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ABSTRACT

This interdisciplinary instructional unit contains eleven lessons for grades 10-12 which focus on the energy component of food production. There are lessons which contrast food production systems in various cultures and also lessons which look at different systems and techniques in use in this country. There are lessons dealing with organic farming and with the use of wild foods. Each lesson gives an overview, target audience, objectives, materials, time allotment, and teaching strategies, in addition to student worksheets. (BB)

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Interdisciplinary Student/Teacher Materials in Energy, the Environment, and the Economy

Agriculture, Energy, and Society

Grades 10, 11, 12

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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counsel on many phases of this materials development and effort.

February 1978
John M. Fowler
Project Director

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Agriculture, Energy and Society

Introduction

This unit contains a mixture of lessons whose major purpose is to cause the student to realize that food production involves much more in the way of energy input than the energy from the sun. The mass production system that dominates agriculture in this country, in fact, can be thought of as one which converts fossil fuel energy into food energy. And it does this at a low efficiency--no better than 10 to 15 percent.

This instructional unit is not intended to be critical of the food production system in this or any other country. It focuses only on the energy component of food production and there are many other components which need to be considered if comparisons are to be made. To emphasize these energy considerations and to make the lessons interesting to students we have produced lessons which contrast food production systems in various cultures and also lessons which look at different systems and techniques in use in this country. We also have a lesson dealing with the use of wild foods.

We hope teachers and students who use this unit will find these contrasts enlightening and will follow our lead in treating them objectively. We do not intend that any of the lessons be used to argue for or against any agricultural practice. We do hope, of course, that those who work with these units will come away with a better understanding of the relationship between food and energy.

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Teacher's Manual

Lesson	Contents	Target Audience
1	<u>Down on the Farm</u> Students assess their awareness of modern energy-intensive agriculture.	Social Studies, Science, Career Development
2	<u>Job Outlook in Food Production</u> Students choose a topic related to jobs in agriculture for a detailed report.	U.S. History, Economics, Career Development
3	<u>The Energy Requirements for Growing Different Foods</u> Are some crops more efficient? Students find out.	Social Studies, Science, Home Economics, Art
4	<u>Energy Efficiency in Corn Production</u> Students discover the economic principle of diminishing returns by looking at corn production over four decades.	Math, Science, Social Studies
5	<u>More and More May Be Less and Less: The Law of Diminishing Returns</u> Students apply the law of diminishing returns in a simulation and in the use of fertilizer	Social Studies, Economics, U.S. History, Contemporary Issues
6	<u>Comparing the Flow of Energy in Two Agricultural Societies</u> Energy flow in two agricultural systems is traced and compared.	Social Studies, Science, Cultural Geography

Lesson	Contents	Target Audience
7	Organic Farming? Both conventional and organic farms are examined from several points of view: energy, economics, and environment.	Social Studies, Science
8	Put the Horse Back in Horsepower? The Man Back in Manpower? Students examine the energy implications of the increasing substitution of chemicals and machines for animal products and human power.	U.S. History (20t Century Studies), Economics, Government
9	Modern Crop Drying: Direct, Efficient Use of Energy Direct use of energy in agriculture is illustrated for students by the process of crop drying.	Social Studies, Science
10	Herbicides: An Indirect Use of Energy Indirect use of energy in agriculture is shown in this lesson on herbicides.	Social Studies, Science
11	Eating Wild Foods: Is It a Reasonable Energy Alternative? Students identify, gather, and eat wild foods. They compare energy costs of foods from domestic and wild sources.	Social Studies, Science, English, Home Economics

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1. Down on the Farm

Overview	The purpose of this lesson is to help you assess your students' awareness of the enormous amounts of energy used by our modern methods of food production and processing. At the end of the self-assessment you may wish to give students the Background Notes. These data will serve as a self-check on individual responses on the Inventory.
Target Audience	Social Studies, Science, Career Development.
Objectives	Students should be able to: 1. Give their own assessment of the U.S. food and energy situation. 2. Evaluate their assessment with factual data.
Materials	Class sets of the Agriculture Inventory and AG-EN Puzzle Class set of Background Notes (Both can be found at the end of this packet in the section called Student Guide.)
Time Allotment	One class period.
Teaching Strategies	Begin this lesson by asking, "What would you say if I told you that it takes the energy equivalent of a half-glass of diesel oil to make one glass of milk?" Startle students further by adding, "Did you know that it takes the energy equivalent of two pounds of coal to produce one pound of bread?" "Did you know that it takes the energy equivalent of three pounds of coal to make one pound of ground beef?" Follow this brief introduction by having students respond to the Inventory on modern agriculture. Allow sufficient time to discuss each statement and to tabulate the results to generate more class interest. Ask: "What factors influenced your answer?"

Ask some students to trace the energy in a glass of milk (or orange juice) back to its origin in the sun. Have them include processing steps in their tracing. For example: cutting, washing, cooking (if necessary), freezing, drying, and packaging. Include the transportation steps: from the farm, to the processing plant, to storage and refrigeration in some cases, to the markets, and finally to the store and home table.

Have students report back to the class whenever their micro tracing is completed. The rest of the class should turn their attention toward reading the Background Notes comparing this new information to their responses on the Self-Inventory.

Special Note

Have your students mark the Inventory again at the end of the entire unit. Re-issue their original ones and have students compare their responses with their end-of-unit ones.

Providing for Individual Differences

Your students may enjoy doing the AG-EN Puzzle and Finding the Mystery Word.

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3. AG-ENERGY WORD SEARCH

A	C	G	P	E	S	T	E	O	R
I	R	A	G	N	O	A	C	P	A
F	O	S	S	I	L	F	U	E	L
E	P	O	U	T	A	O	D	S	E
R	D	L	N	R	R	O	O	T	G
T	R	I	D	O	O	D	R	I	U
I	Y	N	A	G	E	S	P	C	M
L	I	E	N	E	R	G	Y	I	E
I	N	T	O	N	S	E	E	D	S
Z	G	M	E	T	H	A	N	E	A
E	M	A	C	H	I	N	E	R	Y
R	O	T	A	T	I	O	N	Y	E

Hidden in the diagram are sixteen energy in agriculture terms that you and your students will need to know throughout the activities in the packet. Have students try to find as many as they can and circle them across and down. Then you may wish to have students define each word. In addition, have students fill in letters for the Energram. One letter goes in each space. The same letter can be used more than once. Find the Mystery Word.

Answers to Energram:

1. F E R T I L I Z E R
2. M E T H A N E
3. P E S T I C I D E
4. S O L A R / D R Y I N G
5. N I T R O G E N
6. Y I E L D

Answer to Mystery Word:

1. 2nd letter in one — E
2. 6th letter in two — N
3. 2nd letter in three — E
4. 5th letter in four (1st word) — R
5. 6th letter in five — G
6. 1st letter in six — Y

2. Job Outlook in Food Production

Overview

A search for the types of careers related to food is carried out in this lesson. The investigation is pointed at describing a particular career and predicting future trends in careers related to food and energy.

Target Audience

This lesson can be used in existing segments of instruction in U.S. History, Economics, and Career Development.

Objectives

Students should be able to:

1. Examine careers in food production.
2. Determine the part energy plays in these jobs.

Materials

Standard vocational sources presently available in most school Guidance Offices, libraries, resource rooms. (An example is the Occupational Outlook Handbook, Department of Labor). Write to the Department of Agriculture for free or low cost career profiles. Address mail to:

Agriculture Research Service
U.S. Department of Agriculture
Federal Building
Hyattsville, Maryland 20782

Time Allotment

One class period to introduce the research project. One-five class periods for research and preparing the report.

Teaching Strategies

Prior to this lesson, it would be a good idea to devote some time in class to a discussion of the importance of taking good notes. A lesson centered around outlining skills will help the student, not only in his or her notekeeping, but in the student's study skills as well. Stress locating supporting evidence for a general statement.

Developing the Lesson

Have students list the names of ten or twelve careers related to food production, including those in processing and transporting food. Deal with the following in a career search:

1. Present availability of work in the occupation.
2. Present and future earnings.
3. Education and special skills required.
4. Energy relationship to this particular job.

Have students include in their report a description telling how a particular career would be affected by curtailments in energy supplies.

Questions to consider are:

1. How would a change in either the price or the supply of natural gas or oil affect this job?
2. What would be the effect if fuel prices doubled? Tripled?
3. What if electricity became increasingly expensive?
4. What if energy conservation measures (or rationing) were enforced on a large scale?

Have students end their report with an answer to this question: "Would I consider this career for myself?" Why or why not?

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3. The Energy Requirements for Growing Different Foods

Overview

Farms require 2.5 percent of the total energy used annually in the United States (the equivalent of 340 million barrels of oil) for food production. With the on-going "energy crisis" it is important to comprehend the varying amounts of energy necessary to produce different crops. This lesson examines energy data for principal U.S. crops in terms of energy efficiency (per pound and per calorie of useful food). Also explored is the energy intensiveness of protein production in varying foods.

Target Audience

Science, Home Economics, Art, Social Studies.

Materials

Dittoed class copies of two tables, graph and worksheet.

Objectives

Students should be able to:

1. Identify the amounts of energy it takes to produce the food we eat.
2. Determine from tables and other prepared sources that some foods are more efficient than others.
3. Decide which crops are efficient in producing food protein from energy sources.

Time Allotment

One-three class periods.

