



Where will your next meal come from?: Inquiries about food, people, and environment



Module Overview

This module includes three investigations dealing with agricultural systems and the environmental problems and opportunities related to these systems, including their capacities for sustaining human populations.

Investigation 1: Is there a future for subsistence agriculture?

Investigation 1 focuses on subsistence ways of life, which are based on ancient practices far removed from modern technology and urban industrial livelihood patterns. After looking briefly at three main types of subsistence agriculture, students investigate *intensive* subsistence agriculture, specifically Asian rice production, and they interpret satellite images for clues about challenges to the future of this type of agriculture. Students debate the proposition that subsistence agriculture will continue to play a significant role in feeding the populations of the developing world. In contrast to subsistence agriculture, Investigation 2 deals with the industrial, commercial agriculture common in the developed countries in North America and Europe.

Investigation 2: What is industrial agriculture?

The focus is on the high-energy- and technology-using system of commercial agriculture in the developed, industrial world. Students investigate industrial agriculture as a system of inputs and outputs, compare it to subsistence agriculture, examine its effects on human and physical landscapes, and consider how changes in technology are transforming the way it operates. A debate or forum about industrial agriculture enables students to argue its advantages and disadvantages and discuss the ability of agriculture to support future populations without degrading the environment.

Investigation 3: Who will feed the world?

Building on their knowledge of agricultural systems gained from the first two investigations, students look critically at the capacities of these systems for sustaining human populations in a world where one of six people suffers from hunger. Students work in groups to investigate population growth and agricultural production in major world regions and consider how developments in technology and monitoring systems will contribute to feeding people in the future. The investigation concludes with an investment challenge in Mozambique. Students work in groups to make recommendations for improving agricultural production in this country.

Geography Standards

The World in Spatial Terms

- **Standard 1:** How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

Places and Regions

- **Standard 5:** That people create regions to interpret Earth's complexity

Human Systems

- **Standard 9:** The characteristics, distribution, and migration of human populations on Earth's surface

Environment and Society

- **Standard 14:** How human actions modify the physical environment
- **Standard 15:** How physical systems affect human systems
- **Standard 16:** The changes that occur in the meaning, use, distribution, and importance of resources

The Uses of Geography

- **Standard 18:** How to apply geography to interpret the present and plan for the future

Science Standards

Unifying Concepts and Processes

- Change, constancy, and measurement

Science and Technology

- Abilities of technological designs
- Understandings about science and technology

Science in Personal and Social Perspectives

- Population growth
- Natural resources
- Environmental quality
- Science and technology in local, national, and global challenges

Connection to the Curriculum

Where will your next meal come from?: Inquiries about food, people, and environment is an instructional unit—about 3 weeks in length—that can be integrated, either in whole or in part, into high school courses in world geography, demography, nutrition, population geography, economics and economic geography, agricultural geography, regional geography, and global studies. The material supports instruction about economic development and population growth, as well as the dynamic interactions between physical and human environmental change at both local and regional scales of analysis. Connections to mathematics skills are easily made because the material requires students to work with a large amount of quantitative data in graphic and tabular form.

Time

Investigation 1: Five to six 45-minute sessions

Investigation 2: Four to eight 45-minute sessions

Investigation 3: Four to eight 45-minute sessions

Mathematics Standards

Data Analysis and Probability

- Formulate questions that can be addressed with data; and collect, organize, and display relevant data to answer them

Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement

Algebra

- Analyze change in various contexts

Representation

- Use representations to model and interpret physical, social, and mathematical phenomena

Technological Literacy Standards

Nature of Technology

- **Standard 2:** Core concepts of technology

Technology and Society

- **Standard 4:** The cultural, social, economic, and political effects of technology
- **Standard 5:** The effects of technology on the environment
- **Standard 6:** The role of society in the development and use of technology

The Designed World

- **Standard 15:** Agricultural and related biotechnologies



Is there a future for subsistence agriculture?



Investigation Overview

This investigation focuses on subsistence ways of life, which are based on ancient practices far removed from modern technology and urban industrial livelihood patterns. After looking briefly at three main types of subsistence agriculture, students investigate *intensive* subsistence agriculture, specifically Asian rice production, and they interpret satellite images for clues about challenges to the future of this type of agriculture. Students debate the proposition that subsistence agriculture will continue to play a significant role in feeding the populations of the developing world. In contrast to subsistence agriculture, Investigation 2 deals with the industrial, commercial agriculture common to the developed countries in North America and Europe.

Time required (as follows):

Introduction and Part 1: Two 45-minute sessions

Parts 2 and 3: One or two 45-minute sessions

Parts 4 and 5: Two 45-minute sessions

Materials

Briefing (one copy per student)

Log (one copy per student)

Computer with CD-ROM. The Mission Geography CD contains color graphics and links to the World Wide Web.

Reference materials such as encyclopedias

World atlases

Optional: Access to the Internet for data gathering

Content Preview

It is usually impossible to correctly answer questions about the future, such as the question posed in the title of this investigation. Rather, this question is meant to raise awareness and to encourage speculation and skepticism about the future capacity of subsistence agriculture to feed the rapidly growing populations in the developing world. Several arguments could be made based on the content of this investigation, but the central conclusion is most likely to be close to this: because of environmental constraints, primarily shortages of land and water, subsistence farming will be less and less able to support, in the long run, the rapidly growing populations in poor countries. The task of feeding future populations will probably require *both* the cessation of rapid population growth *and* a surplus-producing, high technology-based, and environmentally sustainable agriculture, such as is discussed in Investigation 2 of this module.

Geography Standards

Standard 14: Environment and Society

How humans modify the physical environment

- Explain the global impacts of human changes in the physical environment.

Standard 15: Environment and Society

How physical systems affect human systems

- Analyze examples of changes in the physical environment that have reduced the capacity of the environment to support human activity.

Standard 16: Environment and Society

The changes that occur in the meaning, use, distribution, and importance of resources

- Analyze the relationships between the spatial distribution of settlement and resources.

Geography Skills

Skill Set 4: Analyzing Geographic Information

- Make inferences and draw conclusions from maps and other geographic representations.

Skill Set 5: Answering Geographic Questions

- Evaluate the answers to geographic questions.

Classroom Procedures

Beginning the Investigation

- Hand out copies of the **Briefing** to each student and have them read the **Background** and **Objectives**. Draw out discussion with such questions as:
 - What do you know about subsistence agriculture?
 - What most surprised you in the Background?
 - The title of the investigation raises the question of whether subsistence agriculture has a future. Why would this be argued?
 - Why do you think subsistence agriculture might continue to be important?
 - What is the estimated number of people supported by intensive subsistence farming in the world? (This is the first question on the **Log**, so it can be used to draw attention to the need to give answers on the Log throughout the investigation. The answers to the Log questions are found at the end of this Educator's Guide. Give students a schedule for completing the Log.)
- Form students into FAO (UN Food and Agriculture Organization) teams.
 - Teams work together to collect information from the Briefing and answer questions on the Log.
 - Debate the proposition that subsistence agriculture will continue to play a significant role in feeding the populations of the developing world in the future.
 - Assign groups for the debate: half in favor and half opposed to the proposition.
 - Emphasize the importance of working together to gain the expertise needed to debate at the end of the investigation.

Developing the Investigation

- For Question 1 in **Part 1: Where is subsistence agriculture found?**, students are asked to describe the three types of subsistence agriculture in the world by completing the table. They should use atlases and print and/or electronic sources of information (see **Additional Resources**).
 - Have each group complete the whole table.
 - Or, to save time, divide the work: each group does only one type and then shares with the other groups.
 - Use the answers to the Log in this Educator's Guide to direct students' understanding of the questions.
- Figure 1 in the **Log** is a world map of the distribution of these three main agricultural practices. To answer Question 1, students will need political maps or atlases to locate the countries where these practices are found.
- Parts 2, 3, and 4 of the **Briefing** provide basic information about intensive subsistence agriculture.
 - Students can work through these parts in groups, independently, or as a class.
 - In any case, ask and answer questions to keep students on task and moving through the materials.
 - These parts provide the information needed to answer Questions 2 and 3 on the Log.
- In order to answer Question 4, students should see that Figure 9 contains a time series of three infrared images of Beijing and its surroundings.
 - The caption explains that the light blue color is the infrared signature of concrete, which roughly corresponds to the urban area of Beijing.
 - The surrounding area in red primarily represents agricultural land.
 - The caption also notes that each image is 35 kilometers wide.
 - With this information, challenge students to measure the urban area of Beijing in each of the three years. The following procedure can be used:
 - On the screen or on a color printout, measure the area of the blue core in the middle of each image.
 - Make a linear *scale* for the images by using a sheet of paper along the width of one of the images; tick off the image width and call that 35 kilometers.
 - Make ticks at half the width, which is 17.5 kilometers, 1/4th is 8.75 kilometers, and 3/4ths is 26.25 kilometers.
 - Using this scale, measure the blue core in each image by treating it as a square. For example, the blue area in 1976 was roughly 8 x 8 kilometers or 64 square kilometers, for 1984 it was 9 x 9 or 81 square kilometers, and for 1991 it was roughly 18 x 18 or 324 square kilometers.
- To answer Question 5, encourage students to speculate about what they observe in Figure 10.
 - They might guess that the streams of white are clouds or smoke.

- Actually, it is smoke from land-clearing fires.
- Forests are being burned to clear the land for intensive agriculture.
- Explain to students that to feed ever-increasing populations, more cleared land is required for agriculture.
- This results in rapid deforestation in many developing areas that are experiencing strong population pressure.
- Deforestation can be a serious problem because the soils of many tropical rainforests have too few nutrients to support intensive agriculture. (Students may have prior knowledge of this fact.)
- But in areas where recent volcanic eruptions have enriched the soils with nutrients, such as in this part of Indonesia, the soils may be able to support intensive farming.
- A lot of deforestation in Indonesia is leading to intensive subsistence agriculture, made possible by soils derived from volcanic ash.

Concluding the Investigation

8. In preparation for the debate, have each group answer Question 6, either for or against the proposition.
9. Conduct a formal debate as a whole class, with groups assigned to opposing positions on the proposition:

Resolved: Subsistence agriculture will continue to play a significant role in feeding the populations of the developing world in the 21st century.

Note: Students will not be able to develop, using only the Briefing, all of the possible arguments in this issue, so it is important that you direct their discussion with the points found in the Key to the Investigation Log.

10. Instead of a formal debate, you may wish to have students individually or in groups write down three reasons to support a “yes” answer and three reasons for a “no” answer. Post their reasons on the board in two columns and use them to direct class discussion.

Evaluation

- Evaluate the Investigation Logs using the answers in this Educator's Guide.
- Ideas suggested for extension and enrichment may also be used for evaluation.

Additional Resources

Images and information on the Sahel in Africa
http://kidsat.jpl.nasa.gov/kidsat/photogallery/africa_sahel.GIF

Excellent information on deforestation
<http://earthobservatory.nasa.gov/Library/Deforestation/>

Information on related environmental issues studied by Earth Observing System
http://eosps0.gsfc.nasa.gov/eos_edu.pack

Images of Santa Cruz, Bolivia, deforestation that are detailed enough for analysis in a laboratory setting
http://svs.gsfc.nasa.gov/imagewall/LandSat/santa_cruz.html

An on-line class on global land use issues, many of which are related to this investigation
<http://see.gsfc.nasa.gov/edu/SEES/global/class/>

A good resource for students to see and read about the circumstance of families is:

Peter Menzel. 1994. *Material World: A Global Family Portrait*. San Francisco: Sierra Club Books. This book also exists on a CD.

Good overviews of the concepts presented in this investigation can be found in:

Getis and Fellmann. 1995. *Human Geography. Landscapes of Human Activities*. Fourth Edition. Dubuque, Iowa: Wm. C. Brown.
 Rubenstein. 1994. *An Introduction to Human Geography*. New York: Macmillan.

Log

1. Characteristics of major types of subsistence agriculture

Characteristic	Pastoral Nomadism	Shifting Cultivation	Intensive Subsistence
3 countries representative of type	Namibia, Kenya, Mali, Niger, Saudi Arabia, Iraq, Iran, Russia, Chad, Mongolia, Afghanistan, and others	Brazil, Venezuela, Columbia, Nigeria, Tanzania, Chad, Senegal, Indonesia, and others	India, China, Vietnam, Cambodia, Bangladesh, Pakistan, Mexico, Peru, and others
Climate	Hot and cold dry climates (tundra, steppes, savannas, deserts)	Humid tropical (rain forests)	Warm to temperate humid climates or dry climates with irrigation
Percentage of world land area covered	20%	25%	10%
Population density (high, medium, or low)	Low	Low to medium	High
Percentage of world population supported	<1%	5%	50%
Output per unit area (High, medium, or low)	Low	Medium	High
Output per unit of human effort (high, medium, or low)	High	Medium	Low
Other	Reliance on herd animals (cattle, sheep, goats, reindeer, horses); people move with herds	Clear plots in forest for planting; when soil loses fertility in 2-3 years, shift to other plots	Small, permanent, irrigated, fertilized plots, produce rice and vegetables

2. On the timeline below, write in the annual activities of traditional wet rice double cropping in China.

	Jan	
	Feb	
Turn soil with wooden plow and water buffalo; rake smooth, fertilize, and water the plot; transplant seedlings into plot	Mar	
Weeding and watering	April	
Weeding, watering, and fertilizing	May	
Allow rice to draw starch; let water out to dry rice; harvest in late June or early July	June	
Separate rice from stalks, vegetable gardening	July	Vegetable gardening
	Aug	Turn soil with wooden plow and water buffalo; rake smooth, fertilize, and water the plot; transplant seedlings into plot
	Sept	Weeding and watering
	Oct	Weeding, watering, and fertilizing
	Nov	Allow rice to draw starch; let water out to dry rice; harvest in November or early December
	Dec	Separate rice from stalks

3. Identify six important features of intensive subsistence agriculture on your own as you read the Briefing:
- *Growing a variety of crops helps reduce risks from crop failure, which can be caused by poor weather or pests.*
 - *Labor is divided among the rice fields and the vegetable garden.*
 - *Supports large, densely settled populations in regions of the world with large populations like India, China, and Southeast Asia.*
 - *Families must produce enough food for survival on very small parcels of land.*
 - *The same fields are planted year after year.*
 - *Livestock are generally not permitted to graze in any area that could be used for crops.*
 - *Little grain is used for animal feed, and cattle are limited by lack of grazing land.*
 - *Subsistence farmers grow rice in much of Southeast Asia, Southeast China, and East India.*
 - *Fish are cultivated in aquaculture ponds integrated with intensive agriculture.*
 - *In drier areas where irrigation can be provided, a variety of crops are grown, including wheat, barley, oats, corn, sorghum, millet, soybeans, cotton, hemp, and flax.*
 - *As the need for expanded production rises, many farmers terrace the hillsides of river valleys.*
 - *Where intensive agriculture expands into tropical rain forests, special problems of deforestation may occur.*
 - *Land for cultivation is lost to expanding urban areas.*
4. Using the information on Figure 9, provide a quantitative description of the changes over the 15-year period shown by the three images. How do these changes challenge subsistence agriculture? *Since each image extends 35 kilometers from left to right, students should be able to make a rough estimate of the changing size of the urban core of Beijing—the blue area in the center of each image.*

In 1976, Beijing occupied about 60 square kilometers; in 1984, about 80 square kilometers; and in 1991, about 300 square kilometers. These are rough estimates and students should not be held to exact figures, but they should be able to explain that urban growth of Beijing has severely eliminated many square kilometers of farmland. By extension, you should explain that Beijing is only one example. Cropland is being lost to urban expansion in many of the world's regions.

5. What do you think is shown in Figure 10, and how might this be related to intensive subsistence agriculture?
- *They might guess that the streams of white are clouds or smoke.*
 - *Actually, it is smoke from land-clearing fires.*
 - *Forests are being burned to clear the land for intensive subsistence agriculture.*
 - *Explain to students that to feed ever-increasing populations, more cleared land is required for agriculture.*
 - *This results in rapid deforestation in many developing areas that are experiencing strong population pressure.*
 - *This can be a serious problem because the soils of many tropical rain forests are too poor in nutrients to support intensive agriculture. (Students may have prior knowledge of this fact.)*
 - *But in areas where recent volcanic eruptions have enriched the soils with nutrients, such as in this part of Indonesia, the soils can support intensive farming.*
 - *A lot of deforestation in Indonesia is leading to intensive subsistence agriculture, made possible by soils derived from volcanic ash.*
6. List arguments, *either for or against* the proposition that subsistence agriculture will continue to play a significant role in feeding the populations of the developing world in the 21st century.

Arguments that support the proposition might include:

- If, by *significant role*, we mean millions of people, subsistence agriculture will continue to feed a significant number of people, although admittedly an increasingly large proportion of populations will depend on commercial, surplus-producing agriculture.
- Entire ways of life—traditional livelihood patterns such as Asian subsistence rice culture—will not quickly disappear; cultural and economic changes do not occur easily.

Arguments against the proposition *might* include the following:

- Populations in the developing world are increasingly dependent on the food surpluses produced by the developed world.
- Urban expansion will cause a loss of suitable farm land.
- Soil fertility will become depleted by deforestation on poor agricultural soils.

- Limitations will be caused by shortages of water for irrigation—agriculture will face increasing competition for water from urban, industrial, and other uses.
- Because populations are moving out of agriculture and into urban industrial modes of life, there will be too few subsistence farmers to feed ever-increasing populations.
- Of the total world population, the proportions of urban populations are increasing, and rural (agricultural) populations are decreasing, meaning that the role of subsistence agriculture in feeding populations must decrease and the role of commercial, surplus-producing agriculture must increase.



Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

Background

Will subsistence agriculture continue to feed the billions of people that currently depend upon it? Unlike the large-scale, surplus-producing, industrial farmers in the developed countries of North America and Europe, subsistence farmers produce only enough to feed themselves and their families. Subsistence agriculture, which is mainly found in the developing countries in Asia, Africa, and Latin America, feeds half of the world's population. More important is the fact that the population in the developing countries is increasing much faster than it is in the developed countries. Intensive subsistence rice farming supports nearly three billion people, mostly in Asia. (Much smaller numbers of people practice other forms of subsistence agriculture, such as shifting cultivation in humid tropical regions and nomadism in dry regions.) Subsistence ways of life, which are based on ancient practices far removed from modern technology and urban industrial livelihood patterns, are disappearing. This investigation will help you speculate about the role subsistence agriculture will play in feeding the populations of the developing world in the 21st century.

Objectives

In this investigation, you will

- describe and locate three major types of subsistence agriculture,
- develop expertise about Asian intensive subsistence agriculture,
- interpret NASA satellite imagery to identify challenges to the survival of intensive subsistence agriculture, and
- debate the future of intensive subsistence agriculture.

