learning experiences and highlighting links between sustainable practices and food security. http://education.nationalgeographic.com/education/news/cultivating-life-sonoran-desert/?ar_a=1

New Tools and Technologies in Agriculture

A Natural Solution
A short video about biopesticides. These pesticides, derived from natural combatants like plants, animals, and bacteria, are a growing segment of the pesticide market. As more consumers demand safer foods made with fewer harsh chemicals, the demand for these biopesticides grows. http://education.nationalgeographic.com/education/video/a-natural-solution/?ar_a=1

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Food and Global Food Security

What the World Eats
An interactive that shows the differences in diet between various countries. http://education.nationalgeographic.com/education/media/dietary-consumption-around-world/?ar_a=1

Food Staples
A detailed description of the various food staples used around the world, an explanation of what food staples are, and how they contribute to a community's diet. There is also discussion of "food appropriation," in which staples in one part of the world become popular in another, driving prices up (i.e. quinoa from the Andean countries becoming a popular food in the U.S.). http://education.nationalgeographic.com/education/encyclopedia/food-staple/?ar_a=1

Staple Food Crops of the World
This GeoTour in the Mapmaker Interactive allows students to see where certain food staple crops are grown and consumed throughout the world. http://education.nationalgeographic.com/maps/wbt-staple-food-crops-world/

The Paradox of Undernourishment
This article discusses inequalities in food production and food access, providing a map of the world's most undernourished countries. http://education.nationalgeographic.com/education/news/paradox-undernourishment/?ar_a=1

Sustainable America: All About Food
A set of infographics from Sustainable America, a non-profit organization that seeks to educate and empower more Americans to take steps towards sustainable living. http://education.nationalgeographic.com/education/media/sustainable-america-all-about-food/?ar_a=1

Planet Food Interactive and Educator's Guide
The Planet Food Interactive gives students the opportunity to understand where their food comes from, and to understand the economic and environmental geographies that underlie our food choices. http://education.nationalgeographic.com/education/media/planet-food/?ar_a=1

Food Crops in the Americas
This activity challenges students to map land use, land cover, and agriculture in the Americas, pushing them to draw conclusions about the relationship between an environment and the crops that grow there. http://education.nationalgeographic.com/education/activity/food-crops-americas/?ar_a=1

Saving Seeds
An article on global seed banks, special facilities used to preserve seeds of threatened plant species that have been pushed out by mono-cropping. A great resource to alert students to the tremendous genetic diversity of crops on Earth. http://education.nationalgeographic.com/education/news/saving-seeds/?ar_a=1

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For Further Exploration

General

American Farm Bureau Foundation for Agriculture
http://www.agfoundation.org/resources/addressing-misconceptions

The United Nations: Food Security and Sustainable Agriculture
http://www.un.org/en/sustainablefuture/food.asp

The United States Department of Agriculture
http://www.usda.gov/wps/portal/usda/usdahome

The United States Department of Agriculture Economic Research Service
http://www.ers.usda.gov/topics.aspx

Organic Farming

FAO background information on organic farming
http://www.fao.org/organicag/oa-home/en/

Organic Farming and Climate Change
http://www.fao.org/docrep/005/y4137e/y4137e02b.htm

Genetically Modified Crops

Bittersweet Harvest: The Debate Over Genetically Modified Crops
http://search.proquest.com/docview/230862619/fulltext?accountid=3615

Urban Agriculture

Urban Agriculture
https://afsic.nal.usda.gov/farms-and-community/urban-agriculture

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