Teaching Strategies

Distribute dittoed class sets of Activity 1. Generate class interest by asking questions about large numbers: one million, for starters. One million hamburgers placed end to end would reach to the moon. How many times around the earth would a chain of hamburgers go? Get eventually to the figure in the overview of this lesson, the number of barrels of oil used annually in food production in the United States.

[illegible]ing the Lesson

Before having students complete Activities 1, 2 and 3, explain the terms ratio and energy efficiency.

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Ratios for the Table in Activity 1 follow:

The Energy Required to Produce Food Products Consumed in a Year by One Person

Plant Product	Food Consumed (lbs/person/year)	Energy Required to Produce Food (gallons of oil/person/year)	Ratio (lbs/gals)
Flour & Cereal	140.0	2.2	64
Sugar	122.0	1.4	86
Vegetable Oils	41.8	3.7	11.3
Fruits	131.5	1.9	68.9
Potatoes	104.9	0.6	175
Beans, Peas & Nuts	16.1	1.8	9
Green & Yellow Vegetables	215.1	2.3	93.5
Miscellaneous	14.8	0.2	74
	786	14.1	

Animal Product	Food Consumption (lbs/person/year)	Energy Requirement (gallons of oil/person/year)	Ratio
Beef	116.0	19.1	6.1
Dairy	356.0	4.7	75.0
Pork	67.4	4.8	14.0
Animal Fats and Oils	14.6	3.5	4.2
Poultry	52.4	1.6	32.8
Eggs	39.0	1.3	30.0
Veal and Lamb	5.5	0.8	6.9
Fish	15.2	2.1	7.2
	666.1	37.9	

Student Activity 1

How Much Energy in Gallons of Oil Is Needed to Grow the Food We Eat?

The preceding chart shows the amount of fuel American farmers use to grow the food we put on our dining tables each year. First calculate the ratio of food consumed to energy required. Then fill in the blanks with the correct ratios for each food product. For example, for flour and cereal the ratio is:

$$\frac{\text{Food Consumed}}{\text{Energy Required}} = \frac{\text{140 lbs/person/year}}{\text{2.2 gallons of oil/yr}} = \text{64 lbs of food per gallon of oil}$$

Next, answer each of the following:

1. Which foods require the most gallons of oil to be grown?
   (Animal products.)

2. Which require the least?
   (Plant products.)

3. The energy ratios on the chart are based on energy used in farming. The higher the ratio, the more efficient the farming process. What additional information would you need in order to say that a certain food product is energy-efficient?
   (The total amount of useful food in the product; the amount of energy needed to process the food.)

4. Which two animal products would you eat if your only consideration was to choose energy-efficient products?
   (Dairy and poultry.)

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5. What evidence in the table suggests why few countries in the world eat a lot of beef?
(It takes too much energy to produce beef and costs too much.)

Student Activity 2 Which Plants are Energy-Efficient?

When we say a farm crop is energy-efficient, we mean that the ratio of the food energy in the plant to the energy used in growing it, is high. Some crops are more efficient than others; some aren't efficient at all. Look at the table below. Pick out your favorite food. Is it energy-efficient? Remember that in reading ratios, the higher the number, the more efficient the plant is.

Look at the table, then answer each question.

Table 2

Energy Efficiency Ratios for Common Crops

Crop	Ratio
Sorghum	5.3
Corn	4.4
Wheat	3.2
Soybeans	2.7
Oats	2.6
Potatoes	1.5
Rice	1.4
Apples	1.3
Grapes	1.1
Tomatoes	0.7
Green Beans	0.5
Peaches	0.6
Lemons	0.1

1. Which <u>two</u> crops get the best return in food energy from investments of energy used to grow and harvest them?
   (Sorghum and corn.)

2. Which four barely return the energy used in their production?
   (Tomatoes, green beans, peaches, and lemons.)

3. Which four are losing the energy-in/energy-out race?
(Tomatoes, green beans, peaches, and lemons.)

4. Suppose you are the agriculture minister in a developing, poor nation. Basing your choice on the table above, which three crops would you recommend for your nation's farmers? Why?
(Sorghum, corn, and wheat - because they are the most energy-efficient, they give back more in food energy than they use in cultivation.)

5. Playing the "What If..." game can give you plenty to think about. For example: What if... there was a great demand for more fruits and vegetables worldwide. What effect would this demand have on the following:

   a. The demand for fossil fuels?
   (The demand would increase.)

   b. The price of oil and natural gas?
   (The price would rise.)

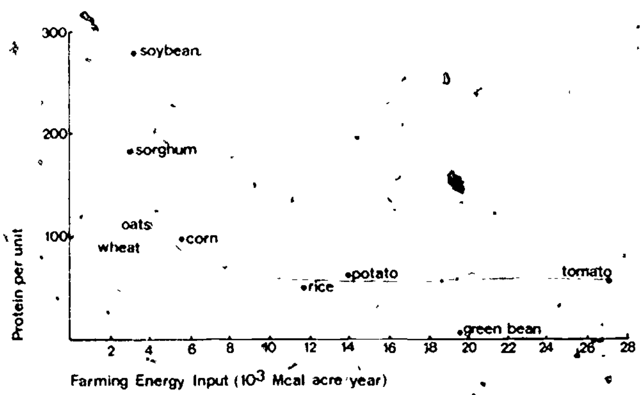
   c. Having enough food to feed the world's people? *(Answers will vary. If more emphasis is placed on growing inefficient crops, the total amount of food produced would decline.)*

   d. Conflict between rich and poor nations?
   (Answers will vary. Conflict could erupt if rich nations were to hoard certain foods or put unfair restraints on food sales.)

ERIC

Student Activity 3 — How Efficiently Do Plants Convert Fossil Fuel Energy Into Protein?

Examine the graph below and compare crops in terms of protein produced for each unit of energy put into its cultivation. Then answer the questions.



1. Which five crops are the most efficient at producing protein? Are these five grains or vegetables? *(Soybeans, sorghum, oats, wheat and corn. Grains.)*

2. Which four are least efficient protein producers? *(Rice, potatoes, green beans and tomatoes.)*

3. Soybeans are highly efficient in producing protein. However, a great deal has to be done to make them appealing to taste. How does this statement help explain why soybeans generally are fed to animals and not to humans? *(The animals convert the protein into tissue that can be consumed by humans.)*

4. Much of the delight of eating is provided by animal protein. Getting our protein this way is expensive. How can the information on the graph help you decide to eat soyburgers someday? What would have to change for you first? *(More people could get needed protein at a lower price. Food tastes and attitudes would have to change.)*

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4. Energy Efficiency in Corn Production

Overview	This lesson provides a look at the principles of diminishing returns by examining energy efficiency of corn production in 1945, 1954, 1964 and 1970.
Target Audience	Math, Social Studies and Science.
Objectives	Students should be able to: 1. Compare changes in productivity relative to changes in energy efficiency. 2. Discover that energy efficiency cannot be returned to its 1945 state.
Materials	Dittoed class sets of student worksheet.
Time Allotment	One class period.
Background Information	As taxpayers and future voters, your students need to be acquainted with the problems with which modern farmers contend. The farmers' product is something we all must have to survive. What items have increased most rapidly in price in the grocery store? How are these items related to high energy prices? How has their price been affected by the availability of energy? Answers to such introductory questions as these lead students into a discussion of the ways an oil shortage or the high price of foodstuffs reach out to affect their own lives.

Lead the class into a consideration of the productivity of the American farm. Mention that farms in the United States continue to increase productivity but at the expense of a tremendous investment in fossil fuel energy. The trend is that we must put in proportionally greater amounts of energy for each unit of output.

Teaching Strategies	Turn to the student worksheets and suggest that the students read over the material and the tables, and answer the questions.

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Lesson 4: ENERGY EFFICIENCY IN CORN PRODUCTION: A WORKSHEET

Introduction. This worksheet provides some information and data on the fossil fuel energy used to produce corn. The energy content of the corn produced is also provided. After reviewing the background information and the available data you should answer the questions.

Background Information. Agriculture is now experiencing an unusual combination of circumstances. Farmers must contend with the recent energy price increases and threats of fuel shortages as they attempt to meet an unprecedented demand for farm products. The operation of machinery, the production and application of fertilizers, and the drying of crops for storage require the use of large amounts of energy which may continue to become more expensive and less available.

The success of agricultural production, in the future, may depend on our ability to fully understand how much energy is used in agriculture and on our ability to develop more efficient methods of crop production.

Available Data. You should be able to use the information in this section to determine how efficiently corn has been produced relative to energy. The data was collected from an article published in Science magazine on November 2, 1973. The title of the article was "Food Production and the Energy Crisis". You may wish to read that article in order to obtain a complete understanding of the use of energy on the farm.

GROWTH IN ENERGY USE IN CORN PRODUCTION

Fossil Fuel Energy Inputs (Calories/Acre)

Inputs	1945	1954	1964	1970
Fuel	543,400	688,300	760,700	797,000
Nitrogen Fertilizer	58,800	226,800	467,200	940,800
Pesticides	0	4,400	15,200	22,000
Crop Drying	10,000	60,000	120,000	120,000
TOTAL	925,500	1,548,300	2,241,900	2,896,800

CORN PRODUCTION (per Acre)

Year	Amount of Corn Produced (bushels)	Energy Content of Corn (Calories)
1945	32	3,427,200
1954	41	4,132,800
1964	68	6,854,400
1970	81	8,164,800

Analysis

There are many ways to evaluate the productivity of the farm. One method requires measuring the amount of corn produced during different years. Another method requires the comparison of the energy used to produce the corn with the amount of food energy harvested at the end of the growing season.