Part 1. Where is subsistence agriculture found?

Imagine that you are a geographer working for the United Nations Food and Agriculture Organization (FAO). You are a member of an FAO team assigned to investigate the role of intensive subsistence agriculture in the world. You will debate whether this type of agriculture will continue to support populations in the developing world in the 21st century.

Three main types of subsistence agriculture are

- a) pastoral nomadism,
- b) shifting cultivation, and
- c) intensive subsistence.

Describe these types by completing the table for Log Question 1. In addition to the information in this activity, you should use atlases and other print or electronic reference materials to complete the tables.

Your team should now use the remainder of this investigation to develop expertise about intensive subsistence agriculture.

Part 2. How is intensive subsistence agriculture practiced?

Intensive subsistence agriculture maximizes food production on relatively small fields that are carefully cultivated, fertilized, and irrigated. Intensive subsistence agriculture occupies less than 10 percent of the world's land area but supports about half of the world's population. Intensive subsistence agriculture dominates in regions with large, densely settled populations, such as India, China, and Southeast Asia (Figures 2 and 3).

Intensive subsistence agriculture can support large populations. Families must produce enough food to survive on very small parcels of land. To ensure as much food production as possible:

- no land is wasted,
- fertilizer (usually manure) is used,
- double cropping is common,
- the same fields are planted every year,
- livestock are usually not allowed to graze on land that could be used for crops, and
- little grain is planted for animal feed.

Rice is widely grown by subsistence farmers in much of Southeast Asia, Southeast China, and East India. Rice production involves several steps. Farmers use water buffalo or oxen to plow the field, or paddy. The paddy is then flooded (Figure 2). Dry seeds are then scattered through the field, or seedlings are transplanted from a nursery (Figure 3). The plants grow submerged in water for about three-fourths of the warm, wet growing season, and harvesting is done by



Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

hand. This wet rice cultivation must be done on flat land (like river valleys and delta regions). As the need for expanded production rises, many farmers terrace the hillsides of river valleys to produce more flat land.

Wet rice cultivation requires a constant supply of water through irrigation and drainage. Figure 4 is a Space Shuttle image of Bangkok, Thailand, showing the network of canals used for irrigation for agriculture and domestic water consumption.



Figure 2: Chinese rice farmer using a hand-operated pump to draw water from a canal

Source: <http://www.fao.org/NEWS/FOTOFILER/Ph9716-e.htm>, FAO photo by F. Botts



Figure 3: Indian women farmers transplanting rice

Although women produce more than half the food grown globally, in many countries their nutritional needs are met only after men and children have had enough.

Source: <http://www.fao.org/NEWS/FOTOFILER/PH9737-e.htm>, FAO photo by G. Bizzari



Figure 4: Space Shuttle photography of Bangkok, Thailand

In an infrared photograph, the vegetation appears reddish in hue. In this west-looking view, the city of almost four million people has a vast network of canals that are used for irrigation and drainage.

Source: <http://images.jsc.nasa.gov/images/pao/STS45/10064754.htm>



Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

Part 3: How is wet rice traditionally cultivated in China?

Farmers in some of the more remote parts of China (such as Hunan, Jiangxi, Anhui, inland parts of Fujian and Zhejiang, inland/mountain parts of Guangdong, Guangxi, Guizhou, and some areas of Sichuan) still practice traditional wet rice farming. They plant two crops of rice a year (double-cropping) where it is warm and wet. In the double-cropping cycle, farmers

- turn the soil with an iron-tipped wooden plow pulled by a water buffalo early in March and August;
- rake the plowed soil smooth, fertilize, and water the plot (they must keep the water in the rice field at the proper level as the plants grow);
- transplant rice seedlings from seedbeds into the prepared plot from the middle of March and August (the entire family works in the field taking seedlings by the bunch and pushing them into the soft, water-covered soil, as shown in Figure 3);
- weed the crop in April and September (weeding is done by hand, and everyone old enough for such work participates);

- weed and fertilize again in May and October;
- allow the rice to stand to “draw starch” to fill the hull of the kernels (they let water out of the fields when the kernels draw enough starch, and both soil and stalks dry under the Sun); and
- harvest in late June or early July and in November; they cut off rice plants a few inches above the ground with a sickle; then they separate the rice from the other parts of the crop (Figure 5), which are used for fuel.

When harvest work is done, farmers begin plowing for the next crop. They use the slack season of the rice crop for vegetable gardening. In the hot and damp period of late spring and summer, they grow eggplant and several varieties of squash and beans. After harvesting a crop of vegetables, they turn the soil and break up the clods with a digging hoe, and level it with an iron rake to prepare for a new crop. They weed vegetables constantly, water with the long handled wooden dipper two or three times a day, and fertilize often (Yang 1959).

[Answer Question 2 on Log.](#)



Figure 5: Women winnowing rice in Myanmar

Source: <http://www.fao.org/NEWS/FOTOFIL/PH9722-e.htm>, FAO photo by G. Bizzarri



Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

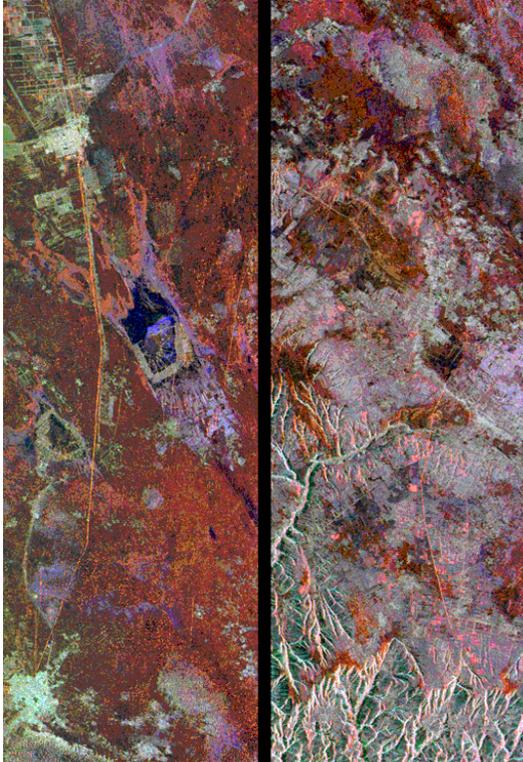


Figure 6: Intensive subsistence wheat agriculture around the Great Wall, north-central China

This radar image, taken on August 3, 1995, shows a segment of the Great Wall. Most of the image is taken up by rectangular patterns indicating agricultural development, primarily wheat fields. The Great Wall appears as a thin orange band, running from the top to the bottom of the left image. The wall is easily detected from space by radar because its steep, smooth sides provide a prominent surface for reflection of the radar beam.

Source: <http://www.jpl.nasa.gov/radar/sircxsar/gwall.html>



Figure 7: Mulberry fields and fish ponds in Jiangsu province in eastern China

Source: <http://www.fao.org/NEWS/FOTOFIL/PH9811-e.htm>, FAO photo by H. Zhang

Part 4. What are other types of intensive subsistence agriculture?

In addition to wet rice cultivation, intensive subsistence agriculture also occurs in drier areas where irrigation is available to provide water for crops during dry seasons. The land is still fully planted with a variety of grains and other crops. These include wheat, barley, oats, corn, sorghum, millet, soybeans, cotton, hemp, and flax. For example, intensive subsistence wheat agriculture is found around the Great Wall of China in a desert region of north-central China, about 700 kilometers west of Beijing (Figure 6).

In many wet areas, aquaculture, or fish farming, is practiced, usually integrated with agriculture (Figures 7 and 8). Fish provide an important source of protein. In a world of land and water scarcity, fish ponds have an advantage over feedlots in producing low-cost animal protein. In contrast to meat production, which is concentrated in industrial countries, some 85 percent of fish



Figure 8: Indian workers harvest carp raised in an inland aquaculture pond

Source: <http://www.fao.org/NEWS/FOTOFIL/ph9711-e.htm>, FAO photo by I. de Borhegyi



Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

farming is in developing countries. China, where fish farming began more than 3,000 years ago, accounted for 21 million tons of the 31 million tons of world aquaculture output in 1998. India was a distant second with 2 million tons. Other developing countries with large aquaculture production include Bangladesh, Indonesia, and Thailand (Brown 2000).

Complete Question 3 on the Log.

Part 5. What are the challenges to intensive subsistence agriculture in the 21st century?

This investigation began by posing the question of whether intensive subsistence agriculture will continue in the 21st century. The answer to this question may depend upon current and future challenges to this form of agriculture. Examine Figure 9 for clues to one important challenge to subsistence agriculture, and write your observations on the Log at Question 4.

To consider another challenge to intensive subsistence agriculture, study the image in Figure 10, which shows an area in the southern part of Borneo, in Indonesia, and record your observations in the Log at Question 5.

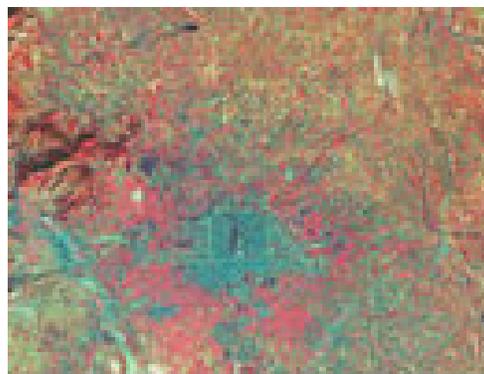
Figure 9: Urban expansion of Beijing, China, over 15 years, as seen by the growth of the area in light blue color, which is the signature of concrete in the infrared image

Source: http://see.gsfc.nasa.gov/edu/SEES/global/class/Chap_8/8_Js/8-03.jpg

Beijing, China, LANDSAT scene 123/32

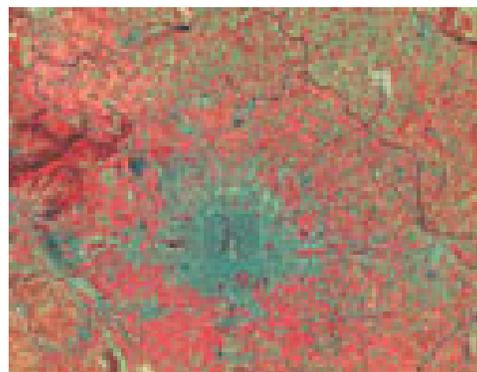
Data extract is 35 kilometers wide

26 Oct 1976



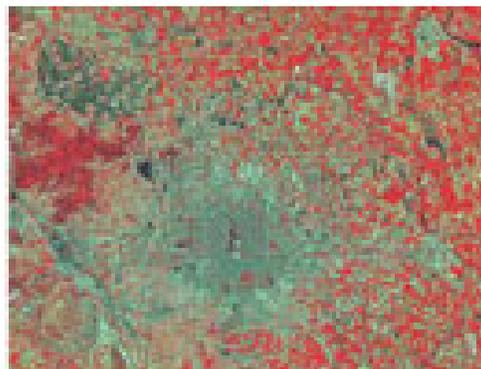
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16 May 1991



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Module 2, Investigation 1: Briefing

Is there a future for subsistence agriculture?

Now that you have completed a basic investigation of intensive subsistence agriculture, your team should:

- Brainstorm arguments *either for or against* the proposition that intensive subsistence agriculture will continue to play a significant role in feeding the populations of the developing world.
- List these arguments on your Log at Question 6.
- You can use these arguments in a debate on the proposition.

References

Brown, Lester R. 2000. Fish farming may soon overtake cattle ranching as a food source. *Worldwatch Institute Alert* 2000-9.

Conklin, H.C. Hanunoo agriculture, FAO Forestry Development Paper No. 12. In Getis, Getis, Fellmann. 1995. *Human geography. Landscapes of human activities*. Fourth Edition. Wm. C. Brown Publishers, Dubuque, Iowa, page 261.

Yang, C.K. *A Chinese village in early communist transition*. Cambridge, Massachusetts: Massachusetts Institute of Technology, 1959. In Getis, Getis, Fellmann. 1995. *Human geography. Landscapes of human activities*. Fourth Edition. Wm. C. Brown Publishers, Dubuque, Iowa, page 263.



Figure 10: Space Shuttle view of a portion of the Kalimantan region in southern Borneo, Indonesia, (3.5S, 113.5E) taken in September, 1991

Source: <http://images.jsc.nasa.gov/images/pao/STS48/10065058.htm>



Module 2, Investigation 1: Log

Is there a future for subsistence agriculture?

1. Use individual or group research to complete the table below.

Characteristic	Pastoral Nomadism	Shifting Cultivation	Intensive Subsistence
3 countries representative of type	1) 2) 3)	1) 2) 3)	1) 2) 3)
Climate			
Percentage of world land area covered			
Population density (high, medium, or low)			
Percentage of world population supported			
Output per unit area (high, medium, or low)			
Output per unit of human effort (high, medium, or low)			
Other			



Module 2, Investigation 1: Log

Is there a future for subsistence agriculture?

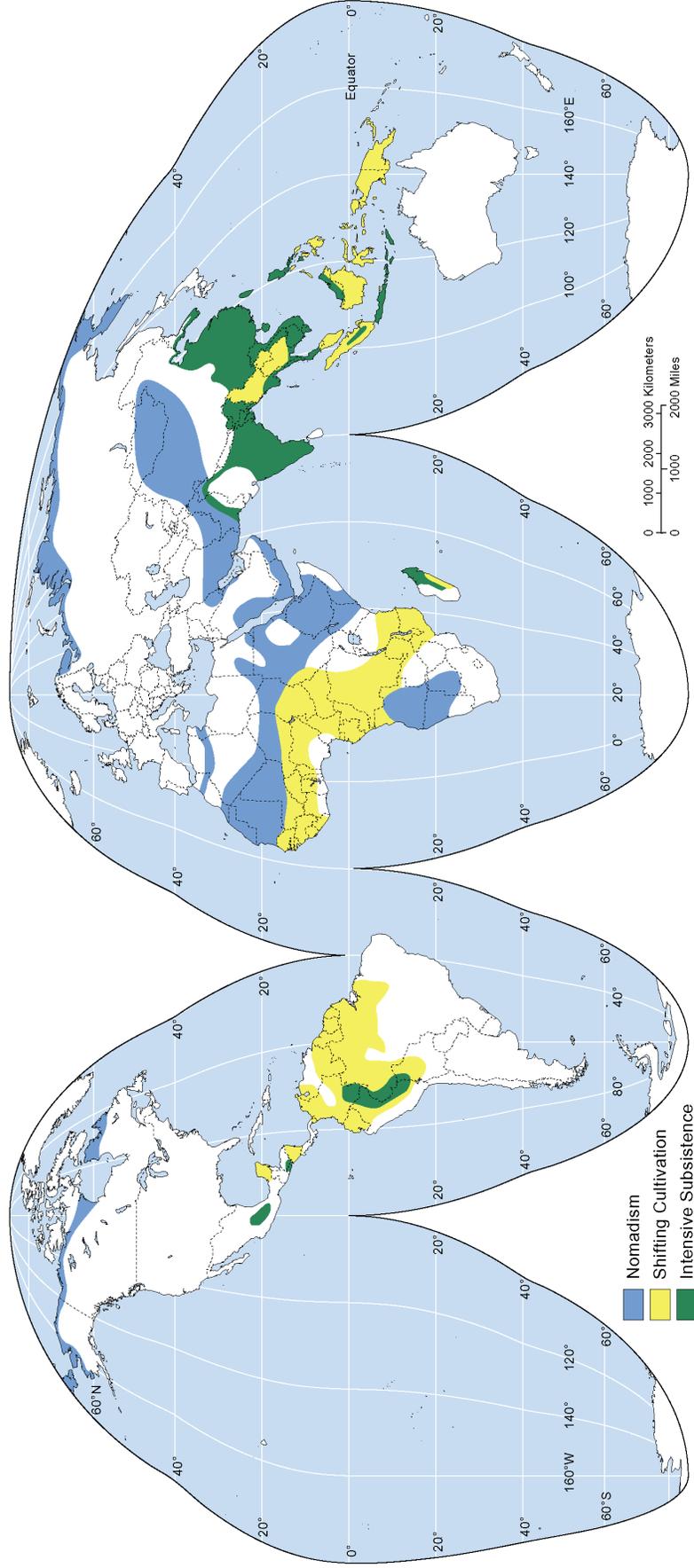


Figure 1: World agricultural practices map



Module 2, Investigation 1: Log

Is there a future for subsistence agriculture?

2. On the timeline below, write in the annual activities of traditional wet rice double-cropping in China. Write the steps for crop #1 on the left and for crop #2 on the right.

	January	
	February	
	March	
	April	
	May	
	June	
	July	
	August	
	September	
	October	
	November	
	December	

3. Identify six important features of intensive subsistence agriculture on your own as you read the Briefing.

- 1) _____
- 2) _____
- 3) _____
- 4) _____
- 5) _____
- 6) _____



Module 2, Investigation 1: Log

Is there a future for subsistence agriculture?

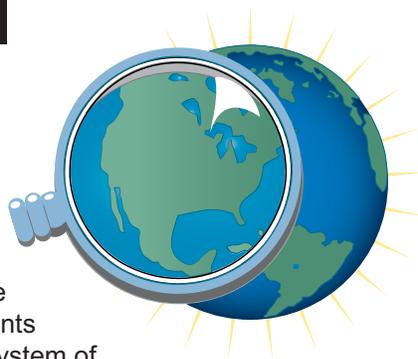
4. Using the information on Figure 9, provide a *quantitative* description of the changes over the 15-year period shown by the three images. How do these changes challenge subsistence agriculture?

5. What do you think is shown in Figure 10, and how might this be related to intensive subsistence agriculture?

6. List three arguments, *either for* or *against* the proposition that subsistence agriculture will continue to play a significant role in feeding the populations of the developing world in the 21st century.



What is industrial agriculture?



Investigation Overview

This investigation focuses on the high-energy- and technology-using system of commercial agriculture in the developed, industrialized world. Students investigate industrial agriculture as a system of inputs and outputs, compare it to subsistence agriculture, examine its effects on human and physical landscapes, and consider how changes in technology are transforming the way it operates. A debate or forum about industrial agriculture enables students to argue its advantages and disadvantages and discuss the ability of agriculture to support future populations without degrading the environment.

Time required:

Introduction and Part 1: One or two 45-minute sessions

Part 2: One or two 45-minute sessions

Parts 3 and 4: One or two 45-minute sessions

Part 5: One or two 45-minute sessions

Materials

Investigation Briefing and Log, one for each student
Computer with CD-ROM drive. The Mission Geography CD-ROM contains color graphics needed for this activity.