You may use percentages to express the change in corn production. For example:

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1945 = 32 bushels
1954 = 41 bushels

$$\text{Percentage Increase} = \frac{\text{amount of increase}}{\text{original amount}} \times 100$$

$$\text{Percentage Increase} = \frac{9}{32} \times 100 = 28\%$$

From this example you can conclude that the corn production in 1954 was 28% greater than the corn production in 1945.

1. What was the percentage increase in the corn production during the 24 years following 1945?
   (It increased 153%.)

You may also use numerical ratios to express the change in corn production. For example:

1945 = 32 bushels
1954 = 41 bushels

$$\text{Production Ratio} = \frac{\text{1954 production}}{\text{1945 production}}$$

$$\text{Production Ratio} = \frac{41}{32} = 1.28$$

From this example you can conclude that the corn production in 1954 was 1.28 times greater than the corn production in 1945.

2. How much greater was the corn production in 1970 than in 1945?
   (2.53 times greater.)

Note: The "energy input" used in the ratio is not <u>all</u> of the energy input. Efficiencies can't be greater than 100%.

You may also compare the energy used to grow the corn with the food energy produced. This comparison can be expressed as a numerical ratio called an energy efficiency ratio. For example:

1945 Energy Input = 925,500 Calories
1945 Energy Yield = 3,427,200 Calories

$$\text{Energy Efficiency Ratio} = \frac{\text{Energy Yield}}{\text{Energy Input}}$$

$$\text{Energy Efficiency Ratio} = \frac{\text{3,427,200 Calories}}{\text{925,500 Calories}}$$

$$\text{Energy Efficiency Ratio} = 3.70$$

From this example you can conclude that the energy yield in 1945 was 3.70 times greater than the energy used to produce the corn.

3. What was the energy efficiency ratio for corn production in 1954, 1964, and 1970?
(*Energy Efficiency Ratio = 2.66 (1954); 3.05 (1964); 2.82 (1970).*)

4. What has happened to the energy efficiency of corn production during the 25 years following 1945?
(*The productivity has increased, but the energy efficiency has declined.*)

5. More and More May Be Less and Less: The Law of Diminishing Returns

Overview	In this lesson your students act out a simplified representation of the law of diminishing returns in the form of a cooperative game. Then they will apply the principle to energy use in modern U.S. agriculture.
Target Audience	Economics, Social Studies, U.S. History, Contemporary Issues classes.
Objectives	Students should be able to: 1. Explain the concept of the Law of Diminishing Returns.
Materials	Large supply of 3 x 5 notecards or pieces of construction paper Scotch tape Dittoed copies of Student Worksheet
Time Allotment	One-two class periods.
Background Information (Teacher Use Only)	To feed the rapidly increasing populations of the world, farmers must continually increase their food production. They have traditionally done this by increasing the amount of tillable lands, developing irrigation systems, using advanced machines, introducing new seed strains, applying pesticides and increasing the amounts of fertilizer. Because of population pressures some of the more productive farm lands (which are more efficient) are being paved over by shopping centers, highways, and homes. Options for replacing the crop yields lost through construction are primarily: (1) bringing into production reserve marginal land; and (2) more intensive agricultural practices on existing land. Neither option is gained without a sacrifice.

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The trade-off is the necessity for an increased application of energy. Put simply, it takes more energy to grow each unit of food. This phenomena relates to a principle found in both industrial and agricultural economics--the law of diminishing returns.

Teaching Strategies

You can promote student interest in this lesson by having your students get involved in producing something--it can be anything, but for simplicity, let the product be, say, a notecard that is to be folded in half, and taped closed. You may imply that the "product" is a very valuable one, and that the class will be making as many as they can within a prescribed period of time. Introduce more liveliness by suggesting that they want to make as many of these valuable "whatevers" as possible so that they can corner the market or have a monopoly of the sales.

Activity 1 Game Plan

Choose two students to act as timer and recorder. The timekeeper will need a clock. The recorder will need to put a grid similar to this one on the board:

Minutes / Number of Students

1	2	3	4	5

Have five student volunteers as production workers. The production should begin with one student folding and taping as many of the "whatevers" as he or she can make in one minute. The result should be recorded on the grid. After the first minute, begin production with two workers, both doing the same thing. Third, fourth, and fifth workers are added at minute intervals. Each turn will provide one minute for the workers to produce their maximum output. However, all ingredients must be kept constant; the only variable allowed is the labor input. The production areas must not change.

Shut down the production line and suggest that your students look at the data that have been recorded on the grid. Ask: What happened to production as more people were added? Did production increase by equal amounts? Did the amounts decrease? Increase?

To illustrate the point more clearly, you may wish to construct another table on the chalkboard, such as the one below:

# Students	Output	Change in Output
0	0	0
1		
2		
3		
4		
5		

Why did output continue to increase, but by decreasing amounts? How could production continue to increase by ever-increasing amounts? If students have too much difficulty with the principle of diminishing returns in operations, return to step-by-step questioning.

What factor of production (land, labor or capital) was used in increasing quantities? *(Labor.)*

What factors of production were fixed (in quantity)? *(The cards, work area, tape.)*

When the number of workers was doubled, did the production double? *(Probably not.)*

At what point in the labor did the extra output begin to decline? *(Probably after the addition of the fourth worker.)*

What is meant by diminishing returns? *(As increasing quantities of a resource are applied to a given quantity of all other factors, increased output obtained in the extra quantities of the resource will eventually decrease.)*

Student Questions

TABLE I

1. What factor of production is used in increasing quantities?
(Fertilizer.)

2. How much is the change each time in fertilizer?
(Fertilizer increases by 40 pounds each time.)

3. What resources must you assume are fixed in quantity if you are to apply the 'law' of diminishing returns?
(Acreage, seed corn, weather, etc.)

4. What is happening to the total production of corn?
(It is increasing at a decreasing rate.)

5. What do you think will happen to the corn yield as the application of fertilizer increases above 200 pounds per acre?
(No increase in extra yield will take place with more fertilizer applied. There is only so much fertilizer that can be applied to the same ground and to the same kind of seeds.)

6. Under what circumstances would a farmer continue to use more and more fertilizer if he gets a smaller and smaller return?
(As long as the cost of the additional fertilizer is less than the money he earns selling the additional crop, it pays to use the fertilizer.)

7. Aside from profit, what other factors might a farmer consider in choosing to use more and more fertilizer?
(Is this the best use of a scarce resource? Can the necessary food be produced without that energy? How much of an environmental impact does the fertilizer have?)

Extending the Lesson

The lesson has dealt with the application of energy in the form of fertilizer. The law of diminishing returns works for all the factors of production. The following chart shows what happens when only the amount of human energy is changed. This chart assumes that all other factors have been held constant.

Student Questions

TABLE II

1. What happens to the total product?
(It increases for most of the time at a decreasing rate. After the eighth worker the total product decreases.)

2. Which additional worker makes the greatest difference in output?
(The second worker.)

3. Which additional worker reduces the total product?
(The eighth worker.)

4. Why might this happen?
(Answers may vary. There may not be enough equipment for all workers; they may get in each other's way.)

6. Comparing the Flow of Energy in Two Agricultural Societies

Overview	This lesson looks at the flow of energy in modern fossil fuel agriculture and in a non-fossil fuel, simpler form of agriculture.
Target Audience	Science, Social Studies, Cultural Geography.
Objectives	Students should be able to: 1. Trace energy flow in a "slash and burn" agricultural system. 2. Compare "slash and burn" agriculture to modern fossil fuel-based agriculture by interpreting energy flow diagrams. 3. Compare input-output ratios in two agricultural systems. 4. Explain why "slash and burn" gardening cannot support a modern society.
Materials	Dittoed class sets of flow chart key and three flow charts.
Time Allotment	Five class periods.
Background Information	The business of agriculture is to gather the stored energy in plants and animals. In modern agriculture fossil fuel energy has largely replaced muscular energy. Very little fossil fuel energy, spent in plowing, cultivating, fertilizers, pesticides, irrigation and harvesting, is converted into food energy by the crop. These energy investments merely help crops convert the energy of sunlight into the energy of food for human beings and animals. The non-fossil fuel agricultural system goes by different names around the world; for example, swidden farming (from the word, singe, meaning to burn), slash-and-burn, slash-mulch, hoe-and-burn, and shifting (digging and moving) cultivation. Sometimes it goes by the simple name of <u>gardening</u>. Whatever the label, this type of agriculture feeds over 200 million people every day.

This type of agriculture is extremely stable. Its stability is partially related to the numerous feedback loops of energy in it. There is little, if any, energy input from outside the system. This is in contrast to the modern farm which utilizes outside energy inputs to perform the services necessary to keep the system stable.

There are many variations of the gardening system, but usually the trees and underbrush are cut and burned, seeds are planted in the ash-rich soil, the crop is weeded by hand, and the crop is harvested. The field is then abandoned after two or three years and left to lie fallow for several more. At the end of the fallow period the farmer cuts the vegetation and again repeats the crop cycle.

Teaching Strategies

Discuss the type of gardening known as "slash-and-burn", using the Background Information as a springboard. Ask students to research a specific primitive agriculture system on either the African, Asian, or American continent, or in places and times in history when farmers had no power sources other than fire and their own muscle and had only the simplest tools.