Content Preview

Industrial agriculture, which is typified by the highly productive commercial agricultural system in the United States, is important to understand because it produces most of the world's food and fiber. But there are two major issues: (1) because it relies on fossil fuels, which are nonrenewable resources, its ability to support world populations in the long run is problematic, and (2) because it sometimes produces serious environmental degradation, it may not be sustainable. Whether or not technology can solve these problems is an open question.

Classroom Procedures

Beginning the Investigation

1. The first sentence of the **Briefing** asks: "Where did your last meal come from?"
 - Ask if it came from subsistence agriculture, which students may have studied previously in this module.
 - Ask for student responses to initiate discussion.
 - Then say that this investigation will help them understand the type of agriculture that provides the food they eat.

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information

- Produce and interpret maps and other graphic representations to solve geographic problems.

Standard 14: Environment and Society

How human actions modify the physical environment

- Evaluate the ways in which technology has expanded the human capacity to modify the physical environment.
- Explain the global impacts of human changes in the physical environment.
- Develop possible solutions to scenarios of environmental change induced by human modification of the physical environment.

Standard 18: Uses of Geography

How to apply geography to interpret the present and plan for the future

- Develop policies that are designed to guide the use and management of Earth's resources and that reflect multiple points of view.

Geography Skills

Skill Set 3: Organizing Geographic Information

- Select and design appropriate forms of graphs, diagrams, tables, and charts.

Skill Set 4: Analyzing Geographic Information

- Make inferences and draw conclusions from maps and other geographic representations.

Alternative: This will take more time than #1 above.

The first sentence of the Briefing asks: "Where did your last meal come from?" Have students

- list what they ate and drank for breakfast, lunch, dinner, and snacks in one day;
- list the places of origin of each of those foods and beverages by both interviewing managers at stores and supermarkets and reading labels (A Big Mac, a pizza, a mocha latte, and a banana split have many ingredients and therefore many places of origin.);
- collate the information for the class as a whole into two lists: foods and places of origin of foods; and
- mark the places of origin on a world map.

Focus class discussion on

- popularity of types of foods;
- spatial distributions and patterns of places of origins of foods;
- speculations about how various foods are produced, including any common elements of agricultural production; and
- any problems or issues regarding agriculture that students may know about.

Developing the Investigation

2. Hand out copies of the **Briefing** and **Log** to each student or to small groups of students.
 - Students can work on this activity individually, but it is recommended that they work in small groups—pairs or triads are especially recommended.
 - You may wish to form groups to take sides in a debate or in a forum, as suggested in Concluding the Investigation, #12 below.
3. Leaf through the materials with the students and point out:
 - the underlined questions to be answered on the Log at the end of the materials (the answers to the questions are found at the end of this Educator's Guide) and
 - a schedule for completing the questions.
4. Have students read the **Background** and **Objectives** sections and then take any questions they may have.
5. Set students working through the **Briefing**, beginning with **Part 1. How productive is industrial agriculture?** which looks at the *output* of industrial agriculture; Part 3 will look at the *input* side of the system. Emphasize the importance of

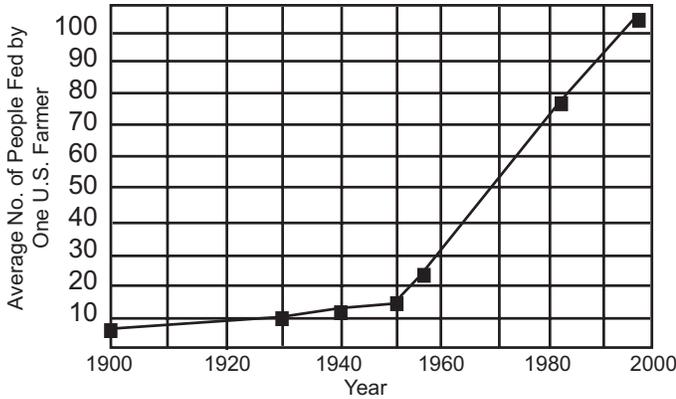
- carefully studying and discussing the tables and figures, including the satellite images;
 - working on group answers to the Log questions; and
 - graphing the data from the 3 tables in Part 1—graphing helps students grasp the relationships and trends portrayed in the tables.
6. To monitor progress and to keep students moving through the **Briefing** at roughly the same pace, ask students to give their interpretations and examples of
 - key concepts (e.g., input-output system, production, productivity, landscape patterns, calorie comparisons, sustainability, precision agriculture, etc.),
 - the satellite images, and/or
 - use the Log questions (or other questions) to generate class discussion.
 7. The purpose of **Part 2: What do the landscapes of industrial agriculture look like?** is to help students practice skills of satellite image interpretation and to learn that industrial agriculture is an important *geographic* phenomenon because it
 - creates many different landscape patterns on Earth's surface,
 - transforms physical landscapes into human landscapes, and
 - varies from place to place because of environmental and human differences.
 Tell students that a geographic landscape can have both physical and human characteristics.
 8. **Part 3: What inputs does industrial agriculture require?** deals with the *input* side of the input-output system.
 - It helps students understand why industrial agriculture is so productive, but
 - it distinguishes different kinds of productivity—those based primarily on labor inputs and those based primarily on energy inputs from fossil fuels.
 9. Students may need assistance understanding some of the arguments presented. For example:
 - Eisenberg, quoted in **Part 4: What problems does industrial agriculture create?** is criticizing industrial agriculture for its negative environmental effects.
 - Students should understand that industrial agriculture requires inputs, such as fertilizer and herbicides that can damage the environment if they are misused.

- Although these practices can produce large amounts of food and fiber in the short run, they also have the potential to produce serious environmental effects in the long run.
 - Technological changes may have *unintended consequences*. For example, contaminated water supplies may be an unintended negative consequence of using chemical fertilizers to increase production.
10. Of course, technological changes may, in turn, also help address unintended negative consequences—they may solve some of the negative environmental effects of industrial agriculture. One such change is the use of remote sensing for *precision agriculture*, which is presented in **Part 5: How are improvements in technology reshaping industrial agriculture?** Precision agriculture is a concept that students (especially urban students) may find difficult.
- You may need to help students interpret the images of agricultural landscapes.
 - Students should understand that agricultural fields are rarely uniform and therefore are not uniformly productive.
 - Fields will often have areas that are wet and dry, high and low, salty and less salty, clayey and sandy, and the like.
 - Remote sensing and precision agriculture assist in tailoring the appropriate amount of seed, fertilizer, water, herbicides, and pesticides needed to increase the productivity on small, nonuniform areas within the larger fields.
 - Such precision allows for better estimates of inputs and outputs.
 - Precision agriculture can also reduce negative environmental effects, e.g., the use of too much fertilizer, which can contaminate ground water.
11. At the end of Part 5, students compare the information given on two images—one a black and white land use map (Figure 9) and the other a color enhanced satellite image (Figure 10).
- They are asked (Question 14) about how the information available from the two images differs and how the “new” information from the satellite image might help them in farming this area in North Dakota.
 - The key to Question 14 offers a range of appropriate changes that students might offer.
- Concluding the Investigation**
12. Organize a debate or a forum about industrial agriculture. For example:
- What are the advantages and disadvantages (“pros” and “cons”) of industrial agriculture?
 - Will industrial agriculture be able to feed future populations? Why?
 - Is industrial agriculture environmentally sustainable? Why?
 - To support their positions in a debate or discussion, students should bring in new information to supplement the data in this activity. For example, perspectives favoring industrial agriculture may be found on web-sites for Cargill (<http://www.cargill.com>) and ADM (<http://www.admworld.com>).
 - Have students write statements that they believe would represent the positions of key parties in the debates about industrial agriculture, and then have them use these statements in a dialog/round-table. Examples of roles could be a gene scientist working for Genentech, an ADM executive, a World Wildlife Fund representative, an official of the United Nations Food and Agriculture Organization (FAO), and the Secretary of the U.S. Department of Agriculture.
13. Have students create a graphic organizer summarizing the inputs and outputs of industrial agriculture. Use the space in the **Log** for Question 16.
14. Have students role-play an international panel of experts charged with making policy recommendations for the improvement of industrial agriculture.
15. Debrief the investigation by discussing the **Logs**. You may wish to use the Objectives listed at the beginning of the **Briefing** to organize the debriefing.

Evaluation

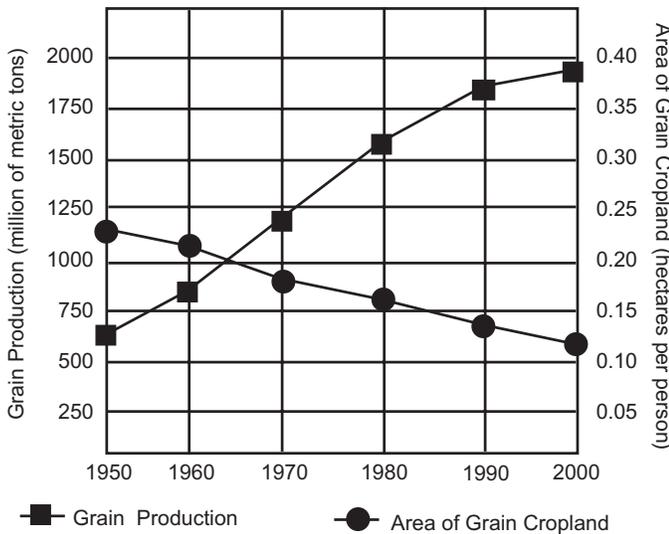
Log

- Complete a graph of the data given in Table 1. What do these data tell you about agricultural trends?



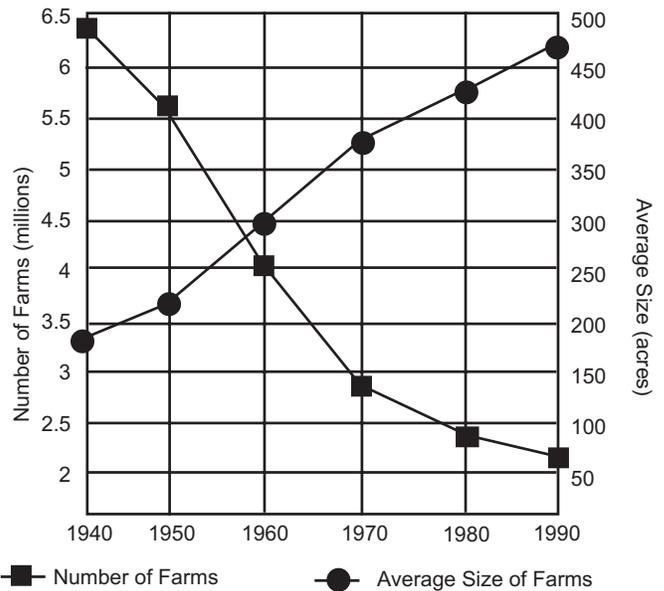
Because of the dramatic increases in the productivity of farm labor, fewer and fewer farmers have produced more and more food. Productivity rose very little from 1900 to 1950 but made large gains from 1950 to 2000.

- Graph the data in Table 2. What do these data tell you about agricultural trends?



There is actually less cropland per person devoted to grain crops today than there was in 1950, but crop productivity and production have increased. The most rapid rates of increase occurred in the period 1960 to 1980. Since then, production rate increases appear to be less rapid.

- Graph the data given in Table 3. What do these data tell you about agricultural trends?



The graph shows that the size of farms has increased while the number of farms has decreased. Decreases in the number of farms appear to have been most rapid in the period from 1950 to 1970. The number decreased very little from 1980 to 1990.

- Agriculture was described as an input-output system. Write down three other examples of an input-output system and explain your examples.

Examples abound, including

- manufacturing, fishing, mining, lumbering;
- education, health care, Social Security, national defense; and
- a bicycle, a car, computer, bank account, interest-bearing savings account, etc.

- Explain the difference between “production” and “productivity” using examples that are *not* found in these materials.

Production: amount of output (“product”) of a system, e.g., the number of pounds of beef produced last year in Nebraska, number of tons of fish caught by the fleet in Alaska in 1999, etc.

Productivity: ratio of input to output, or amount of output per amount of input, e.g., 20 loaves of bread (the output) was produced with one hour of labor (an input) is a measure of productivity of labor; total costs of mining a ton of iron ore; etc.

6. Describe the trends in industrial agricultural production and productivity in the 20th century.
 - *An American farmer fed seven people in 1900 and 96 people in 1999.*
 - *In 1920, about 30 percent of Americans were farmers, but by 1990 only 2 percent farmed.*
 - *Grain production expanded five times as much since 1900 as during the preceding 10,000 years.*
 - *From 1950 to 1989, the amount of grain cropland in the world fell from 0.23 to 0.14 hectares per person, yet the amount of grain production rose from 650 to 1,700 million metric tons.*
7. In **Part 2: What do the landscapes of industrial agriculture look like?** you were shown satellite images of only a few examples of these landscapes. Write down two more examples of different landscapes of industrial agriculture that you have personally seen.
Examples abound:
 - *feed lots for hogs and cattle;*
 - *intensive vegetable production, such as potatoes, carrots, lettuce, onions, etc.;*
 - *intensive fruit and flower production, such as oranges, apples, cherries, peaches, carnations, roses, etc.;*
 - *packing houses, bakeries, and other industrial buildings to process food and other agricultural products;*
 - *sheds for mass production of chickens, turkeys, and eggs; and*
 - *grain elevators, bins, warehouses, railroad, truck, and port facilities for storage and shipping of agricultural products.*
8. What are the characteristics of industrial agriculture? In other words, what do all the examples of this type of agriculture have in common? List as many characteristics as you can:
 - *monocropping (only one crop per field)*
 - *use of manufactured fertilizers, herbicides, and pesticides*
 - *use of hybrid or genetically altered seeds*
 - *use of specialized machinery: tractors, combines, cultivators, seeders, pickers, balers, dryers, etc.*
9. What natural resource is used to make fertilizers, pesticides, and farm machinery? List three other agricultural inputs that come from this natural resource.
Fossil fuels, particularly petroleum and natural gas, are used to make fertilizers, pesticides, and farm machinery. Other inputs dependent on petroleum or natural gas include:
 - *fuel to run farm machinery, such as tractors, combines, irrigation pumps, and grain dryers;*
 - *fuel to run trucks, trains, and ships that distribute the inputs to the farmer and the outputs to the consumer; and*
 - *energy used to process, package, and market agricultural products.*
10. Do you think the increasing use of fertilizer in industrial agriculture is a practice that can be sustained in the future? Why?
This question, which raises the fundamental concern of sustainability, requires more critical thought than a yes or no answer. Sustainability is a contested term, but generally it is understood to denote a practice that does not unduly degrade human and physical systems and will last into the future. The increasing use of energy-based fertilizer will put a strain on the available sources of fossil fuels. Unlike renewable resources such as hydroelectric, wind, and solar power, fossil fuels are finite or nonrenewable resources. Also, fertilizer use can have negative effects on soil and water supplies. Therefore, it is possible to conclude that this is not a sustainable practice in the long-term future. On the other hand, improvements in technology have contributed to better methods of extracting fossil fuels without skyrocketing price increases. It is also possible to argue that technology will continually improve to meet demand, such as by finding new ways to extract fossil fuels, finding alternative ways of producing and/or applying fertilizers, and producing altered seeds that require less fertilizer.
11. By what measure is “traditional” agriculture more productive than industrial agriculture? By what measure is industrial agriculture more productive than traditional agriculture?

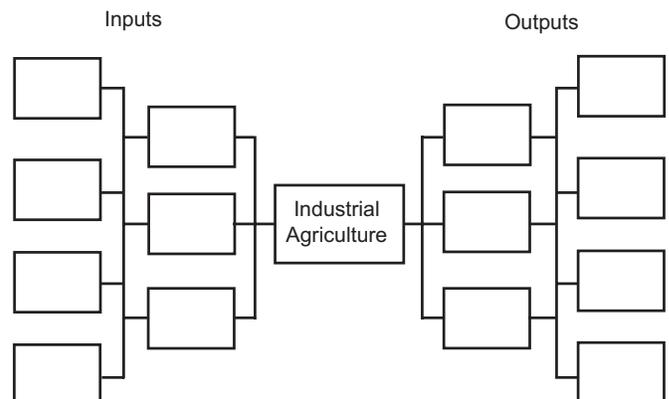
Traditional agriculture is more productive than industrial agriculture as measured by the inputs and outputs of energy measured in calories. Industrial agriculture is more productive than traditional agriculture as measured by the input of human labor. Industrial agriculture substitutes fossil fuels energy for labor.

12. What trends do you see in the amount of money spent (expenditures) on agricultural production in the United States? What is your evidence? Do these data enable us to conclude anything about changes in productivity? Why or why not?
Expenditures on fertilizer, labor, and (animal) feed in U.S. agricultural production from 1992 to 1997 were increasing, according to the U.S. Department of Agriculture (Figure 6). These data only allow us to conclude that expenditures on these items rose during that period. We would need to compare these expenditures on inputs with production data (outputs) in order to make conclusions about changes in productivity.
13. From the quote from Eisenberg and other information you have gathered, list what, in your opinion, may be the three biggest problems of industrial agriculture and support your choices.
Students may list any three reasonable concerns, including the following, but be sure they support their choices:
- soil erosion,
 - contamination of water by agricultural chemicals and waste products,
 - dependence on nonrenewable fossil fuels,
 - depletion of water supplies by increasing irrigation,
 - silting of reservoirs,
 - salinization of soil from improper irrigation, and
 - contamination of food by agricultural chemicals and waste products.
14. What information can you get from remote sensing, and how would this information help you if you were a farmer? Examine the satellite image in Figure 10. What changes would you make on your plot of land? Why?
Remote sensing provides detailed information about where crops are located, as well as how they are developing. Farmers can use these images to determine the location of wet spots, soil erosion, and wind damage that affect crop productivity. Remote sensing and precision agriculture help the farmer to accurately determine how much water, seed, fertilizer, herbicide, and pesticide is required for specific plots within a large field. Precision agriculture allows farmers to be more precise in

their use of inputs, thereby decreasing costs and reducing possible environmental damage.

Students should consider recultivating and refertilizing the areas that were accidentally skipped. Additionally, the down-out should be treated to increase the yield of sugar beets. Finally, there is a large planter skip in the sugar beets that should be replanted. It is likely that this would not have been detected visually until later in the planting cycle. By acting on this new information, the farmer could increase the yield of sugar beets.

15. How might the new technologies of remote sensing and precision agriculture help solve three of the problems of industrial agriculture that are mentioned in **Part 4. What problems does industrial agriculture create?**
- Soil erosion might be reduced by identification of eroding spots and reduction of overwatering.
 - Contamination of water by agricultural chemicals and waste products might be reduced by application of only as much chemicals as needed so chemicals will not run off into water supplies.
 - Depletion of water supplies by increasing irrigation might be reduced by precise application of water to eliminate overuse of water.
 - Salinization of soil might be reduced by precise application of irrigation water so that salt deposits do not develop.
16. Create a graphic organizer to illustrate an input-output model of industrial agriculture.
Students should create models similar to the example below, but students should be given the flexibility to illustrate their understanding in a variety of ways. Be sure that students understand and can appropriately use the concept of input-output in the context of agricultural production.





Module 2, Investigation 2: Briefing

What is industrial agriculture?

Background

Where did your last meal come from? It was probably produced by industrial agriculture, a high-energy and technology-using system of commercial agriculture that spans the globe. (The term “industrial” is used because it is associated with industrialized countries in Europe and North America rather than with the traditional low-energy and low-technology subsistence agriculture of Asia, Africa, and Latin America.) Industrial agriculture is the dominant type of agriculture in Europe and North America. It is also found in other countries such as Japan, Australia, South Africa, Argentina, and southern Brazil. It is especially associated with agriculture in the United States. Even some developing countries have small segments of this type of agriculture, often found alongside traditional forms of subsistence agriculture.

Found in a variety of physical environments, industrial agriculture creates a variety of landscapes. It is highly productive when measured in terms of labor—a single worker can produce food and fiber (such as cotton) for large numbers of people. Industrial agriculture is responsible for large gains in food and fiber output, but it requires a host of costly inputs that may cause environmental problems. In this activity, you will investigate industrial agriculture as a system of inputs and outputs. You will also examine the effect of this system on human and physical landscapes, and consider how changes in technology are transforming the way this system operates. Finally, you will debate the pros and cons of industrial agriculture.

Objectives

In this activity you will

- describe and explain the productivity of industrial agriculture,
- use satellite imagery to interpret landscapes created by industrial agriculture,
- explain industrial agriculture as an input-output system,
- discuss environmental problems associated with industrial agriculture, and
- explain how remote sensing and precision agriculture are being used to increase agricultural efficiency and reduce environmental problems.

Part 1: How productive is industrial agriculture?

Agriculture can be thought of as an input-output system. Farmers must put land, labor, and materials into the system in order to derive outputs, or farm products, from the system. The term production refers to the total amount of output from a given enterprise (e.g., Jones’ farm produced 10,000 bushels of wheat last year). Productivity, on the other hand, refers to the amount of output (e.g., 40 bushels of wheat produced) per amount of input (e.g., hectare of land). Generally, farmers try to increase productivity by reducing inputs and/or increasing outputs. Industrial agriculture has been highly successful at increasing productivity, as the following passage illustrates:

When [the 20th] century began, each American farmer produced enough food to feed seven other people in the United States and abroad. Today [1999], a U.S. farmer feeds 96 people [Table 1*]. Staggering gains in agricultural productivity in the United States and elsewhere have underpinned the emergence of the modern world as we know it. Just as the discovery of agriculture itself set the stage for the emergence of early civilization, these gains in agricultural productivity have facilitated the emergence of our modern global civilization.

This has been a revolutionary century for world agriculture. Draft animals have largely been replaced by tractors; traditional varieties of corn, wheat, and rice have given way to high-yielding varieties; and the world irrigated area has multiplied sixfold since 1900. The use of chemical fertilizers—virtually unheard of in 1900—now accounts for an estimated 40 percent of world grain production.

Technological advances have tripled the productivity of world cropland during this century. They have helped expand the world grain harvest from less than 400 million tons in 1900 to nearly 1.9 billion tons in 1998. Indeed, farmers have expanded grain production five times as much since 1900 as during the preceding 10,000 years since agriculture began (Brown 1999: 115).

*Of course, one farmer does not feed 96 people all by himself. He or she has a lot of help from the fertilizer producer, fuel dealer, machinery builder, seed geneticist, veterinarian, grain elevator operator, truck driver, and others who work to support industrial agriculture.



Module 2, Investigation 2: Briefing

What is industrial agriculture?

Table 1: Number of people for whom food was produced by each U.S. farm worker

Year	Number of people
1900	7
1930	10
1940	11
1950	15
1957	23
1981	78
1999	96

Sources: Seitz 1995; Brown 1999

Throughout this investigation, you will find questions that you should answer on the Log. The first asks you to graph the data given in Table 1. What do these data tell you about agricultural trends?

The key reason that industrial agricultural systems use genetically improved seeds, pesticides, herbicides, fertilizers, and often irrigation is that they increase output. Since World War II, U.S. farmers have more than doubled the total production of grain crops (Table 2). These major grain crops include wheat, rice, corn, oats, and barley. Two-thirds of the world's croplands are planted in cereal grains that are a critical resource for feeding human and animal populations (Brown 1987).

Table 2: World grain production and area of grain cropland per person, 1950-2000

Year	Grain Production (millions of metric tons)	Area of Grain Cropland (hectares* per person)
1950	650	0.23
1960	800	0.21
1970	1,200	0.18
1980	1,550	0.16
1990	1,800	0.14
2000	1,900	0.12

Sources: Brown 1987; 1989 (data for 1990 and 2000 are estimated) *1 hectare = 2.471 acres

On the Log at #2, graph the data given in Table 2. What do these data tell you about agricultural trends?

Industrial agriculture has been called "agribusiness" because of the large size of farms and the large inputs of money required to run these systems. Because hundreds of thousands of dollars must be invested in today's "corporate" farms, the small, family-owned and operated farm has difficulty competing and thus is in rapid decline (Table 3).

On the Log at #3, graph the data in Table 3. What do these data tell you about agricultural trends?

It is the nature of commercial, as opposed to subsistence, agriculture to produce surpluses for sale. In some countries, industrial agriculture produces huge surpluses, which are exported to other countries. These surpluses have great economic importance. For example, grain surpluses are vital in world trade, and wheat is the most important grain traded. In fact, wheat is second only to petroleum in terms of world trade value. Five surplus-producing entities account for 90 percent of the world's grain exports: the United States, Canada, Argentina, Australia, and the European Union (mainly France). The United States exports one-third of all the wheat in world trade, half of all coarse grains (those used mainly for livestock feed—barley, oats, corn, millet, sorghum), and is the world's greatest exporter of rice. Distribution is even more concentrated. Just

Table 3: Number and size of U.S. farms

Year	Number of Farms (millions)	Average Size (acres)
1940	6.4	170
1950	5.6	210
1960	4.0	300
1970	2.9	370
1980	2.4	430
1990	2.1	460

Sources: Seitz 1995



Module 2, Investigation 2: Briefing

What is industrial agriculture?

five privately-owned corporations control 85 percent of U.S. grain exports, 80 percent of Argentina's wheat exports, 90 percent of Australia's sorghum, and 90 percent of all wheat and corn from the European Union. Of the five multinational corporations—Cargill, Continental, Bunge and Born, Louis Dreyfus, and Andre Carnac—only Cargill began in the United States. The others started in Europe in the 19th century. These international giants have interests in banks, railroads, shipping, and insurance as well as in agriculture (Marshall 1991).

Cargill and Archer Daniels Midland (ADM), another U.S.-based agribusiness, have far-flung operations. For example, Cargill markets, processes, and distributes products at locations in 60 countries (<http://www.cargill.com>). ADM's worldwide trans-

portation network, which includes 13,000 railcars, 2,250 barges, and 1,200 trucks, links over 205 domestic and internationally based plants to process cereal grains and oilseeds into many products used for food, beverages, and animal feed markets worldwide <<http://www.admworld.com>>.

Answer questions 4, 5, and 6 in the Log.

Part 2. What do the landscapes of industrial agriculture look like?

Industrial agriculture creates many different landscapes, including dry land cereal farming, beef feed lots, apple orchards, and irrigated rice fields, to name only a few. Consider, for example, a landscape of corn and wheat near Dodge City, Kansas (Figure 1).

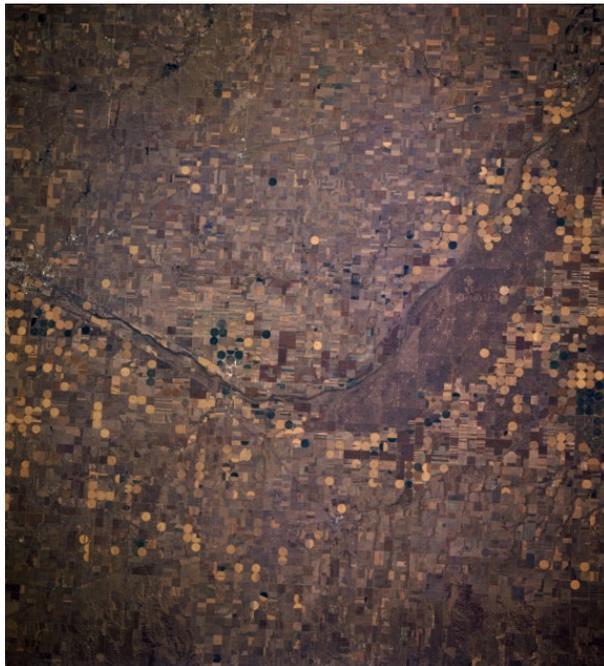


Figure 1: Arkansas River and Dodge City, Kansas, October 1995

Thousands of farm fields along the Arkansas River in western Kansas are featured in this photograph. The Arkansas River is observable as the dark line in the center of the picture. Dodge City (left center), a distribution center in this wheat and livestock area, also produces agricultural implements and supplies. How do you think all those circles were made?

Source: <http://earth.jsc.nasa.gov/photoinfo.cgi?PHOTO=STS073-704-092>



Figure 2: Center-pivot irrigation in south-central Nebraska (1986)

Source: <http://www-geoimages.berkeley.edu/Geoimages/Starrs/CENPIVOT.html>



Module 2, Investigation 2: Briefing

What is industrial agriculture?

As with many human traces on the landscape, industrial agriculture typically produces regular-looking patterns, which are readily observed and interpreted from above with satellite imagery. In the landscapes in Figures 1 and 2, the patterns are rectangles and circles. Rectangular crop fields derive from the land survey system in this part of the United States—the system of townships and ranges based on longitude and latitude. The rectangles in this image are wheat fields, which are probably not irrigated. However, superimposed on this essentially rectangular system are very large circles. What are they?

The large, field-sized circles are formed by a special technology called *center-pivot* or *circle method* irrigation. The center-pivot machine has a large arm, supported by wheels, that sprays water as it rotates around a center pivot. Water is pumped up to the surface from a large underground **aquifer** (called the Ogallala Aquifer, which underlies much of the Great Plains of the United States) and distributed onto the crops in a large circle. Corn and alfalfa, crops that require more water than wheat, are growing in these circular fields. Figure 3 shows a center-pivot rig watering alfalfa.

Irrigated farming produces more per acre than nonirrigated farming, but it also costs more. Center-pivot irrigation uses water more efficiently than does flood irrigation, but it requires more energy inputs. Energy, in the form of gasoline or diesel fuel, is required to run the pumps and engines that drive these machines. Currently, heavy pumping is lowering the water table of the Ogallala aquifer. The lower it gets, the more energy is needed to pump the water to the surface.

Industrial agriculture includes both irrigated and nonirrigated, or dry land, farms. In dry regions such as the Great Plains of the United States, the availability of water for irrigation is vital to high levels of production of crops and livestock. To



Figure 3: Center-pivot irrigation

Source: <http://clay.agr.okstate.edu/alfalfa/images/water/irrig-02.htm>

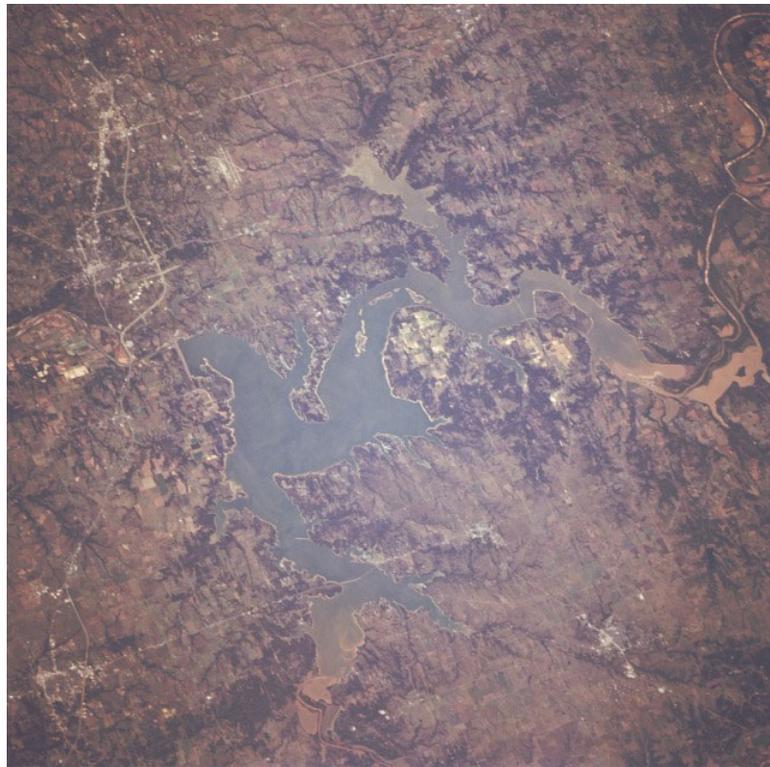


Figure 4: Lake Texoma, Oklahoma, and Texas

Source: <http://earth.jsc.nasa.gov/photoinfo.cgi?PHOTO=STS068-247-079>



Module 2, Investigation 2: Briefing

What is industrial agriculture?



Figure 5: Land leveling for California rice production

Source: <http://agronomy.ucdavis.edu/ucce/PRODUCT/rpic03.htm>

ensure supplies of water, large dam projects are often associated with agricultural landscapes (Figure 4).

Lake Texoma (Figure 4) was created when the Denison Dam was built on the Red River between Oklahoma and Texas. The dam serves the region as a source of hydroelectricity, irrigation water, and recreation. A number of cities can be seen in this photograph, including the city of Durant, Oklahoma, a commercial and processing center for agricultural products including peanuts, winter wheat, cotton, and cattle. As with the previous satellite images, you can see here how industrial agriculture has left its imprint on the physical landscape.

Industrial agriculture is not just recognizable as corn and wheat fields utilizing center-pivot irrigation. Rice production in the United States, for example, leaves a distinct geographic landscape. Figure 5 is a photograph of land leveled into terraces for rice production in California.

Rice production in California is highly mechanized, requiring only about four hours of labor per acre. In contrast, nonmechanized rice production in much of Asia and Africa requires more than 300 hours of labor per acre. Mechanization includes laser technology to precision-level rice land and establish field grades, large tractors, and heavy-duty implements to prepare seedbeds, and combines with half or full tracks for harvesting in muddy soils.

Aircraft are used for seeding, pest control, and some fertilization.

Figure 5 shows terraces precisely leveled by laser technology, which allows for the maintenance of a uniform water depth within the basin to improve rice production. Precision leveling also improves water-use efficiency. Following the adoption of laser-leveling technology in the late 1970s, more than 90 percent of California rice land was precision-leveled (Hill et al. 2000). As with the previous images of industrial agriculture, rice production in the United States combines a variety of energy-intensive techniques and leaves a specific type of landscape observable from above.

Answer questions 7 and 8 in the Log.

Part 3: What inputs does industrial agriculture require?

The tremendous gains in the productivity of industrial grain agriculture in the 20th century were built on five technologies, four of which were available before 1900 (Brown 1999):

- irrigation, which goes back several thousand years;
- chemical fertilizer, based upon the work of a German chemist in 1847;
- plant breeding, from Gregor Mendel's discovery of the principles of genetics in the 1860s;
- short-stawed wheats and rices, from Japanese success dwarfing cereals in the 1880s; and



Module 2, Investigation 2: Briefing

What is industrial agriculture?

- hybrid corn, from development in 1917 at the University of Connecticut.

One should add to this list the application of huge amounts of energy, especially petroleum, which is needed to

- manufacture, transport, and operate farm machinery;
- build and operate irrigation systems;
- manufacture, transport, and apply pesticides and herbicides;
- mine, manufacture, and transport fertilizers; and
- process, package, transport, and display food.

How have farmers increased their yield in grain crops while utilizing less agricultural area (Table 2)? Agricultural systems use a variety of inputs to improve their yield. One of the most important inputs to industrial agriculture is fertilizer produced from petroleum. Table 4 documents the amount of fertilizer use throughout the world.

Changes in the use of fossil fuels and other energy inputs in agriculture over time are shown in Table 5.

Table 4: World fertilizer use, 1950-1995

Year	Millions of Metric Tons
1950	14
1960	27
1970	63
1980	112
1990	140
1995	120

Sources: Brown 1987; 1997; 1999

Table 5: Energy use in world agriculture (millions of barrels of oil)

Year	Fuel*	Fertilizer Manufacture	Other **
1950	160	70	46
1960	321	133	91
1970	498	310	162
1980	789	552	268
1985	940	646	317

Notes: *Fuel = fuel for tractors and other farm machines, including irrigation equipment. **Other = energy used to (1) synthesize pesticides and herbicides, (2) manufacture farm machinery, (3) apply fertilizer, and (4) dry grain. Figures are estimates because no reliable data exist.

Source: Brown 1987

Table 6: Calories* of energy used to produce 1 calorie of food in various food production systems

Calories	Traditional Agriculture	Industrial Agriculture
10-20		Ocean fishing
5-10		Feedlot beef
2-5		Intensive eggs
1-2	Coastal fishing	Modern milk from grass-fed cows
0.5-1	Low-intensity eggs	Intensive soybeans and peanuts
0.2-0.5	Range-fed beef	Intensive corn
0.1-0.2	Low-intensity corn, peanuts	Intensive wheat, potatoes
0.05-0.1	Wet rice	Intensive rice
0.02-0.05	Wet rice	

* A measure of heat energy, 1 calorie will raise 1 gram of water 1 degree Celsius.

Source: Adapted from Paul R. Ehrlich et al. 1977. *Ecoscience: Population, Resources, Environment*, p. 349. W. H. Freeman and Company



Module 2, Investigation 2: Briefing

What is industrial agriculture?

The high productivity of labor in industrial agriculture (Table 1) is made possible by the application of huge amounts of energy. In traditional, or subsistence, agriculture, the amount of energy used is small compared to the yield, but in industrial agriculture, more energy is expended than produced (Table 6). For example, to produce and deliver to a U.S. consumer one can of corn that has 270 **calories** in it, a total of about 2,800 calories of energy must be used. And to produce about 4 ounces of beefsteak, which also provides about 270 calories, takes 22,000 calories of energy (Seitz 1995).