Encyclopedias, anthropology texts, and embassies of selected countries will provide an initial source of information. Students could work on their research projects as individuals or in small groups. The time allocated could be either short, providing for only a cursory overview, or of longer duration, depending upon your objectives and student interest. Oral reports, displays, pictures, could serve as a means of exchanging information on non-fossil fuel agricultural systems.

Developing the Lesson

Show the symbols for charting energy flow (Figure 1). Go over the definition of each symbol. Divide the students into groups of two to four and assign the task of using the symbols to complete the chart on Worksheet #1. Their goal is to develop an energy flow system which charts the cultivation (by use

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of hand tools), irrigation, application of pesticides, harvest and preparation for consumption of a crop of peas grown in the "typical" home garden. You'll probably need to work closely with the groups so that they will be successful in charting the energy flow.

Special Note

The main purposes of the charting exercise for the students are: (1) to gain a working definition of each of the variables which are involved in food production in a small garden plot, and (2) to apply this knowledge to interpreting the energy flow charts of both shifting and fossil fuel based agricultural systems.

After the groups have finished the assignment, prepare a composite of their ideas on an overhead transparency or the chalkboard. This will permit you to reinforce the major concepts in an energy flow system and to clear up any misconceptions held by the students.

Student Activities 2, 3

Assuming your students have developed a working understanding of charting energy flow, have them compare and contrast the flows in gardening and modern agricultural systems. Help them answer the set of questions that accompany the two charts.

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Comparing Two Agricultural Systems

Charts 2 and 3 both outline agricultural systems which grow corn. Follow the energy flow in both, then answer the questions.

1. What is the unlimited energy source in both systems?
   (Sunlight.)

2. Where does each system draw upon stored energy?
   (In gardening agriculture, stored energy is drawn from crib corn and seed corn. For the mechanized farm stored energy is drawn from heat, hybrid seeds, irrigation, fertilizer, insecticides, herbicides, transportation, machinery and power.)

3. Where is energy (in the form of heat) lost in each system?
   (For each system the student should describe energy loss each time the symbol ⏚ is encountered in each chart.)

4. How do the following interact in a gardening agricultural system to produce a corn crop? Use Worksheet 1 or 2 to locate the interaction.

   Sun's energy
   Seeds
   Soil
   Work done by the farmer
   Weeds
   Collecting and storing corn

   (For the gardening agriculture energy flow diagram, soil conditions (water and nutrients) are shown to interact with sun energy inputs, seeds, and work performed by person to produce a corn crop. Also sun energy and soil conditions interact to produce weeds, weeds and work by farmer interact to decrease the number of weeds, farmer interacts with mature corn crop to collect and store yield.)

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5. Which system gives the largest yield? By how much? How many times greater?
(The largest yield is from the mechanized farm.

20,000,000 - 1,800,000 = 18,200,000 kilocalories per acre per year

1,800,000 x Y = 20,000,000
Y = 11.1 times greater production.)

6. Compare the two systems in terms of the human energy needed per acre per year. Which is the greater? By how much? How many times greater?
(More energy is expended by the gardening agriculture farmer.

60,000 - 12,000 = 48,000 more kilocalories per acre per year

$\frac{60,000}{12,000}$ *= 5 times more energy expended)*

7. Complete this statement. The yield of the mechanized farm is approximately ______ times greater than that of the gardening system. While the farmer on the mechanized farm did only about ______ times as much work to produce the crop.
(11; one-fifth.)

8. In making your comparisons, why wouldn't it be quite fair to compare only the energy expended directly by each farmer?
(Because in mechanized farming, the farmer is dependent on other systems in which human energy is expended (for example, the manufacture and delivery of pesticides and fertilizer, and the growing and development of hybrid seeds). In a gardening agricultural system, the farmer is the only source of human energy.)

9. Calculate the output in kilocalories for each one (1) kilocalorie of input. Do this for each system, mechanized and gardening. You will need to know that, in addition to human energy input in the mechanized system, there is also 7.14×10^6 kilocalories of fossil fuels.

$$\frac{\text{(output) yield}}{\text{(input) labor} + \text{fossil fuel}} = \text{ratio of output to input}$$

(Gardening Agriculture: $\frac{1,800,000}{60,000 + 0} = 30$ *kcal*

Mechanized Agriculture: $\frac{20,000,000}{12,000 + 7,140,000} =$

$\frac{20,000,000}{7,152,000} = 2.8$ *kcal)*

10. The above calculations show that mechanized farming is less efficient relative to energy input/output. Why are many of the areas that formerly used a gardening system introducing more mechanized farming?
(Possible responses should include the idea that gardening supports a very low number of people per acre per year compared to mechanized farming; therefore mechanized farming is introduced to feed the increasing population.)

7. Organic Farming?

Overview

The debate concerning organic farming vs. conventional methods centers around the impact agricultural chemicals may have on the environment. However, as the costs of agricultural chemicals have quadrupled, so has the concern for the economic usefulness of large amounts of chemicals. In this lesson, students compare the economic and energy implications of both methods of farming.

Target Audience

Science, Social Studies.

Objectives

Students should be able to:

1. Discuss the results of comparing economic and energy factors of organic farming with those of inorganic (conventional) farming.

Materials

Dittoed copies of Student Worksheet.

Time Allotment

One class period.

Teaching Strategies

Begin by discussing the topic of organic farming. You may wish to bring publications such as the Mother Earth News to class and distribute group copies. Or you may wish to develop the association between organic farming and health food stores. Such an association may serve to initiate discussion and spark interest in the lesson.

Developing the Lesson

Distribute copies of Organic Farm Worksheet and tell students that the information concerns two kinds of farms. At the end of the reading period, suggest that they answer the questions. (The activity part of the lesson may be used as a homework assignment or completed in class.) Discuss the answers in class after your students have completed the questions.

This discussion should include the various aspects of using both methods. Questions could proceed along these lines: (1), Why do farmers use fertilizer? *(So that the crops will mature completely. Fertilizers are used to increase quantity and quality of crops.)* (2) What types of fertilizer can a farmer choose from? *(Inorganic, organic, combination of both.)* (3) What factors must the farmer consider before making a choice? *(Cost, quality, availability, feasibility of use.)*

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CORN CROP PRODUCTION

	Conventional		Organic	
	1974	1975	1974	1975
Value per Acre of Corn	$172	$193	$159	$169
Production Costs per Acre	$ 46	$ 54	$ 28	$ 34
Net Income per Acre	$126	$139	$131	$134

ENERGY USE/DOLLAR INCOME IN CORN PRODUCTION

	Conventional		Organic	
	1974	1975	1974	1975
Calories per dollar of income	4,325	3,750	1,800	1,650

Student Questions

After reading the introduction and reviewing the available data, you can complete the following:

1. How can you explain the smaller value of the corn yield on the organic farm? *(Answers will vary. Help students see that conventional farm methods apply large amounts of fertilizers to produce record crops. Organic farms use natural fertilizers from farm animals and plants.)*

2. Since the energy requirement for the production of inorganic fertilizer is approximately eight times that of organic fertilizers, why are the production costs for a conventional farm and an organic farm so

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drastically different? What contributes to the costs of organic and inorganic farm fertilizer use?
(Use of natural fertilizer requires more use of labor and/or machinery. Farmers must pay for commercially produced fertilizer as well as for applying it.)

3. Suppose you want to farm organically. What might you have to consider before using this method?
(The organic farm will not produce as much corn as the energy-intensive conventional farm. While both methods require labor, the organic farmer may have to do more field work. Fertilizer prices may continue to increase.)

4. How does the average income per acre in the years 1974-75 compare on both farms?
(Both have the same average yearly income per acre.)

5. How do you think an energy shortage would affect the choice between organic farming and conventional farming?
(The organic farmer uses much less fossil fuel energy than the conventional farmer. Energy shortages may cause many conventional farmers to consider switching to organic farming, or to farming using a bit of both methods.)

6. How much energy in calories per acre could be saved if all corn was produced by organic farm methods? Use 1975 figures.
(139 dollars/acre x 3750 cal/dollar = 521,250 cal/acre.
134 dollars/acre x 1650 cal/dollar = 221,100 cal/acre
521,250-221,100 = 300,150 cal/acre.)

7. What additional information would be valuable if you had to decide whether or not to go into organic farming?
(Answers will vary, e.g., fuel prices, how to produce a better and larger crop, details on using a combination of both methods.)

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8. Put the Horse Back in Horsepower? The Man Back in Manpower?

Overview	The main purpose of this lesson is to present to your students the information concerning the substitution of machines and agricultural chemicals for human power and animals over the last sixty years.
Target Audience	American History (20th Century Studies), Economics, Civics or Government.
Objectives	Students should be able to: 1. Identify the cause(s) that lead to substituting resources and energy sources. 2. Analyze the effects of resource substitutions on the rate and amount of energy use.
Materials	Dittoed class sets of Table I and II
Time Allotment	One class period.
Teaching Strategies	Begin the lesson by giving the class some data about the growth of food production and increases in farm productivity in this country in this century. For example: in 1909 corn production averaged 26 bushels per acre. In 1971, production averaged 87 bushels per acre. The value and amount of farm production has almost doubled since 1940.

Ask the class to name the factors of production in farming. These are land and the natural or man-made resources such as fertilizer, labor, capital, and management.

Ask the class what changes they think have taken place in these factors of production. You can point out that between 1940 and 1970 the total farm population dropped from approximately 30 million to nine million or from 23% of the popula-

tion to just over 4% of the population. Machines and chemical fertilizers have helped to make each of these workers so much more productive.