Thus, we can say that in terms of labor inputs, industrial agriculture is highly productive, but in terms of energy inputs, it is not. Because of this, Barbara Ward was led to remark:

The high-energy U.S. food system is one reason why the United States, for 5 percent of the world's people, is now consuming nearly 40 percent of its nonrenewable resources (Ward 1979: 92).

The use of various inputs in industrial farming assures that fluctuations in prices affect the amount of money spent on these inputs. Figure 6 is a listing of costs for three farm inputs from 1992-1997.

Answer Questions 9-12 in the Log.

Part 4. What problems does industrial agriculture create?

In the following passage from a prominent magazine, one critic suggests some of the problems with industrial agriculture as it was practiced in the United States during the 20th century.

A third of [U.S.] farmland topsoil, accumulated over millennia, [has been lost in the last century]. For every bushel of corn that Iowa grows, it sheds at least two bushels of soil. Farm runoff is . . . poisoning our drinking water . . . In 1948, at the dawn of the chemical age, American farmers used 15 million pounds of insecticides and lost 7 percent of their crops to insects; today they use 125 million

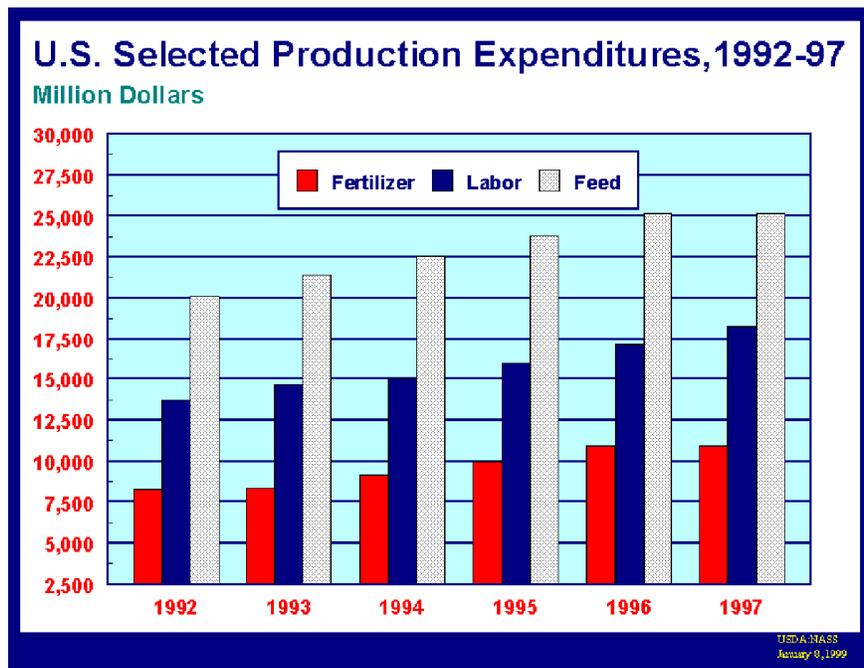


Figure 6: U.S. production expenditures for commercial agriculture, 1992-97

Source: USDA <http://www.usda.gov/>



Module 2, Investigation 2: Briefing

What is industrial agriculture?

pounds and lose 13 percent. Because most agricultural chemicals are made from fossil fuels, we [use] three calories of energy to produce each calorie of food we eat . . . In contrast, Tsembaga farmers in New Guinea, using Neolithic slash-and-burn methods, [use] less than a 10th of a calorie for each calorie they eat. For each American man, woman, and child, our agriculture [uses] 160 pounds of nitrogen, phosphate, and potash fertilizer each year, and 325 gallons of water each *day*. The Ogallala aquifer of the Great Plains held enough water 40 years ago to fill Lake Huron; in another 20 years it may be too low to pump. The great dams of the West are silting up. Sloppy irrigation and poor drainage . . . have caused [salty] conditions on 10 percent of our crop and pasture land. Should we escape the fate of the ancient empires that were done in by erosion, we may instead face that of the Sumerians, whose civilization crumbled as their soil turned salty (Eisenberg 1989: 59).

Answer Question 13 in the Log.

Part 5: How are improvements in technology reshaping industrial agriculture?

The use of remote sensing and **precision agriculture** is a promising attempt to reduce the reliance upon certain inputs, while improving both crop productivity and the environment. At the present time, diminishing crop prices coupled with increased costs have led to numerous attempts by farmers to increase yields per acre. Increasing irrigation, fertilizer, insecticide, and herbicide have been attempted, and excessive applications of these inputs means more costs and increased environmental pollution. As a result, industrial agriculture is moving toward the use of remote-sensing technologies and *precision agriculture*, a farming technology that attempts to specify the exact quantities of water, fertilizer, herbicide, and pesticide needed. Precision agriculture is being used to identify when and where these inputs should be applied to each specific field.

At the Global Hydrology and Climate Center in Huntsville, Alabama, managed by the Marshall Space Flight Center, NASA scientists are collaborating with university scientists in Alabama and Georgia to apply remote-sensing technology to support precision farming (NASA Marshall News

1999). In precision farming, growers break fields down into regions, or cells, analyzing growth characteristics of each cell and improving crop health and yield by applying precise amounts of seed, fertilizer, herbicides, and pesticides as needed. Traditionally, farmers have lacked the ability to make close analyses of specific cells. When they fertilized their crops, they simply spread the fertilizer uniformly across the entire field. Improvements in technology, including the use of remote sensing, allow farmers to tailor the amount of this agricultural input more precisely.

Remote sensing uses instruments on airplanes or orbiting satellites to gather information about Earth's surface. These instruments, which measure electromagnetic radiation, including thermal energy reflected or emitted by all natural and synthetic objects, can be an excellent tool for increasing agricultural production. As Doug Rickman, lead scientist for the Global Hydrology and Climate Center, stated:

We can fly over an area and precisely map its plant quality and soil makeup—including mineral variation and organic carbon content—in approximately 6-foot increments. Farmers have sought this ability for 30 years (NASA Marshall News 1999).

Figure 7 is a remote-sensing image of land types of the Midwest. The various colors indicate different types of land systems that scientists can then identify to assist agricultural production.

Using remote sensing, scientists can identify areas that will naturally have a low yield and reduce the amount of fertilizer applied. As Paul Mask, professor of agronomy at Auburn University, stated:

If the maximum capability of an area is 50 bushels an acre, there is no need to fertilize for 120 bushels. It does no good (NASA Marshall News 1999).

Such precise crop maintenance benefits society in another way, according to Mask:

Excess nitrogen can leak into groundwater. Other fertilizers can increase pollution problems,



Module 2, Investigation 2: Briefing

What is industrial agriculture?

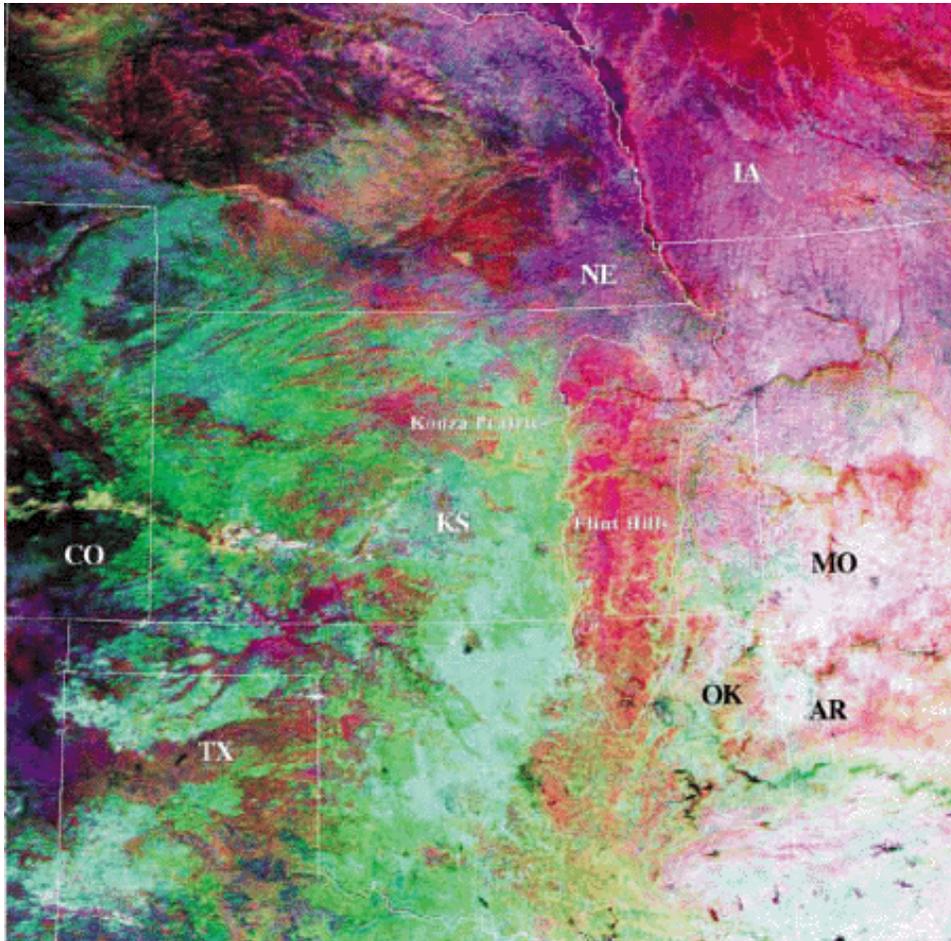


Figure 7: AVHRR composite image of the central United States showing land cover classification

Source: http://www.earth.nasa.gov/visions/app_factbk99/

threatening public health. By adding only the amount of fertilizer the land and the crop can effectively use, we can reduce such problems.

When NASA began studying precision agriculture techniques in the 1970s, the practice was hampered by scientists' inability to accomplish such precise mapping. Measuring yield was also inconvenient, time consuming, and often imprecise. According to Doug Rickman:

To measure a single field of 80 to 100 acres, you might take six soil samples from different parts of the field, send them to a lab, and wait days or weeks for the results. And six samples don't give you a very accurate measure anyway — soil quality can vary dramatically all across that area (NASA Marshall News 1999).

Remote sensing, therefore, offers an improvement to sampling techniques that can assist precision agriculture techniques.

The Kansas Applied Remote Sensing Program is using remote sensing to determine corn and wheat yields in the Midwest region of the United States. Figure 8 shows the 1998 corn yield estimates in Iowa. This type of information assists farmers in predicting their yields and in improving agricultural output.



Module 2, Investigation 2: Briefing

What is industrial agriculture?

1998 Corn Yield Estimates in Iowa

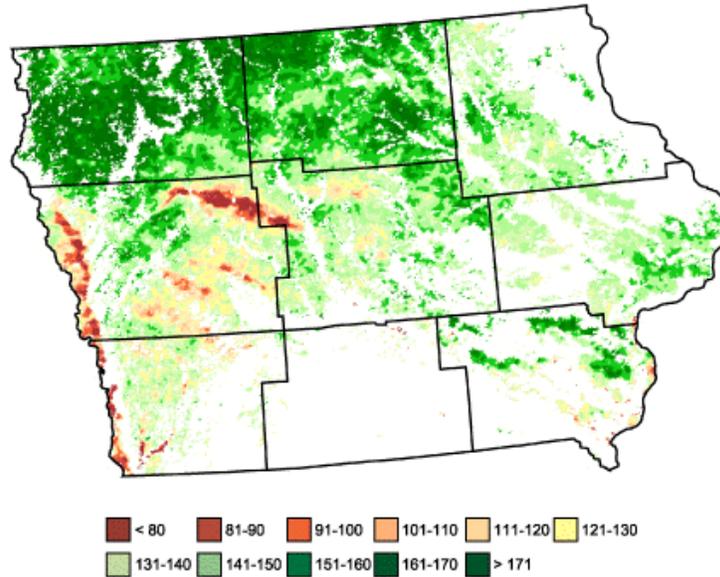


Figure 8: 1998 Iowa corn yields measured as NDVI (greenness) of crops so yield predictions can be made

In the first half of the corn growing season, strong winds and several isolated hailstorms did large amounts of damage to the corn crops in Iowa. This image is used to demonstrate that the areas damaged by the storms had reduced yields.

Source: <http://www.kars.ukans.edu/products/iowa.htm>

The Upper Midwest Aerospace Consortium (UMAC) is another group investigating the use of remote sensing for increasing agricultural output. UMAC is providing remote-sensing data to sugar beet growers in the Red River Valley in North Dakota, an important sugar beet producing region. UMAC scientists use aerial crop scouting to examine an area of 6 miles by 10 miles covering St. Thomas Township in North Dakota. Let's imagine how this type of information is helpful to farmers.

Scenario: Imagine that you own the farmland mapped in Figure 9. Notice that you have three crops (wheat, sugar beets, and potatoes) distributed together on the land. You have decided to

buy a satellite image of your plot so you can look at a precision agriculture image of the plot to determine any needed changes. You buy Figure 10.

Answer Question 14 in the Log.

For industrial agriculture to increase output while reducing the need for inputs that put strains on the environment, techniques like precision agriculture will need to be utilized in the future. Remote sensing and other satellite technologies will be extremely useful in reducing the need for fertilizers and pesticides, while also improving crop yields.

Answer Question 15 in the Log.



Module 2, Investigation 2: Briefing

What is industrial agriculture?

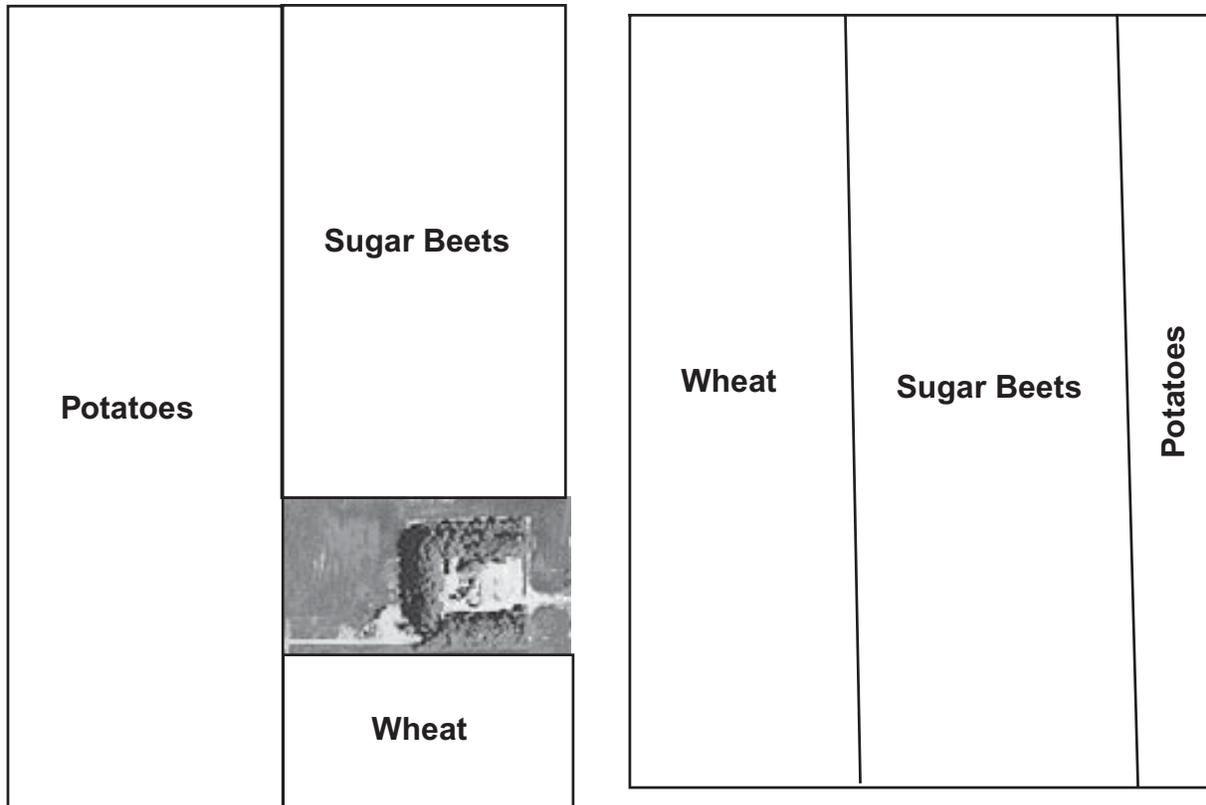


Figure 9: Map of images shown in Figure 10

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Module 2, Investigation 2: Briefing

What is industrial agriculture?

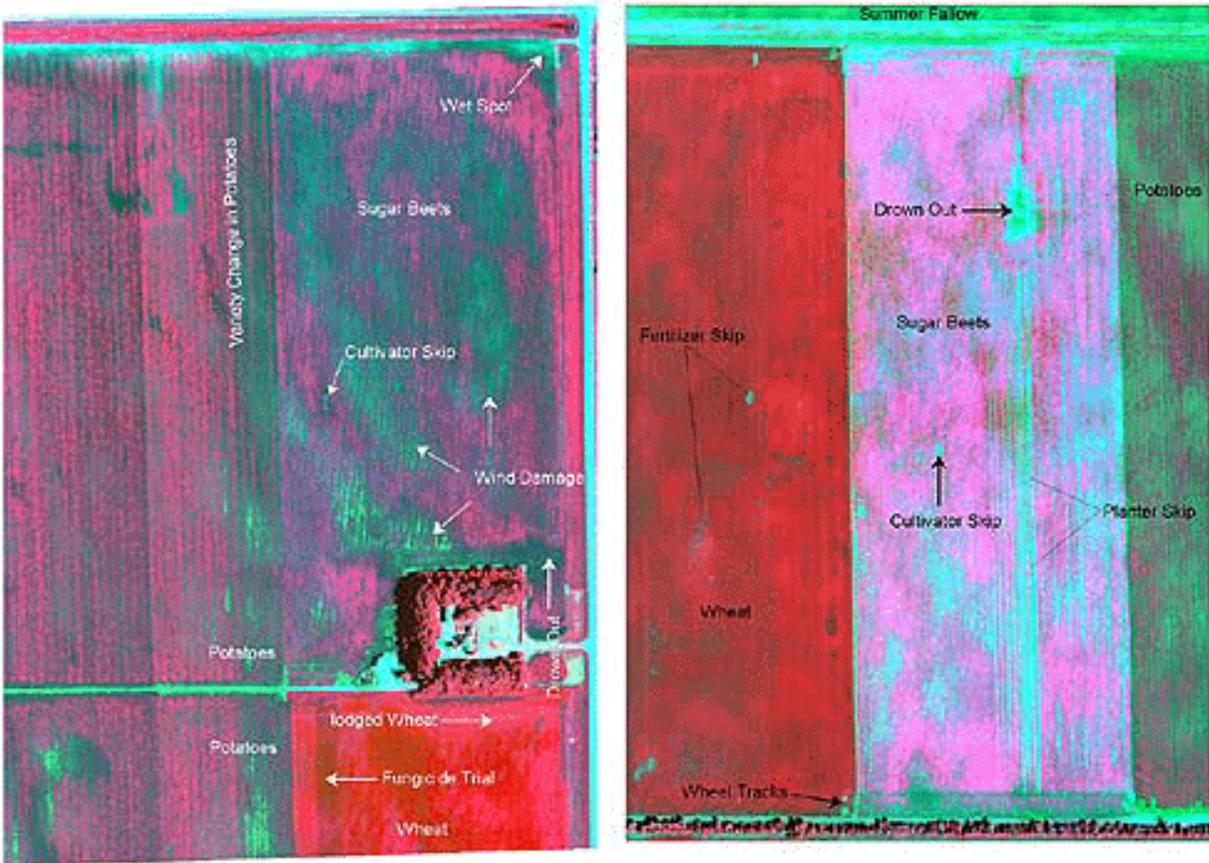


Figure 10: Remote sensing of North Dakota

Figure 10 is a picture taken on July 11, 1999. The area was flown over twice using the Positive Systems' ADAR 5500 camera, which collects half-meter resolution digital data in four multispectral bands. The spectral channels used to generate these color composites are green, red, and infrared. In this case, crops with fully developed canopy appear red. Sugar beets, still in their early stages, are pink, and the recently planted crops where the background soil reflectance dominates, appear green.