Developing the Lesson

Distribute copies of the student worksheet. Explain that the information on the table is in the form of an index. An index is a system of numbers. These numbers indicate change in quantity as compared with quantity at some point in time. For example, the number of farm workers in 1970 is compared to the number of farm workers in 1910. In Table 1 the base year is 1910. Table I indexes the quantities of farm inputs.

For every hundred farm workers in 1910 there were 27 workers in 1975. For every 100 tons of fertilizer used in 1910, 2,262 tons were used in 1975.

Table II indexes the value of farm resources. In this case the base year is 1950. If a unit of fertilizer cost $100 in 1950, it cost $103 in 1970. If a unit of farm land cost $100 in 1950, it cost $194 in 1970.

In looking at the chart the students should note the great increase in farm wages as compared to the relatively constant cost of fertilizer.

Lead the class to a discussion of why the farmers have shifted in their use of the factors of production. Farmers, like all business people, are interested in the cost-effectiveness of decisions. How can they get the most production for the least cost?

Ask the class why they think the value of farm real estate has grown so much. Answers could include the growing population, the movement out of cities and into suburban and rural areas, the reduction of available farm land.

As farm land grows more and more valuable, what decisions might a farmer make? *(Answers could include more intensive use of the land which involves greater use of fertilizer and other energy and resources. Other farmers have chosen to sell their land because they can make more money. [illegible], farmers might try to raise the price of [illegible] products to help [illegible] their increasing costs.)*

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To understand the reasons for the substitution of capital for labor and animal power, the students should have some understanding of the concept of <u>productivity</u>. The following simple illustration may help explain the concept.

> A farmer has a herd of dairy cattle which give 100 gallons of milk per day. The farmer and three farm hands milk the cows. The farmer replaces the three farm hands with a milking parlor which he operates. This is a change in productivity, since output (milk production) divided by input (labor) went from 100/4 to 100/1. The farmer, using the machine, is more productive than each person was working alone. In this case, total productivity has remained the same.

Ask the class what factors the farmer should consider before replacing men with machines. This is another question about cost effectiveness.

Ask how the situation may change as the price of fossil fuel energy increases and becomes more scarce. Answers could include an increase in farm prices, a reduction of crop production or a return to more labor intensive production.

Concluding the Lesson

Discuss the reasons that the productivity of one factor of production such as energy or labor may increase or decrease at a different rate than the total productivity of all the factors of production.

Student Questions

TABLE I

1. What conclusions can you draw from Table I about changing factors of production used in farming?
(Each decade has seen a rapid rise in machinery use, chemical fertilizers, and a decline in the use of human and animal labor.)

2. Which factors of production have declined in use?
(Use of human labor, use of animal labor.)
Which have increased?
(Power and machinery.)
Which have stayed about the same?
(Value of real-estate.)

3. As the use of farm labor, horses and mules has declined, what factors of production have taken their place?
(Mechanical power and machinery.)

4. Which of the factors of production are most energy-intensive?
(Machinery and fertilizer.)

5. What factors explain why there have been changes in the type of farm inputs?
(Cost and availability.)

TABLE II

1. Which prices have increased, decreased, or stayed about the same?
(Decreased: none; Increased: farm wage rates, farm real estate, farm machinery; Stayed about the same: fertilizer costs.)

2. Which prices have increased the most?
(Farm real estate.)

3. How have the increases in the costs of the factors of production on the farm affected their use?
(Among the possible responses: There is a relation between the decline in farm labor and the increase in wages. Also the small increase in fertilizer costs can be seen as contributing to its increased use. The rapid increase in farm real estate prices may be a factor in keeping land use down.)

4. What reasons can you give for different rates of increase in the cost inputs?
(Land is scarce while demand is growing. This draves prices up. For some time the cost of natural gas was low so fertilizer prices remained low.)

5. In 1973 the cost of oil and natural gas nearly quadrupled. What effect might this have on the relative price of fertilizer?
(Since natural gas is used in the manufacture of fertilizer these costs will increase. As a result farmers may use relatively less.)

9. Modern Crop Drying: Direct, Efficient Use of Fossil Fuels

Overview

Modern agriculture relies on LP (liquid petroleum) gas to dry crops. This saves on field losses and preserves grain. However, this use of fossil fuel energy is expensive. Students compare the cost of drying crops using this method to the traditional field drying method.

Target Audience

Science, Social Studies.

Objectives

Students should be able to:

1. Determine the cost of drying crops using LP gas.
2. Compare this cost to traditional methods, but include a consideration of crop losses incurred with these methods.
3. Suggest alternative energy sources that could be used to dry crops. Identify these as direct or indirect uses of energy.

Materials

Dittoed class set of Student Worksheet.

Time Allotment

Twenty minutes of in-class time.

Teaching Strategies

You might begin this lesson by reminding students that the average American farmer of today feeds over 50 people. But this is not done without a great dependence on energy--in its many and various forms. What are some of these forms? (Write these on the chalkboard as the students name them.) Classify these forms into direct and indirect energy use. Explain that this lesson is about direct energy use. Next, distribute the student factsheet and ask students to read the background exposition carefully before starting on the questions. Help students complete the worksheet and then guide the class discussion toward a consideration of alternative direct (and indirect, if necessary) energy forms which could be

used successfully in drying crops. These should include mentioning solar energy.

Extending the Lesson

Invite an Agriculture Extension Agent to talk to the class about the economic feasibility of large scale solar crop drying.

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Student Questions

Suppose you are a farmer with most of your Midwest farm acreage in corn. You must choose between using LP gas to dry your corn, or allowing it to dry by itself in the fields.

1. You have planted 25 acres of corn. How many bushels of corn can you expect to harvest?
(25 acres x 80 bushels/acre = 2000 bushels.)

2. It takes 1 gallon of LP gas to dry every 6 bushels of corn. How many gallons will you use to dry your total corn crop?
$\left(\frac{2000 \text{ bushels}}{6 \text{ bushels/gal.}} = 333 \text{ gallons.}\right)$

3. How much would the gas cost you?
(333 gallons x 30 cents/gallon = $99.90.)

4. If you choose to let the corn dry by itself in the field, you could lose as much as 5% of your total crop. What would this mean in dollars?
[(2000 bushels x $3/bushel = $6000) x .05 = $300.]

5. How much would the price of LP gas have to increase before it would make more sense economically for you to use nature's drying method?
($300 ÷ $100 = 3 x 100% = 300%.)

6. What are some ways crops can be damaged if they are left standing in the fields? List them.
(Weather, bleaching, mold, rodents and birds.)

7. Suppose you must consider using methods other than LP gas to dry corn. What methods might you consider?
(Answers may vary. You may suggest that the use of solar crop dryers is being evaluated. Many universities have been granted funds by the United States Department of Agriculture to determine the economic feasibility of large scale solar crop drying. Information can be obtained from your local Agricultural Extension Agent.)

10. Herbicides: An Indirect Use of Energy

Overview	Herbicides, unlike crop drying, use energy indirectly. This lesson has the student look at energy benefits by comparing indirect energy used in herbicides with crop yield.
Target Audience	Science and Social Studies.
Objectives	The student should be able to: 1. Compare the use of herbicides with other methods of weed control in relation to net energy derived. 2. Identify other indirect energy uses on the farm. 3. Explain the reasons for herbicide use, by listing its advantages and disadvantages.
Materials	Dittoed class set of Student Worksheet.
Time Allotment	Twenty minutes of in-class time.
Teaching Strategies	Plunge directly into the topic of herbicides. Students may make contributions based on controversy of pesticides in the news. If it appears it would be helpful, list on the board: <u>herbicides</u>, <u>energy-consuming</u>, <u>energy-producing</u>, <u>kilocalorie</u> (a kilocalorie is equal to 1000 calories) and take a few moments to describe the terms to the students. Explain that <u>herbicides</u> both consume and produce energy (higher crop yield). During the manufacturing process and the spraying of herbicides by tractor or plane, we find that herbicides are consuming energy. When there is more energy produced than consumed, we can say there is a net energy "profit". Herbicides become energy producers when the net energy "profit" is a result of a greater crop yield. Distribute the worksheets to the students and ask the students to look over the chart. Answer any questions concerning the chart and then help the students to complete the worksheet.

Lesson 10: HERBICIDES: AN INDIRECT USE OF ENERGY
STUDENT QUESTIONS

Energy Input

1. Suppose a farmer chooses the first method listed on the chart. Why might he decide to use weed control?
(To get a higher crop yield.)

2. What is the energy difference (in kcal.) between the two methods of weed control?
(56,005 - 37,920 = 18,085 kcal.)

3. Why do you think there are more kilocalories used in the cultivation method?
(Cultivating is usually done several times in a growing season; therefore, plowing uses more energy than the spraying of herbicides.)

4. The chart doesn't show how energy is consumed when manufacturers make herbicides. Energy is also consumed in other steps before it gets to the farm. List these energy-consuming steps.
(Students should mention packaging, transporting, business operations, etc.)

Energy Output

5. There were 100,800 kilocalories per acre produced in the 1974 study. Write the kilocalories per bushel for each weed control method in the blanks on the chart. Which method produced the most kilocalories per bushel--no weed control, cultivation, use of herbicides? How can you prove it?
(Answer to chart:

No weed control:	*54 x 100,800 = 5,443,200 kcal*
Cultivation:	*81 x 100,800 = 8,164,800 kcal*
Herbicides:	*90 x 100,800 = 9,072,000 kcal*

9,072,000 kcal - 5,443,200 kcal = 3,628,800 kcal is the difference between no weed control and herbicide method.