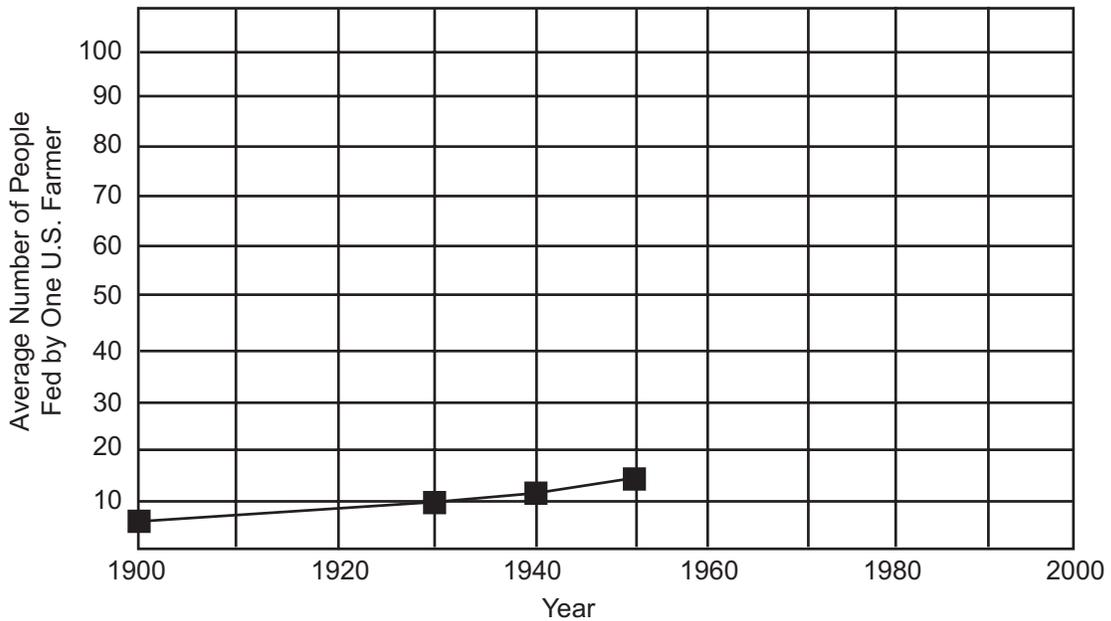
Source: <http://www.umac.org/new/stthomas.html>



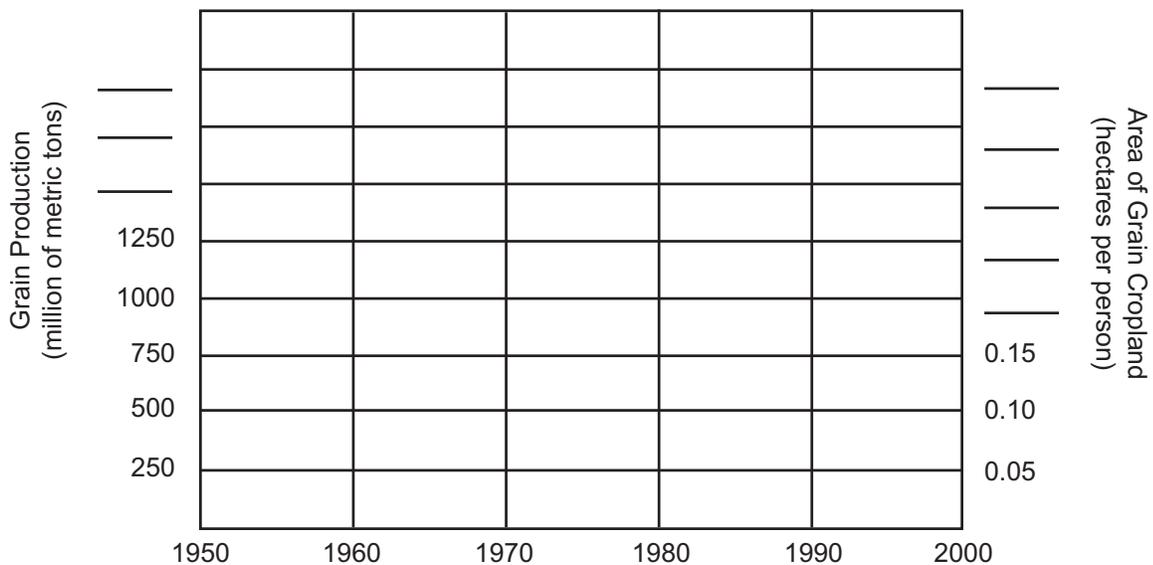
Module 2, Investigation 2: Log

What is industrial agriculture?

1. Complete the graph of the data given in Table 1. What do these data tell you about agricultural trends?



2. Graph the data given in Table 2. What do these data tell you about agricultural trends?

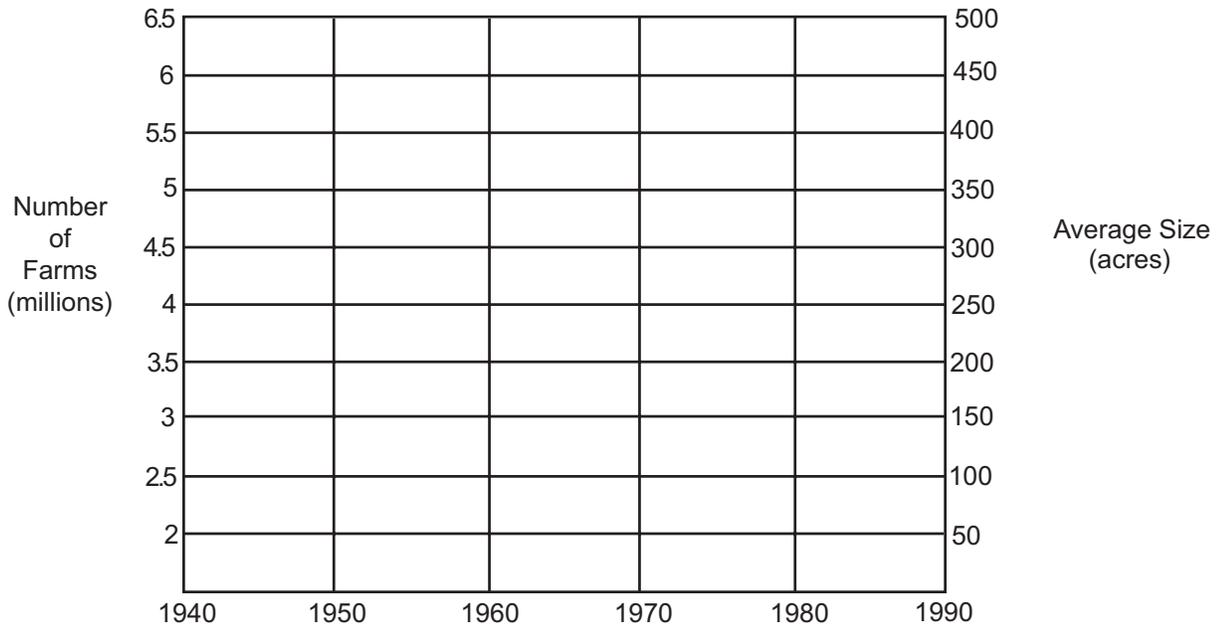




Module 2, Investigation 2: Log

What is industrial agriculture?

3. Graph the data given in Table 3. What do these data tell you about agricultural trends?



4. Agriculture was described as an input-output system. Write down three more examples of an input-output system and explain your examples.

1)

2)

3)

5. Explain the difference between “production” and “productivity” using examples that are *not* found in these materials.



Module 2, Investigation 2: Log

What is industrial agriculture?

6. Describe the trends in industrial agricultural production and productivity in the 20th century.

7. In **Part 2: What do the landscapes of industrial agriculture look like?** you were shown satellite images of only a few examples of these landscapes. Write down *two* more examples of different landscapes of industrial agriculture that you have personally seen.

1)

2)

8. What are the characteristics of industrial agriculture? In other words, what do all the examples of this type of agriculture have in common? List as many characteristics as you can.

9. What natural resource is used to make fertilizers, pesticides, and farm machinery? List three other agricultural inputs that come from this natural resource.

1)

2)

3)



Module 2, Investigation 2: Log

What is industrial agriculture?

10. Do you think the increasing use of fertilizer in industrial agriculture is a practice that can be sustained in the future? Why or why not?

11. By what measure is “traditional” agriculture more productive than industrial agriculture? By what measure is industrial agriculture more productive than traditional agriculture?

12. What trends do you see in the amount of money spent (expenditures) on agricultural production in the United States? What is your evidence? Do these data enable us to conclude anything about changes in productivity? Why?



Module 2, Investigation 2: Log

What is industrial agriculture?

13. From the quote from Eisenberg and other information you have gathered, list what, in your opinion, may be the three biggest problems of industrial agriculture, and support your choices.

1)

2)

3)

14. What information can you get from remote sensing, and how would this information help you if you were a farmer? Examine the satellite image in Figure 10. What changes would you make on your plot of land and why?

15. How might the new technologies of remote sensing and precision agriculture help solve three of the problems of industrial agriculture mentioned in **Part 4**. **What problems does industrial agriculture create?**

1)

2)

3)



Module 2, Investigation 2: Log

What is industrial agriculture?

16. Create a graphic organizer to illustrate the inputs and outputs of industrial agriculture.

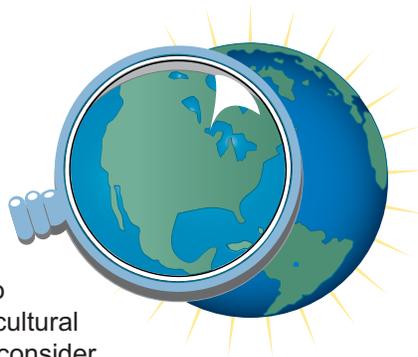
Inputs

Outputs

Industrial
Agriculture



Who will feed the world?



Investigation Overview

Investigation 3 focuses on meeting the food needs of an increasing global population. Students work in groups to investigate population growth and agricultural production in major world regions and consider how developments in technology and monitoring systems will address these concerns in the future. The investigation concludes with an investment challenge in Mozambique. Students work in groups to make recommendations for improving agricultural production in this country.

Time required: Four to eight 45-minute sessions (as follows):

Introduction and Part 1: One or two sessions

Part 2: One or two sessions

Part 3: One session

Part 4: One or two sessions

Materials

A copy of Investigation Briefing and Log for each student. The key to the Log is included in this Educator's Guide.

Computer with a CD-ROM drive. The Mission Geography CD contains color graphics needed for this activity.

World atlases

Optional: Access to the Internet, which offers opportunities for extending this activity.

Content Preview

Investigating food production involves a number of topics. First, an increasing global population will continue to put pressure on world regions to increase agricultural production to meet demand. Population growth is centered in the developing world regions including Asia and Oceania, Latin America and the Caribbean, and sub-Saharan Africa. Measuring agricultural production in relation to population growth puts sub-Saharan Africa in the most tenuous position, as per capita (per person) food production declined 12 percent between 1965 and 1985. Increasing agricultural production will involve a variety of techniques including satellite measurements of vegetation growth. Additionally, investing in certain types of crops will play a key role in meeting human demand.

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information

- Produce and interpret maps and other graphic representations to solve geographic problems.

Standard 5: Places and Regions That people create regions to interpret Earth's complexity

- Use regions to analyze geographic issues and answer geographic questions.

Standard 9: Human Systems

The characteristics, distribution, and migration of human populations on Earth's surface

- Predict trends in spatial distribution of population on Earth, and analyze population issues and propose policies to address such issues.

Standard 14: Environment and Society

How human actions modify the physical environment

- Evaluate the ways in which technology has expanded the human capacity to modify the physical environment.

Standard 18: Uses of Geography

How to apply geography to interpret the present and plan for the future

- Use geography knowledge and skills to analyze problems and make decisions within a spatial context.

Geography Skills

Skill Set 4: Analyzing Geographic Information

- Make inferences and draw conclusions from maps and other geographic representations.
- Use the processes of analysis, synthesis, evaluation, and explanation to interpret geographic information.

Classroom Procedures

Beginning the Investigation

- Hand out a **Briefing** and **Log** to each student and have them read the **Background** section. Draw out discussion with such questions as:
Do you think hunger and famine will be eliminated during your lifetime? Why or why not?
What do you think Secretary Glickman meant by his statement about an “unstable food supply”?
What do you see as the difference between increasing food production *and* increasing food availability?
What is meant by “agricultural sustainability?” Why do you think this is an important idea?
- Tell students that they will work in regional teams in the first part of this activity and that they will conclude by making group investment decisions for stimulating agricultural production in Mozambique.

Developing the Investigation

- Have students read the **Objectives** and take any questions they may have.
- Leaf through the materials with students and point out the underlined Log questions to be answered on the Investigation **Log** at the end of the materials. The key to the **Log** is found at the end of this Educator's Guide. Give students a schedule for completing the **Log**.
- Direct attention to the **Scenario: Planning to feed world regions** section. Divide the class into six teams roughly equal in size. Each team is to represent a major world region. The six world regions are listed in Table 2. Emphasize the importance of studying and discussing the materials as a team and of working on team answers to the **Log** questions.

Alternative: If you prefer smaller teams, you may wish to form two teams for each region. To have students appreciate the differences in population between these regions, you might ask them to compute the proportional representation of the teams using the “Percentage of World Population” column in Table 1. For example, 55 percent of the students would represent Region 4, and 4 percent would represent Region 3. You might even use these proportions to form teams, but that would give you teams of very uneven sizes.

- Have teams meet to locate their world region on a map and to identify the countries that comprise their region. Have teams share this information with the entire class.
- Set students working through the materials, beginning with **Part 1: How do the populations of world regions compare?** Direct attention to Table 1, which marks each year the global population increased by 1 billion. Have students add a column to Table 1 by calculating the number of years between the next billion increment. There will be eight entries:

Growth from:	
1 to 2 billion	130 years
2 to 3 billion	30 years
3 to 4 billion	15 years
4 to 5 billion	12 years
5 to 6 billion	12 years
6 to 7 billion	13 years
7 to 8 billion	14 years
8 to 9 billion	17 years

Assist students in graphing this table at Question 1 on the **Log**.

- After the regional teams have worked through **Part 3: What is the need for increasing agricultural production?**, they should begin on **Part 4: Investing in Mozambique**. Be sure students understand that Part 3 demonstrated that of all the major world regions, sub-Saharan Africa will have the hardest time producing enough food to meet demand. As a result, Part 4 will focus on Mozambique as a case study to investigate how agricultural production can be increased.

Students can stay in their assigned groups, but they are no longer representing a major world region. Instead, they should pretend to be part of a FAO team investigating how to increase food production in Mozambique. The first section will ask them to estimate the cropland use intensity (CUI) value for 1973, 1992, and 1995 using Figures 8, 9 and 10. Students should make estimations based on the percentages given in the figures. It is not critical that they get the exact answers; rather, they should understand that the CUI is currently very low for Mozambique.

Students should continue to work in their groups and have an opportunity to complete their major task: making investment decisions for the agricultural sector. Students are given the task of investing \$40 million in a variety of agriculture and fishery sectors to improve production in the country to 90,000,000 tonnes. Investments must be made in multiples of \$5 million, and students can invest as their team desires, but they must support their decisions on Log Question 9. Students will need some guidance with this part of the investigation as Table 5 provides some steering information on the value of these investments as either a source of consumption or foreign exchange. Table 5 presents these as multipliers, which students can utilize to make investment decisions. They should multiply their investment by the value of the multiple, and then multiply this again by the production increase in tonnes to determine the investment outcome. Remind students that they want to invest for both consumption and foreign exchange. Point out that the foreign exchange earned by exporting crops can be used for consumption or to buy food on the international market. Students should also be encouraged to diversify in order to assist in protecting against harmful pests or bad weather that might destroy a single crop.

- Have teams report their investment recommendations and reasons to the whole class, and have the class discuss, classify, and evaluate these recommendations according to agreed upon criteria, such as importance, practicality, agreement with facts, etc.

Concluding the Investigation

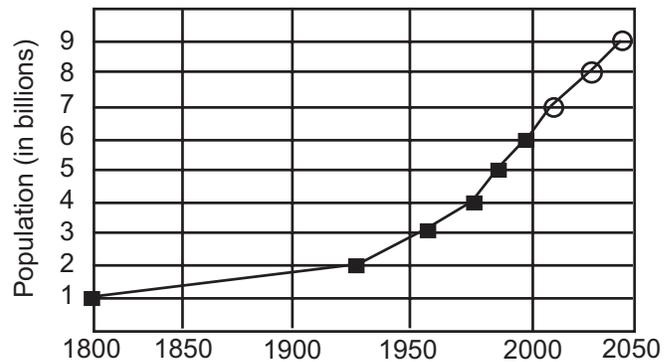
- Debrief the investigation by discussing the Log questions. You may wish to debrief the activity even further by referring to the **Objectives** listed at the beginning of the **Briefing**.

Evaluation

Evaluate the Logs using the answers in this Educator's Guide. You may wish to provide your own guidelines for the team investment reports, or you may simply ask for a numbered list of recommendations.