9,072,000 kcal - 8,164,800 kcal = 907,200 kcal is the difference between cultivation and herbicide methods.)

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Net Energy "Profit"

6. Net energy in kilocalories/acre as calculated from the data of the Minnesota study shows the net energy "profit" due only to weed control (see Column 4 of the chart). What is the difference in net energy between herbicide method and each of the other methods?

(Herbicides vs. no weed control = 3,590,880 kcal - 0

= 3,590,880 kcal

net energy "profit")

(Herbicides vs. cultivation = 3,590,880 - 2,665,595

= 925,285 kcal

net energy "profit")

Concluding the Lesson

Point out to the class that the use of herbicides is utilizing indirect energy. Have students list some other indirect uses of energy in modern agriculture. *(Manufacture of fertilizers, equipment, insecticides, transportation and storage among others.)*

Extending the Lesson

If time permits and it appears there is a student interest, you may encourage the discussion and exploration of the effects of herbicides on the environment.
(The danger to wildlife; for example, the genetic defects showing up in offspring; danger to humans through breathing and ingesting residues; etc.)

11. Eating Wild Foods: Is It a Reasonable Energy Alternative?

Overview	In this lesson students learn to identify, collect, and prepare a "banquet" serving only edible wild plants. Included are discussions on energy used to collect, grow, process, transport, and derived from wild and domestic plants.
Target Audience	Science, Social Studies, Home Economics, and English.
Objectives	Students should be able to: 1. Identify and collect edible wild plants. 2. Discuss the potential of wild plants as food sources.
Time Allotment	Two-four days, either after school or during school hours.
Special Note	This lesson depends, in part, on the time of the year, class interest, and the location of your school. Students living in urban environments can anticipate some difficulty in finding wild plants near the school grounds. (However, they are there, even growing in cracks in the pavement.) Wintertime, of course, would make this activity useless. We suggest inserting this lesson into the class schedule during suitable growing months.
WARNING	"Eating may be dangerous to your health." It is sometimes difficult to identify edible wild plants. If you are not familiar with plant identification, seek advice before beginning this lesson.

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Teaching Strategies

You might begin by assigning some student the task of locating and interviewing a person in the community who collects, prepares and eats wild plants. They may use the interview questions and record sheet that are provided. Direct the students to continue their research on edible wild foods and have them write an illustrated report.

Developing the Lesson

Introduce the agricultural energy requirements of modern farming by approaching them from the angle of looking backward. What were the primary energy sources on the farm before the gasoline engine, electricity, and artifically produced fertilizer? Contrast these sources of energy with the sources of energy today. Did any of the people you interviewed mention how the process of growing crops has changed in the past few years?

Invite a naturalist or a botanist to come to the classroom to talk about common "weeds" which can be used as the ingredients for a salad. If possible, have slides or pictures at hand to help students identify these plants. Have the speaker take the class on a field trip on school grounds and help students collect their "weedy" salad things.

Distribute the list of edible plants to the class. Help the students pick a variety of plants that would make an enticing salad. The class could be divided into small groups and assigned to gather the greens, or make the dressing, or supply the condiment part of the "banquet". At the appropriate time hold a "wild food party". Serve salads prepared totally from wild plants, totally from store-bought plants, and a mixture of both. Assign a student to record the reactions to the taste in a series of taped interviews with their classmates. During the small talk part of the dinner, have students discuss why the United States experienced a return to the land (living off nature) movement during the late sixties and early seventies.

a. What would be the advantages and disadvantages of your personal involvement in returning to "Mother" nature?

b. Why is it not possible for modern society to support more than a small minority of its citizenry in such ventures? (This question may require application of conclusions

formed in the lesson on The Energy Requirements for Growing Different Foods.)

Special Note

The "returning to the land-living off of nature" lifestyle resembles in several ways the gardening type of agricultural systems. Lesson 6 compares energy flow through shifting agricultural systems to modern agricultural practices in the United States.

Concluding the Lesson

Utilizing the student-acquired data from the wild food-gathering field trips, have the students compare the grocery-store salad and the free-for-the-taking wild salad in terms of food energy. Refer to the chart for the more common caloric count of common weed foods. Is there a large difference in the total calories of each salad? *(No.)* However, there is a large energy input in the growing and processing of domesticated plants. Have students consider sources of energy, the energy used to cultivate, harvest, transport, and refrigerate domesticated green vegetables and plants.

Suggest the task of drawing a map that shows the location of each wild plant they collected. Next have them trace on the map the shortest route from the school to the plants. Based on an average of 15 miles to the gallon to drive a car to the location, estimate the number of Calories needed to gather the greens for the class salad. Remember that one gallon of gasoline contains 29,665 Calories of energy. How much fossil fuel energy would be saved if each person walked to the wild plants?

Special Note

You may wish to point out that the energy used in walking, harvesting, and preparing food is not really being considered in this activity.

Now have your students estimate the amount of energy involved in transporting lettuce, tomatoes, and other vegetables from the truck farms to the stores in your area. A call to a local trucking firm or railway freight office can provide your students with this information about gasoline and oil. Have students compare the difference in energy consumed in both systems. What other energy considerations could be mentioned?

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Extending the Learning

In addition to the wild foods party, your class might enjoy making a wall mural showing pressed specimens or drawings of edible wild plants. They should include information about each plant, such as life cycle, geographical distribution, nutritional value, and past economic significance. If they can find stories or folklore about some of the plants, they should include these as well. This might become part of the mural title.

Below is a list of books to help you and your students:

Background References for Both Teachers and Students

Angler, Bradford. Feasting Free on Wild Edibles. Harrisburg, Pa.: Stackpole Books, 1969. 288 pages.

Berglund, Brendt and Clare E. Bolsby. The Edible Wild. New York: Charles Scribner's Sons, 1971. 188 pages.

Crowhurst, Adrienne. The Flower Cookbook. New York: Lancer Books, 1973. 198 pages.

Gibbons, Euell. Euell Gibbons' Beachcomber's Handbook. New York: David McKay Co., Inc., 1972. 230 pages.

__________. Stalking the Healthful Herbs. New York: David McKay Co., 1966.

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Student Guide

ERIC

Activity 1 - Down on the Farm

Student Activity 1 - INVENTORY

Directions: Read each statement carefully. Place a check (✓) in the column which most nearly indicates your opinion. The symbols represent the degree of your opinion.

SD = Strongly Disagree
D = Disagree
N = Neutral or don't know
A = Agree
SA = Strongly Agree

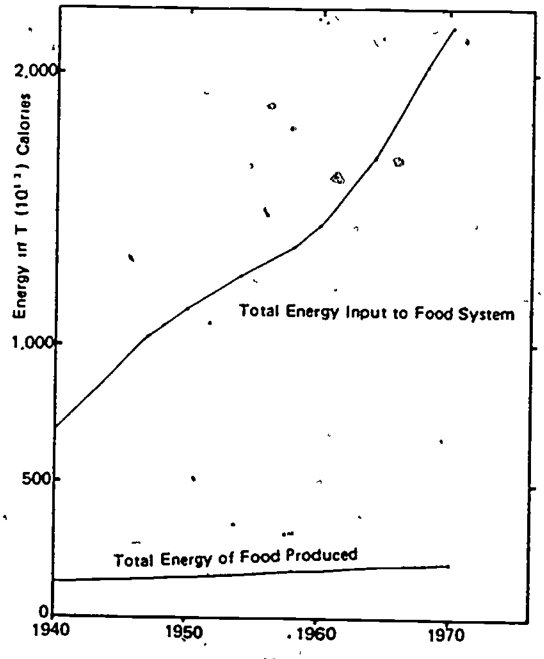
	SA	A	N	D	SD
1. To help conserve fossil fuels, Americans should eat less meat.					
2. It is possible to reduce the rate of energy used in farming and still provide every American with an adequate diet.					
3. The amount of petroleum used on American farms is greater than that used in private automobiles.					
4. We get energy from food we eat; however, today, we use more energy in growing and preparing food than we get out of it.					
5. A farmer's expenses can affect my life.					
6. Each acre of crop land always becomes more productive as more fertilizer is applied.					
7. Farm workers and farm animals are more energy-efficient than tractors and other machinery.					
8. Our farmers rely on domestic supplies of oil and natural gas to run their farms.					
9. When we eat food, we're eating up our oil supplies for the future.					
10. Sometimes less can be more. We have fewer farms today, but each farmer produces more. This situation can go on forever.					