Log

- The graph of Table 1 should look like the following:



This is a classic J-curve of population growth with very little growth, then growth increasing at greater and greater rates (reflecting exponential growth) shown by a steeply rising curve, and finally, growth beginning to slow as seen in the flattening of the curve when the population is very large.

- Using Figure 2, compare and contrast the diet in your region with the other regions.
This will depend on the student's choices of which foodstuffs to emphasize. Use Figure 2 to guide your assessment of their answers.
- How do you explain these differences in diets?
Diets around the world vary a great deal due to the availability of certain foodstuffs. For example, people in the developed world can afford to eat livestock products and fats more regularly than people in developing countries. Food production also contributes to variation in diets, as well as differences in food preferences.
- Compare and contrast the dietary energy supply levels in your region with the other regions. Specifically, name the countries (and their levels) in your region that have the highest and the lowest dietary energy supplies, and compare and contrast these with other countries with very high and very low levels.
As with Question 2, this answer depends on the students' choices of which countries in their region to emphasize. Use Figure 3 to guide your assessment of their answers.

5. With your team, brainstorm a list of reasons that might account for the variations in dietary energy supply levels between regions and countries and within countries.
- *Varying capacities to purchase food (people in richer countries can afford more livestock products and fats, for example)*
 - *Different availability of foods among countries*
 - *Diets of richer countries usually more balanced nutritionally and also contain a greater proportion of protein, particularly of animal origin, than those of the poor countries*
 - *Developing countries' diets characterized by a higher proportion of cereals*
 - *Significant variations in diet among countries reflecting differing production capabilities, access to food types, and tastes even for countries at similar income levels*
6. According to Figure 6, which regions in Africa have “very poor vegetation”? Why do you think this is so? *Northern Africa has very poor (or sparse) vegetation because of the climate and physical landscape. The Sahara Desert and the Sahel characterize this region, which has little to no rainfall on a regular basis. In the southern portion of Africa, the Kalahari and other deserts limit the amount of vegetation growth.*
7. According to Figure 6, which regions in Africa have shown “improvement” in their vegetation growth? *There are a few locations that have shown improvement in vegetation growth. Southern Africa, parts of South Africa, Botswana, and Namibia, have demonstrated improvement. Additionally, there has been improvement in parts of central Africa and in western Africa near the Ivory Coast.*
8. Estimate the cropland use intensity (CUI) for 1973, 1992, and 1995. How does this information assist your group in understanding agricultural production in Mozambique?
- The CUI maps (Figures 8-10) showed that 22 percent of the land was cropped before independence (1973). The CUI dropped to 5 percent by the end of the civil war in 1992 and rebounded to 17 percent by 1995. This information is helpful for a number of reasons. First, it allows agricultural agencies to identify the current state of agricultural intensity in the country. All of these estimates are very low, indicating that greater investment in the agricultural sector is needed. Secondly, the CUI allows for an assessment of where agriculture is currently practiced within the country. This is extremely useful for determining which locations require future investments.*
9. Put your group investment recommendations for the \$40 million in the table, and explain why you are investing this way.
- Students should complete the table in the Log to get an investment return of 90,000,000 tonnes or higher, which was their investment challenge.*
- The investment decision that results in the highest production value is investing all \$40 million into maize or rice (resulting in a return of 120,000,000 tonnes of maize or rice). This is not the most ideal investment, however, because it forces the country to rely on only one crop. This could be disastrous if certain types of weather or pests destroy the crop. Students should try to balance investments in maize with rice and fishery products that are a valuable source of foreign exchange. In evaluating their answers, however, it is more important that students support their decisions. Choosing to invest in crops, rice and maize for example, is important for food security. On the other hand, students may choose to invest in crops that are a source of foreign exchange for the country. In this case, investing in nuts or fisheries would be logical.*



Module 2, Investigation 3: Briefing

Who will feed the world?

Background

More than one billion of today's six billion people suffer from hunger. How many will be hungry when the world's population doubles, as it is expected to do by the end of the 21st century? Or is it possible that hunger and famine will be eliminated in this century? Whether or not there will be enough food is a matter of speculation, but we can be certain that feeding the world will be a huge challenge. It will affect all regions of the world and all economic, political, social, and environmental systems. As former U.S. Secretary of Agriculture Dan Glickman said, "An unstable food supply is the greatest threat to our national security" (Smith 2000:14). Experts believe that it is crucial that we increase both food production *and* food availability to needy populations. If this can be done, we will also need to achieve agricultural sustainability—that is, to protect the environment against degradation from increased agricultural production. In this activity, you will investigate global food production and hunger. Additionally, you will examine sub-Saharan Africa to consider the ways that famine might be alleviated in the future.

Objectives

In this investigation, you will

- compare population growth and nutritional levels of world regions,
- consider the demands of increasing global population upon food production,
- learn that food security requires both a food supply and access to that supply,
- consider the role of industrial agriculture in feeding the developing world,
- examine ways that technology can help to prevent famines, and
- make investment decisions to stimulate agricultural production in sub-Saharan Africa.

Scenario: Planning to feed world regions

Imagine that you are a geographer working for the United Nations Food and Agriculture Organization (FAO). You have recently been assigned to a team of scientists investigating food and population issues in a major world region. Use Parts 1 and 2 of this investigation to help you assess, and report to the entire group, the status of population and food production in your region.

Part 1. How do the populations of world regions compare?

Understanding world hunger requires an analysis of the changing global population. To appreciate how the global population has changed, look at Table 1, which lists the years when the world's population reached an additional billion.

Table 1: Years when world population reached an additional billion

Population	Year
1 billion	1800
2 billion	1930
3 billion	1960
4 billion	1975
5 billion	1987
6 billion	1999
7 billion (estimate)	2012
8 billion (estimate)	2026
9 billion (estimate)	2043

Sources: U.S. Bureau of the Census 1998; Population Reference Bureau, Inc., 1999

As you work through this investigation, you should answer the underlined questions on the Investigation Log. For Question 1, make a line graph of the world's population from 1800 to 2043.

Nearly all of the population increase in the 21st century will occur in the poorer, developing regions of the world, specifically Africa, Asia (except Japan), Latin America and the Caribbean, and Oceania. By comparison, populations in the industrialized, developed countries will remain relatively constant (Figure 1).



Module 2, Investigation 3: Briefing

Who will feed the world?

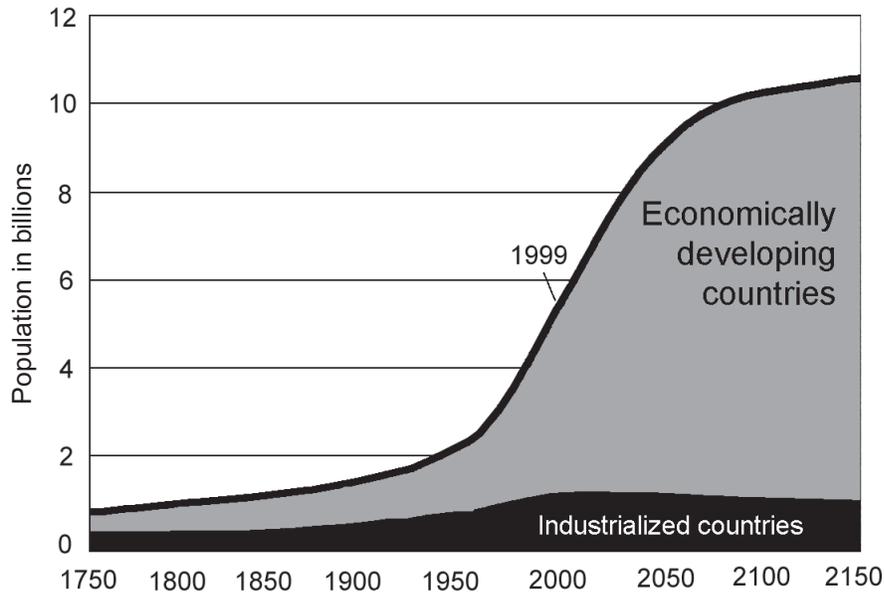


Figure 1: World population growth, 1750-2150 (population after 1999 is estimated)

Sources: The World of Child 6 Billion. 1999. Washington, D.C.: Population Reference Bureau and National Peace Corps Association. <http://www.prb.org> and <http://www.rpcv.org>

Table 2: Regional contribution to world population and world population increase in 1998

Region	Percentage of World Population	Percentage Contribution to World Population Increase
1. Eastern Europe and Newly Independent States	9	1
2. Sub-Saharan Africa	10	20
3. Near East and North Africa	4	9
4. Asia and Oceania	55	57
5. Latin America and the Caribbean	10	10
6. Industrialized Countries (U.S., Canada, Western Europe, and Japan)	12	2

The current contributions to world population by rich and poor regions can be seen in Table 2. Use the table to assess the population growth in your region.

Part 2. How do the diets of world regions compare?

Food is divided into many types, including animal oils and fats, milk and eggs, sugars, roots and tubers, and cereals. Each region has a different proportion of types of food in its diet (Figure 2). For example, Figure 2 shows that, in Latin America and the Caribbean, cereals make up 40 percent of the diet, and in East and Southeast Asia, 60 percent of the diet.

Sources: U.S. Bureau of the Census, 1998



Module 2, Investigation 3: Briefing

Who will feed the world?

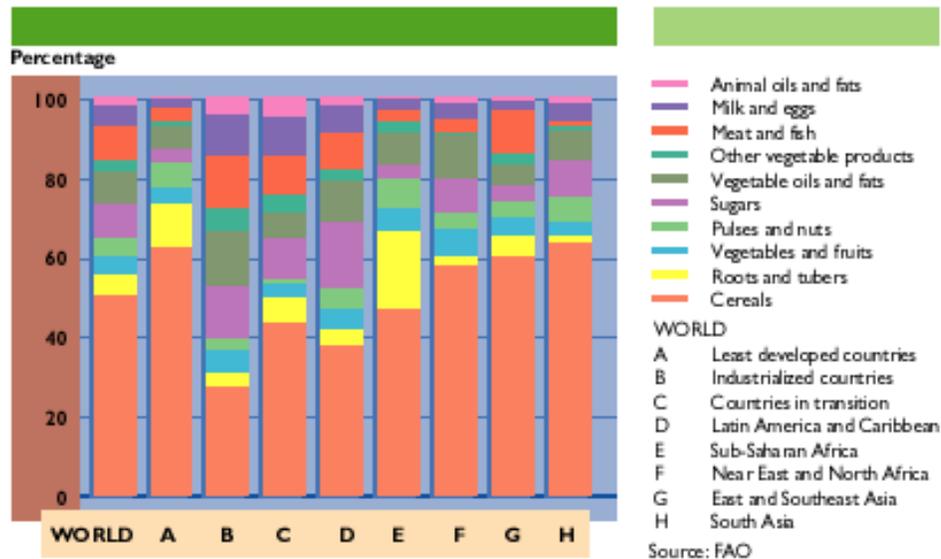


Figure 2: Share of food groups by region and country

Source: United Nations Food and Agriculture Organization 1998, The State of Food and Agriculture 1998: FAO Agriculture Series No. 31, <http://www.fao.org/docrep/w9500e/w9500e03.gif>

Use Figure 2 to determine what types of foods contribute to diet in your world region. (In reading Figure 2, teams assigned to Region 1 should use column C; Region 4 uses columns G and H; and Region 6 uses column B.)

You can use the information from the Log questions to help your team develop its recommendations. Answer Log Questions 2 and 3.

About 840 million people in the developing world suffer from malnutrition (Table 3). With less than 2,000 calories per person per day on average, about 15 percent of Earth's people live a life of permanent or intermittent hunger (Conway 2000). Malnutrition is particularly devastating

Table 3: Malnutrition in developing regions in 1998

Region	Number of Malnourished People (in millions)	Percentage of Population Malnourished
2. Sub-Saharan Africa	215	43
3. Near East and North Africa	37	12
4. Asia and Oceania	524	18
5. Latin America and the Caribbean	65	15

Source: United Nations Food and Agriculture Organization, 1998



Module 2, Investigation 3: Briefing

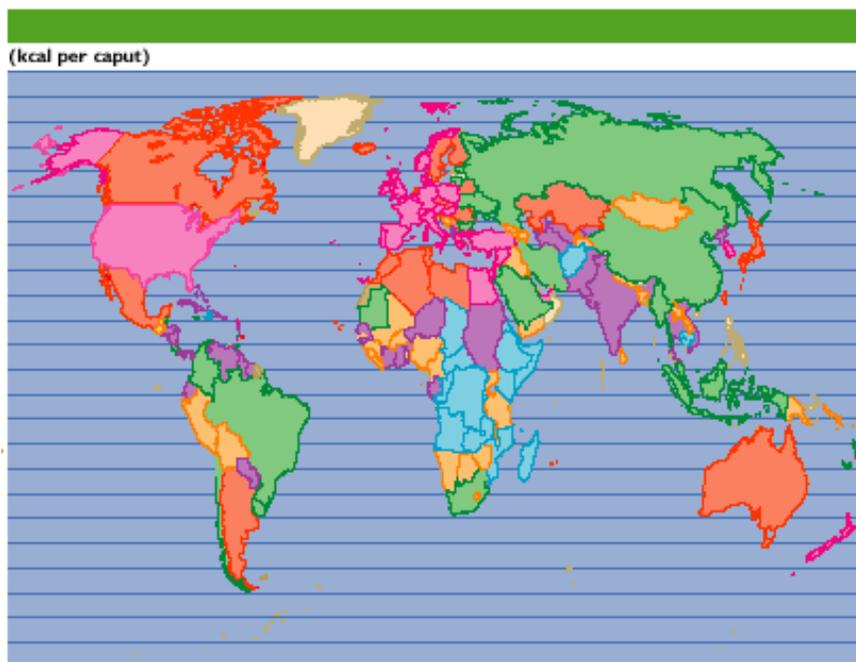
Who will feed the world?

to the young and elderly. Malnutrition weakens the body's immune system to the point that common childhood ailments, such as measles and diarrhea, are often fatal. Each day, 19,000 children die as a result of malnutrition and related illnesses (Brown 1999; World Food Summit 1996).

In contrast with developing regions, in some of the countries in Region 1 (Eastern Europe and Newly Independent States) and Region 6 (the industrialized countries—Japan, U.S., Canada, and Western Europe), over half of all adults are medically overweight (Gardner and Halweil 2000). This condition occurs when food energy intake exceeds energy

use, which contributes to the risk of death from high blood pressure, coronary heart disease, stroke, diabetes, and various forms of cancer. As can be seen from the global distribution of dietary energy supply levels (Figure 3), the people in some regions are overfed and in others they are underfed.

Figure 3 is a map of the countries of the world and their average per person dietary energy supply, measured in kilocalories (kcal) per day. Use Figure 3 to determine the dietary energy supply levels in your world region, and answer Log questions 4 and 5.



Source: FAO

Figure 3: Dietary energy supply levels by country in 1998

Source: United Nations Food and Agriculture Organization 1998, The State of Food and Agriculture 1998: FAO Agriculture Series No. 31, <http://www.fao.org/docrep/w9500e/w9500e02.gif>



Module 2, Investigation 3: Briefing

Who will feed the world?

Part 3. What is the need for increasing agricultural production?

Throughout the 1970s, the world watched in horror as numerous African countries suffered through droughts that led to massive famines. The images sent around the world (Figure 4, for example) only emphasized the belief that there wasn't enough food to feed the increasing global population. Although scientists have argued that famines are often caused by peoples' **lack of access to food** (access is blocked, for example, by low incomes, political conflicts, and wars), as opposed to a **shortage of food** (Sen 1981), most agree that the amount of food must continue to increase in the future to meet the demands of increasing populations.

Following large increases in global agricultural production from the Green Revolution, we still need to increase the amount of food produced. In fact, yields for cereals in the developing world decreased in the period 1985-94, following the peak Green Revolution yields (Figure 5). This recent decrease in rice, wheat, and maize yields is an even larger problem when population growth is considered.

Agricultural systems will be challenged in the future, as rising population levels will put pressure



Figure 4: Refugee camp in Africa

Source: United Nations Food and Agriculture Organization, 1998, <http://www.fao.org>

on their capacity to meet human demand. These pressures will be felt most where population growth is highest and incomes are lowest. This formula points to Africa, especially the sub-Saharan region, as the area with the greatest problem. A rapidly growing population in Africa will demand increases in agricultural output. Between 1965 and 1985, total food production grew in sub-Saharan Africa by 54 percent, but *per capita* food production declined by 12 percent (Turner et al. 1996).

You may have learned from the **Industrial Agriculture** investigation in this module that at the beginning of the 20th century, each

American farmer produced enough food to feed seven other people in the United States and abroad, but at the beginning of the 21st century, a U.S. farmer feeds 96 people (Brown 1999). This staggering fact resulted from the use of new technologies for planting, cultivation, and harvesting; irrigation and chemical fertilizers; and plant breeding and improvements, especially in wheat, rice, and corn. Wheat and rice are consumed largely by humans, but most of the world's corn harvest is fed to livestock and poultry (Brown 1999).

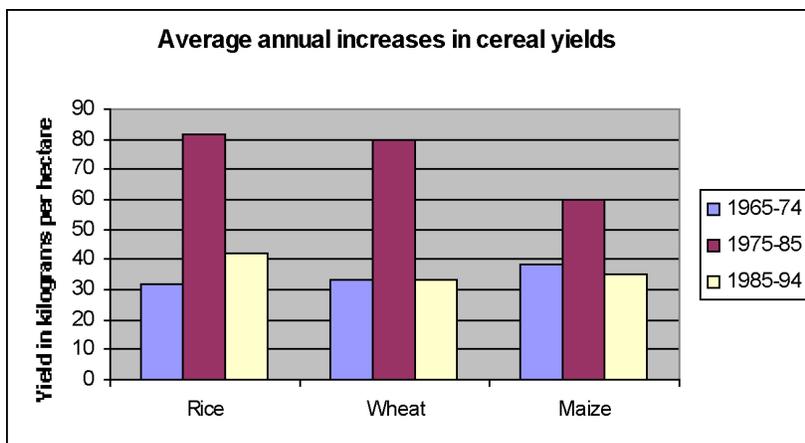


Figure 5: Cereal yields in developing countries from 1965-1994

Source: Conway 2000: 13



Module 2, Investigation 3: Briefing

Who will feed the world?

These technologies have produced enormous grain surpluses, especially in the United States, Canada, Europe, Australia, and Argentina. Many developing countries have been forced to buy these surpluses to help feed their rapidly growing populations. They often pay for these food grains with nonfood cash crops they grow such as coffee, tea, sugar, and cotton. Solutions to feeding the rapidly growing populations in the developing world must consider industrial agriculture, along with other strategies, to increase agricultural production.