TABLE 5-8
Energy Use in the U.S. Food System (in 10^{12} Calories)

Component	1940	1947	1950	1954	1958	1960	1964	1968	1970
				On Farm					
Fuel (direct use)	70.0	136.0	158.0	172.8	179.0	188.0	213.9	226.0	232.0
Electricity	0.7	32.0	32.9	40.0	44.0	46.1	50.0	57.3	63.8
Fertilizer	12.4	19.5	24.0	30.6	32.2	41.0	60.0	87.0	94.0
Agricultural Steel	1.6	2.0	2.7	2.5	2.0	1.7	2.5	2.4	2.0
Farm Machinery	9.0	34.7	30.0	29.5	50.2	52.0	60.0	75.0	80.0
Tractors	12.8	25.0	30.8	23.6	16.4	11.8	20.0	20.5	19.3
Irrigation	18.0	22.8	25.0	29.6	32.5	33.3	34.1	34.8	35.0
Subtotal	124.5	272.0	303.4	328.6	356.3	373.9	440.5	503.0	526.1
				Processing Industry					
Food Processing Industry	147.0	177.5	192.0	211.5	212.6	224.0	249.0	295.0	308.0
Food Processing Machinery	0.7	5.7	5.0	4.9	4.9	5.0	6.0	6.0	6.0
Paper Packaging	8.5	14.8	17.0	20.0	26.0	28.0	31.0	35.7	38.0
Glass Containers	14.0	25.7	26.0	27.0	30.2	31.0	34.0	41.9	47.0
Steel Cans and Aluminum	38.0	55.8	62.0	73.7	85.4	86.0	91.0	112.2	122.0
Transport (fuel)	49.6	86.1	102.0	122.3	140.2	153.3	184.0	226.6	246.9
Trucks and trailors (manufacture)	28.0	42.0	49.5	47.0	43.0	44.2	61.0	70.2	74.0
Subtotal	285.8	407.6	453.5	506.4	542.3	571.5	636.0	787.6	841.9
				Commercial and Home					
Commercial Refrigeration and Cooking	121.0	141.0	150.0	161.0	176.0	186.2	209.0	241.0	263.0
Refrigeration Machinery (home and commercial)	10.0	24.0	25.0	27.5	29.4	32.0	40.0	56.0	61.0
Home Refrigeration and Cooking	144.2	184.0	202.3	228.0	257.0	276.6	345.0	433.9	480.0
Subtotal	275.2	349.0	[illegible]	416.5	462.4	494.8	594.0	730.9	804.0
Grand Total	685.5	1,028.6	[illegible]	1,251.5	1,361.0	1,440.2	1,690.5	2,021.5	2,172.0

Source: "Energy Use in the U.S. Food System," C. Steinhart and [illegible] Science 184, 307-315, 1974, Table 1.

FIGURE 5-8
Total Energy Use in Food System Versus Calories of Food Produced (food is population times 2,700 Calories per day)



Data from Table 5-8.

Figure 5-9
Growth in Energy Consumption of Food System Components

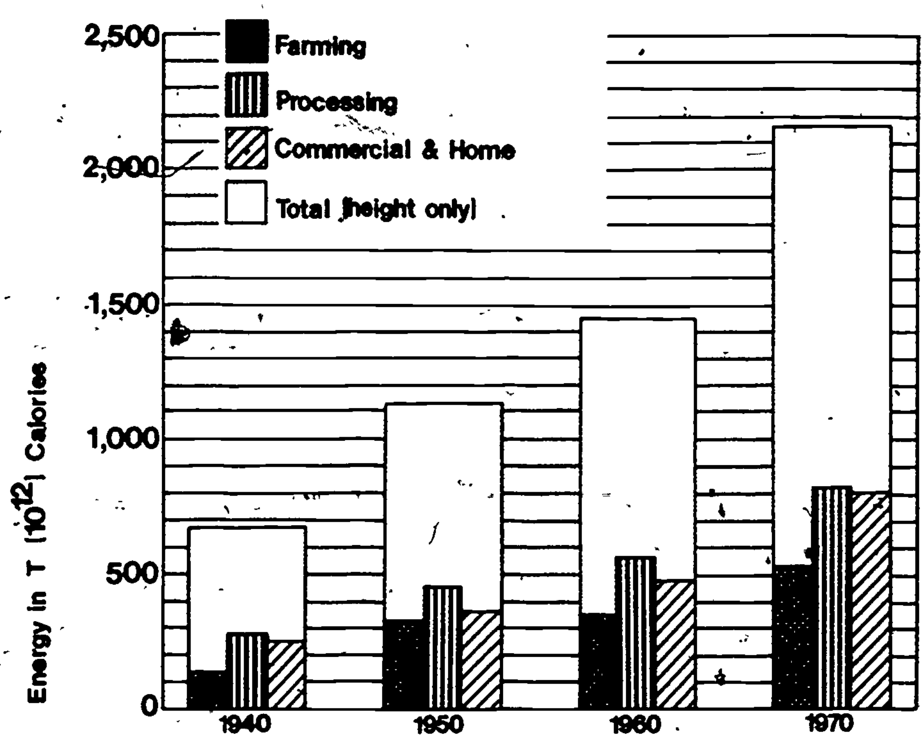
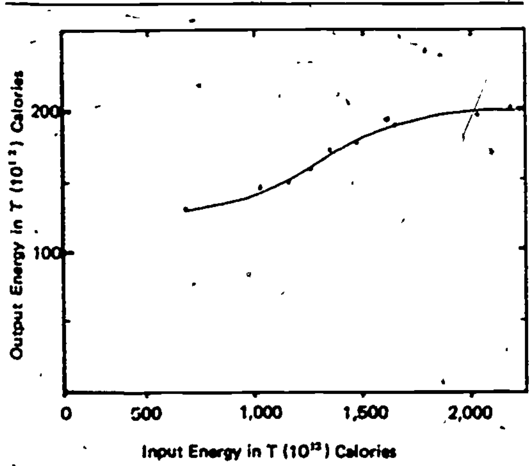


FIGURE 5-10
Food Energy Output Versus Energy Input to Food System



Data from Table 5-8.

Student Activity 2 Background Notes on Modern Agriculture

John M. Fowler

"...If the energy expended in growing, processing, packaging, and transporting food is divided by the food consumed per household we find a factor of 7 or 8. What this means, at face value, is that it requires 7 or 8 Calories of fossil fuel energy to get 1 food Calorie on our plate. We are eating fossil fuels. The food crisis and the energy crisis are therfore joined..

There are several reasons why it is important that we examine our food industry from an energy point of view. It uses a significant amount of energy, 12 or 13 percent of the national total. It is important, therefore, to understand in what form and for what purposes that energy is used in order to make rational choices among the various energy futures before us. More important, however, is the worldwide food shortage and America's role as food supplier. What are the energy implications of that policy? Finally, we may want to explain our food production system as a model for others to copy. Is this system one that can meet world needs?

The energy cost of U.S. food production: How much energy does it take to put a Calorie of food before an American consumer? To answer this question it is necessary to determine the energy consumption in the four major components of the food system: the farm, the processing industry, the commercial retailing industry and the home. In each of these there are direct uses (fuel and electricity) and indirect uses (energy consumed in the manufacture of food-related equipment, or in transportation and in the manufacture of fertilizers, pesticides, herbicides, etc.)

We present in Table 5-8 the results of energy audit of the food system from 1940 to 1970. (The source of that study is indicated on the table.) In Figure 5-8 we plot the total energy and compare it with the energy of the food produced. Figure 5-9 shows the growth in the amount of energy in each of four component sectors.

The ratio of the amount of energy used in the system to the number of Calories eaten by the population has grown from 5.3 in 1940 to 10.9 in 1970. Figure 5-9 shows us where this growth has occurred. Energy consumption has grown in each of the three categories but the fastest growth has been in the energy (direct and indirect) used on the farm. Over the 30-year period, total farm energy use increased by a factor of 4.2 (compared with 3.0 for food processing and 1.2 for the commercial and home sector). We can see from Table 5-8 that fuel use, electricity, fertilizer, and the energy to build farm machinery accounted for most of

that growth.

It should be emphasized that even with the detail of Table 5-8 these data are still fairly rough. There is no account taken, for instance, of food wasted or the growing amount of food exported. It is certainly accurate enough, however, to raise some serious questions for the future.

If we look at the data of Figure 5-8 in a somewhat different way, and plot the food energy output against the fossil fuel energy input, we obtain the interesting curve of Figure 5-10. It is a curve which suggests the end of growth. It is easy for us to interpret this figure in the present context. It suggests that we cannot gain very much more food energy from our system by merely putting more fossil fuel energy into it.

It does not say that we are farming as efficiently as possible, for we are considering all the energy used in the system and as we see in Figure 5-9, the farm energy only represents a quarter of the total. From other studies[1], however, it appears that with some crops, corn is the example quoted, we are already using 1,000 Calories of energy per square meter (farm energy alone) and achieving energy yields of 2,000 Calories of energy per square meter from the grain alone. These numbers are to be compared with 5,000 Calories per square meter of energy that the corn plants can take in from sunlight. Since the energy output is almost one-half the captured solar energy it is unlikely that we can gain much more farming efficiency by adding more fertilizers, plowing more often, using more herbicides, etc. In fact, if we look at yields per acre as tons of fertilizer applied per acre, we obtain a curve similar to the one shown in Figure 5-10. It is an S-curve and we are on the flat top. We cannot buy much more plant productivity with energy.

Agricultural practice is a deep and engrossing subject, and there is much more which could be said. There are a variety of suggestions for increasing yields without increasing acreage, by reducing fertilizer per acre and bringing such "soil bank" land as remains unused back into production, or by using more of the organic waste we produce, as land conditioners and supplementary fertilizer. We will leave that fuller discussion to others.

---

[1] "Food Production and the Energy Crisis", Pimentel, Hurd, Bellotti, Forester, Oka, Sholes, Whitman, <u>Science 182</u>, pp. 443-449, November 2, 1973.

There are conclusions we can suggest, however, from this energy-focused consideration. The first is that food prices will rise with energy prices. They are, in fact, expected to rise more rapidly than energy since a large part of the energy input is of the indirect sort expended in manufacturing. It may be that energy costs will become high enough to make farming depart from its path of increasing capital intensiveness and make a partial return to farm labor an economic alternative.