Another part of the solution may involve the use of new technologies to reduce the chance of famines brought on by environmental fluctuations. For example, NASA satellite data, which are used to study the expansion and contraction of the deserts and semiarid lands of Africa, are the principal source for providing early warning of potential famines around the African continent.

Since 1987, scientists at NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, and the U.S. Agency for International Development (USAID) have been cooperating on a project to provide data to USAID's Famine Early Warning System (FEWS). They seek to understand natural variations of climate that relate to desert boundaries and adjacent semiarid areas, and to determine any changes in climate between 1980 and 2000 (Dunbar and Kenitzer 1993).

As Dr. Compton J. Tucker, a scientist in the Laboratory for Terrestrial Physics at Goddard, states:

The Agency for International Development of our State Department came to us after seeing some of our publications on remote sensing of the Sahel of Africa and indicated it was interested in studying the famine stricken regions in Africa. Since we use satellites to look at vegetation in these regions, we can obtain data on countries that historically have been affected by famine and do so very close to real time.

Using daily data from the National Oceanic and Atmospheric Administration (NOAA) -7, -9 and -11 meteorological satellites, scientists measure the density of green vegetation in a specific region every 10 days. As Tucker states:

Since 1981, we have compiled a time series of plant-growth histories for the entire continent of Africa, and we use it to assess current and future vegetation growth. This information is used by USAID's FEWS to determine where droughts are occurring, their severity, and how widespread they are.

USAID's FEWS augments the satellite data with meteorological information and socioeconomic information, where available, to determine the location and severity of drought in Africa, Tucker said. When drought conditions are detected, a FEWS team can begin coordinating relief efforts, if required. For example, changes in vegetation can indicate oncoming drought. Figure 6 shows a series of satellite vegetation models for the African continent. The *Normalized Difference Vegetation Index* (NDVI) is a measure of the greenness of the vegetation, which is used to generate assessments and make predictions. The first image is the NDVI taken during January 1-10, 2000. The second image (vs Previous) is a comparison of the first image to previous years. Finally, the third image (vs Average) is a comparison of the first image to the average NDVI for the continent.

NASA research and USAID's FEWS are examples of how improvements in technology will contribute to agricultural productivity in various regions of the world. At the very least, having more data on vegetation growth and precipitation patterns should assist in reducing the chance of famines on the African continent.

Answer Questions 6 and 7 on the Log.



Module 2, Investigation 3: Briefing

Who will feed the world?

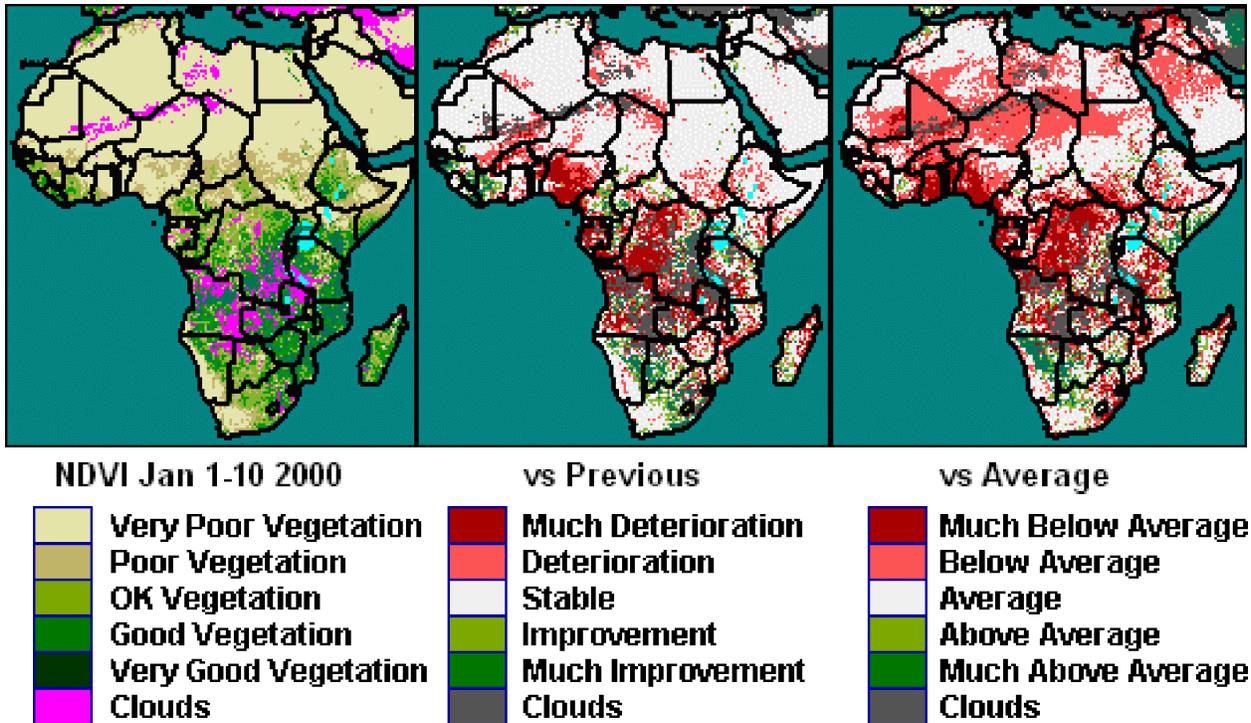


Figure 6: Satellite vegetation analysis for Africa

Source: USAID Famine Early Warning System, 1999, http://www.info.usaid.gov/fews/imagery/sat_afr.html

Part 4. Scenario: Investing in Mozambique

Since sub-Saharan Africa faces the greatest challenge for increasing agricultural production to meet a growing population, this section addresses a specific sub-Saharan country. Continue to imagine that you are a geographer working for the United Nations Food and Agriculture Organization (FAO). Your team has been given the task of investing \$40 million to stimulate food production in Mozambique, one of the poorest countries in sub-Saharan Africa. Mozambique is located in southern Africa and has been significantly affected by colonialism and war. Mozambique was a colony of Portugal until 1975, when an 11-year war of independence ended with the establishment of an independent, Marxist government. But a 17-year civil war started soon after independence, with an internal military uprising that was supported by some foreign governments.

The civil war affected the people of Mozambique severely, especially in rural areas. Hundreds of thousands of people were killed. Over a million people fled the country, especially to Malawi, and more than a million others were displaced within Mozambique (Sill 1992). Many rural people migrated to the cities and the coast where the government maintained control. The country went into severe economic decline and agriculture was disrupted, so the country could not feed itself. By the late 1980s, Mozambique had one of the lowest per-capita caloric intakes in the world (Sill 1992).

USAID and FEWS have been active in Mozambique for a number of decades. As you learned earlier, FEWS utilizes satellite images to determine the health of vegetation in certain areas. Figure 7 shows maps of the NDVI for southeastern Africa comparing the average with conditions in 1991.



Module 2, Investigation 3: Briefing

Who will feed the world?

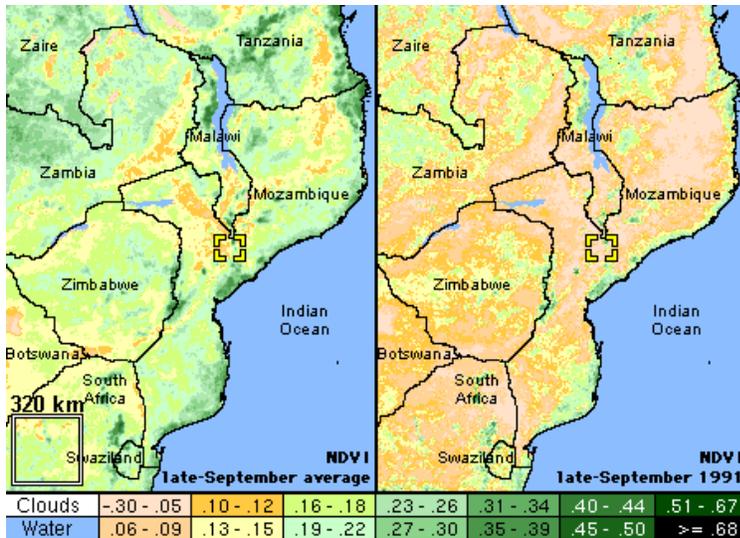


Figure 7: NDVI maps of southeastern Africa, including Mozambique

Source: <http://edcwww.cr.usgs.gov/earthshots/slow/Mozambique/Mozambique>
 Note: This is animated at the above site, so you can observe the changes over the course of one year.

In 1995, three years after the war ended, USAID asked the U.S. Geological Survey (USGS) to document the migration of rural Mozambicans during the civil war using LANDSAT and other satellite data. In areas of subsistence agriculture, cropland use intensity (CUI) approximates population density. CUI can also be used to connect agricultural statistics with specific geographic locations. For example, if Sofala Province reports a 50 percent rise in planted grains, CUI can identify where in the province the grains were planted.

Utilizing the CUI can assist your group in deciding how to invest in Mozambique because you can assess the current state of agriculture in the country. Using the process outlined above, a small part of Mozambique was mapped five different times, representing various stages in the civil war. The CUI for 1973 is represented as Figure 8 below.

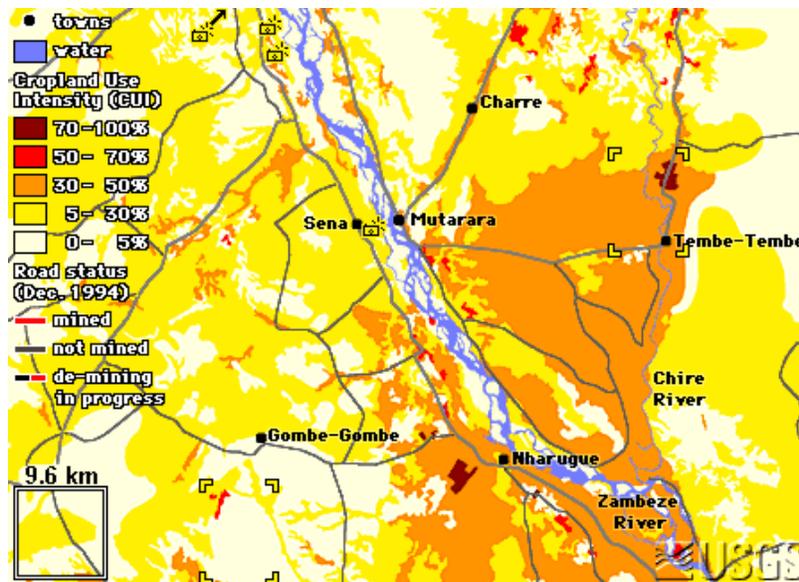


Figure 8: Estimated CUI in 1973

Source: <http://edcwww.cr.usgs.gov/earthshots/slow/Mozambique/Mozambique>



Module 2, Investigation 3: Briefing

Who will feed the world?

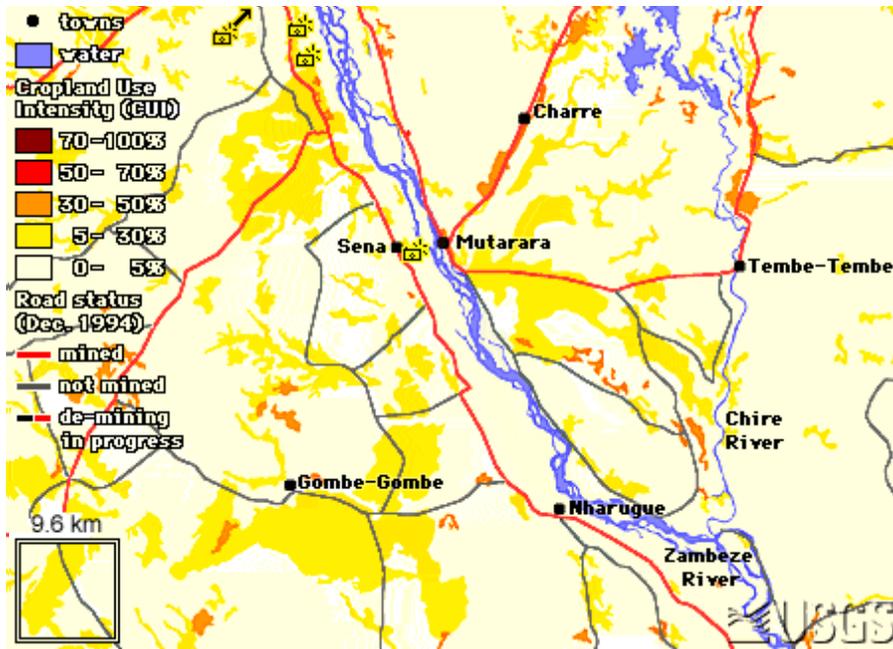


Figure 9: CUI in 1992

Source: <http://edcwww.cr.usgs.gov/earthshots/slow/Mozambique/Mozambique>

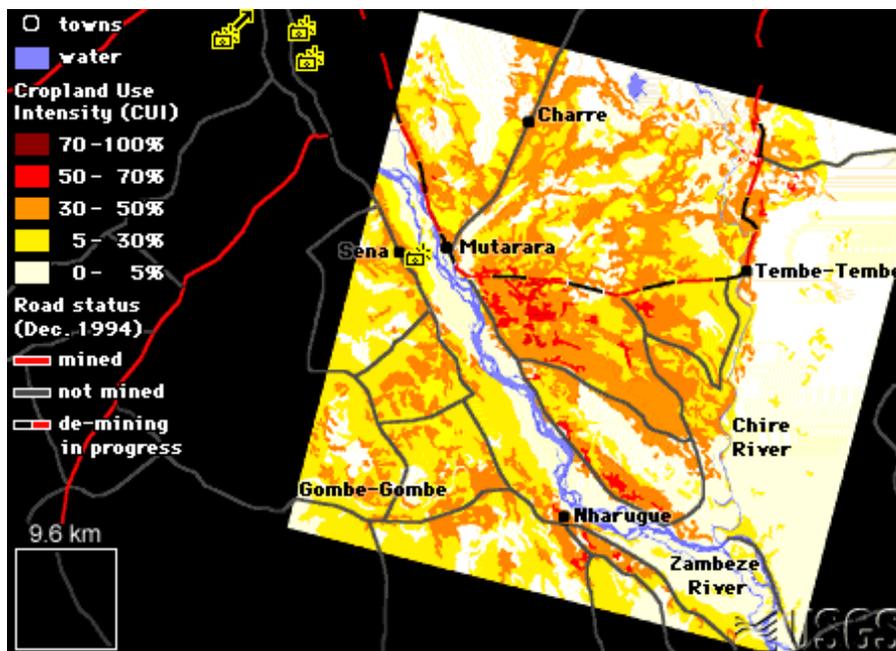


Figure 10: CUI in 1995

Source: <http://edcwww.cr.usgs.gov/earthshots/slow/Mozambique/Mozambique>

The satellite images of the CUI in 1992 and 1995 are represented as Figures 9 and 10.

Begin your task of investing in Mozambique by estimating the CUI from 1973 to 1995. Answer Question 8 on the Log.

Obviously, there is still a pressing need to increase agricultural output in Mozambique. Your team needs to determine how to invest the \$40 million in the agricultural sector. In 1996, Mozambique had 20 million hectares of arable land, of which 10 percent was cultivated (Turner 1999).



Module 2, Investigation 3: Briefing

Who will feed the world?

Table 4 is a breakdown of the major products in the agricultural sector. The fishery sector is also included, since this sector plays a key role in meeting food needs in the country.

Your challenge is to invest \$40 million and increase the total food production to 90,000,000 tonnes. You can invest the money however you want in allotments of \$5 million. Include an explanation for your investment decisions.

As you invest, think about which crops are better for consumption and which crops are a better source of *foreign exchange* (money a country makes from its exports). Remember that the money a country earns from exporting crops can be used to invest in crops for consumption or to buy food on the international market. Table 5 provides some information on the value of these crops as a source of domestic consumption and as an export product for foreign exchange. The multiples indicate the total return that an investment in a particular crop produces. That is, some crops respond to increased investment much more than others. To determine your return on investment, multiply your investment by the multiple value. You should then multiply this value by the production increase per \$1 million investment found in column 1, page 14 of your student log to determine the change in agricultural production as a result of your investment. As you invest, your group should balance the need to increase production for consumption with the need to invest in products for foreign exchange.

Use the table in the Log at Question 9 to list your investments.

Table 4: Agriculture and fishery production in Mozambique

	Current Production (tonnes)
Type of agriculture	
Maize	1,246,000
Rice	186,000
Other grains	387,000
Cassava	5,553,000
Beans	189,000
Peanuts	147,000
Type of fishery product	
Anchovies	300,000
Prawns and shrimp	14,000

Sources: Turner, 1999; Mozambique Agricultural Statistics, <http://www.ine.gov.mz/sector1/agricu.htm>

Table 5: Estimated multiple values for consumption or foreign exchange

	Value for Domestic Consumption as Multipliers	Value as Export for Foreign Exchange as Multipliers
Type of agriculture		
Maize	3	1
Rice	4	1
Other grains	2	1
Fruits/vegetables	2	1
Sugar cane	1	2
Roots*	3	1
Nuts**	1	3
Type of fishery product		
Lobster	1	2
Prawns and shrimp	1	5

*Roots include sweet potatoes, potatoes, and cassava.

**Nuts include peanuts and cashews.



Module 2, Investigation 3: Briefing

Who will feed the world?

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Module 2, Investigation 3: Log

Who will feed the world?

1. Make a line graph of world population from 1800 to 2043, using the data in Table 1. What does this curve look like, and why?

2. Using Figure 2, compare and contrast the diet in your region with the other regions.

3. How do you explain these differences in diets?

4. Compare and contrast the dietary energy supply levels in your region with the other regions. Specifically, name the countries (and their levels) in your region that have the highest and the lowest dietary energy supplies, and compare and contrast these with other countries with very high and very low levels.



Module 2, Investigation 3: Log

Who will feed the world?

9. Put your group investment recommendations for the \$40 million in the table below, and explain why you are investing this way.

	Production Increase Per \$1 Million Investment (in million tonnes)	Consumption Multiplier	Foreign Exchange Multiplier	Investment (in U.S. dollars)	Return on Investment (in million tonnes)
Type of agriculture					
Maize	1.00	3	1		
Rice	0.75	4	1		
Other grains	1.00	2	1		
Fruits/vegetables	0.75	2	1		
Sugar cane	0.75	1	2		
Roots*	0.75	3	1		
Nuts**	0.90	1	3		
Type of fishery product					
Lobster	0.90	1	2		
Prawns and shrimp	0.45	1	5		
Total				\$40 Million	

*Roots include sweet potatoes, potatoes, and cassava. **Nuts include peanuts and cashews.