This energy analysis of agriculture also raises questions as to the wisdom of continuing in the direction of food "mass production" practices. We question it from our own point of view; it has not proven to be an energy-efficient way to feed our own people (although it has been labor-efficient, and so far capital-efficient). It is even less attractive as a way to feed the world's hungry people. As it is now practiced, we are exporting energy when we export grain, 5 or 10 Calories for every food Calorie it contains. That is not a wise strategy for an energy-importing country.

It is an even more questionable decision to consider exporting our agricultural practices. We are engaged in that at present. The so-called "Green Revolution" is based on new strains of high-yield grains, but these new grains require both fertilizer and irrigation. As we see from Table 5-8 both of these are energy-expensive.* (The irrigation energy expenditure in Table 5-8 is based on irrigation of only 5 percent of our crop land.)

We may in fact have something to learn from foreign agricultural practices. By relying on human labor some other countries get many more Calories from the earth and sunlight than they put in. The Chinese peasant gets 50 Calories of food energy back for every 1 he expends on his wet rice fields. The primitive "slash and burn" agriculture of the tropics, in which a new field is cleared of trees every two or three years, gains Calories in almost a 20 to 1 ratio."

Student Activity 3 AG-ENERGY WORD SEARCH

A	C	G	P	E	S	T	E	O	R
I	R	A	G	N	O	A	C	P	A
F	O	S	S	I	L	F	U	E	L
E	P	O	U	T	A	O	D	S	E
R	D	L	N	R	R	O	O	T	G
T	R	I	D	O	O	D	R	I	U
I	Y	N	A	G	E	S	P	C	M
L	I	E	N	E	R	G	Y	I	E
I	N	T	O	N	S	E	E	D	S
Z	G	M	E	T	H	A	N	E	A
E	M	A	C	H	I	N	E	R	Y
R	O	T	A	T	I	O	N	Y	E

Hidden in this puzzle are 16 words. These words apply to agriculture or the use of energy in agriculture. Find the word, circle it. Words can be read horizontally and vertically.

Write the correct word for each definition in the spaces below. One letter goes in each space. The same letter can be used more than once. Then, complete the Mystery Word.

1. A material needed to promote plant growth.
2. A fuel that is produced by the decay of raw waste material.
3. A chemical used to control insect and plant populations.
4. The use of heat from the sun for drying of harvested crops.
5. A chemical substance necessary for the production of protein in plants.
6. The amount of a crop produced per unit of land.

1. _ _ _ _ _ _ _ _ _ _
2. _ _ _ _ _ _ _
3. _ _ _ _ _ _ _ _ _ _
4. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
5. _ _ _ _ _ _ _ _
6. _ _ _ _ _

Mystery Word

1. 2nd letter in one _
2. 6th letter in two _
3. 2nd letter in three _
4. 5th letter in four (1st word) _
5. 6th letter in five _
6. 1st letter in six _

ERIC

Activity 3 - The Energy Requirements for Growing Different Foods

Activity 1

The Energy Required to Produce Food Products Consumed in a Year by One Person

Plant Product	Food Consumed (lbs/person/ year)	Energy Required to Produce Food (gallons of oil/ person/year)	Ratio (lbs/gals)
Flour & Cereal	140.0	2.2	64
Sugar	122.0	1.4	____
Vegetable Oils	41.8	3.7	____
Fruits	131.5	1.9	____
Potatoes	104.9	0.6	____
Beans, Peas & Nuts	16.1	1.8	____
Green & Yellow Vegetables	215.1	2.3	____
Miscellaneous	14.8	0.2	____
	786	14.1	

Animal Product	Food Consumption (lbs/person/ year)	Energy Requirement (gallons of oil/ person/year)	Ratio
Beef	116.0	19.1	____
Dairy	356.0	4.7	____
Pork	67.4	4.8	____
Animal Fats and Oils	14.6	3.5	____
Poultry	52.4	1.6	____
Eggs	39.0	1.3	____
Veal and Lamb	5.5	0.8	____
Fish	15.2	2.1	____
	666.1	37.9	

Student Activity 1 How Much Energy in Gallons of Oil Is Needed to Grow the Food We Eat?

The chart on the preceding page shows the amount of fuel American farmers use to grow the food we put on our dining tables each year. First calculate the ratio of food consumed to energy required. Then fill in the blanks with the correct ratios for each food product. For example, for flour and cereal the ratio is:

$$\frac{\text{Food Consumed}}{\text{Energy Required}} = \frac{\text{140 lbs/person/year}}{\text{2.2 gallons of oil/yr.}} = \text{64 lbs of food per gallon of oil}$$

Next, answer each of the following:

1. Which foods require the most gallons of oil to be grown?

2. Which require the least?

3. The energy ratios on the chart are based on energy used in farming. The higher the ratio, the more efficient the farming process. What additional information would you need in order to say that a certain food product is energy-efficient?

4. Which two animal products would you eat if your only consideration was to choose energy-efficient products?

5. What evidence in the table suggests why few countries in the world eat a lot of beef?

70

Student Activity 2 Which Plants are Energy-Efficient?

When we say a farm crop is energy-efficient, we mean that the ratio of the food energy in the plant to the energy used in growing it, is high. Some crops are more efficient than others; some aren't efficient at all. Look at the table below. Pick out your favorite food. Is it energy-efficient? Remember that in reading ratios, the higher the number, the more efficient the plant is.

Look at the table, then answer each question.

Table 2

Energy Efficiency Ratios for Common Crops

Crop	Ratio
Sorghum	5.3
Corn	4.4
Wheat	3.2
Soybeans	2.7
Oats	2.6
Potatoes	1.5
Rice	1.4
Apples	1.3
Grapes	1.1
Tomatoes	0.7
Green Beans	0.5
Peaches	0.6
Lemons	0.1

1. Which two crops get the best return in food energy from investments of energy used to grow and harvest them?

2. Which four barely return the energy used in their production?

3. Which four are losing the energy-in/energy-out race?

4. Suppose you are the agriculture minister in a developing, poor nation. Basing your choice on the table above, which three crops would you recommend for your nation's farmers? Why?

5. Playing the "What If..." game can give you plenty to think about. For example, What if... there was a great demand for more fruits and vegetables worldwide. What effect would this demand have on the following:

   a. The demand for fossil fuels?

   b. The price of oil and natural gas?

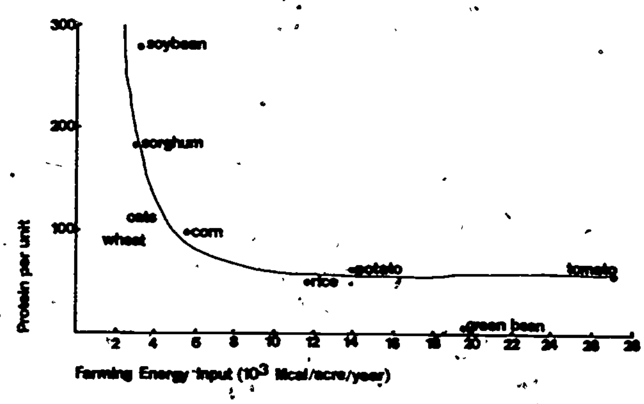
   c. Having enough food to feed the world's people?

   d. Conflict between rich and poor countries?

Student Activity 3

How Efficiently Do Plants Convert Fossil Fuel Energy Into Protein?

Examine the graph below and compare crops in terms of protein produced for each unit of energy put into its cultivation. Then answer the questions.



1. Which five crops are the most efficient at producing protein? Are these five grains or vegetables?

2. Which four are least efficient protein producers?

3. Soybeans are highly efficient in producing protein. However, a great deal has to be done to make them appealing to taste. How does this statement help explain why soybeans generally are fed to animals and not to humans?

4. Much of the delight of eating is provided by animal protein. Getting our protein this way is expensive. How can the information on the graph help you decide to eat soyburgers someday? What would have to change for you first?

Activity 4 - Energy Efficiency in Corn Production

6

A WORKSHEET

Introduction

This worksheet provides some information and data on the fossil fuel energy used to produce corn. The energy content of the corn produced is also provided. After reviewing the background information and the available data you should answer the questions.

Background Information

Agriculture is now experiencing an unusual combination of circumstances. Farmers must contend with the recent energy price increases and threats of fuel shortages as they attempt to meet an unprecedented demand for farm products. The operation of machinery, the production and application of fertilizers, and the drying of crops for storage require the use of large amounts of energy which may continue to become more expensive and less available.

The success of agricultural production, in the future, may depend on our ability to fully understand how much energy is used in agriculture and on our ability to develop more efficient methods of crop production.

Available Data

You should be able to use the information in this section to determine how efficiently corn has been produced relative to energy. The data was collected from an article published in Science magazine on November 2, 1973. The title of the article was "Food Production and the Energy Crisis". You may wish to read that article in order to obtain a complete understanding of the use of energy on the farm.

5

GROWTH IN ENERGY USE IN CORN PRODUCTION

Fossil Fuel Energy Inputs (Calories/Acre)

Inputs	1945	1954	1964	1970
Fuel	543,400	688,300	760,700	797,000
Nitrogen Fertilizer	58,800	226,800	467,200	940,800
Pesticides	0	4,400	15,200	22,000
Crop Drying	10,000	60,000	120,000	120,000
TOTAL	925,500	1,548,300	2,241,900	2,896,800

CORN PRODUCTION (per Acre)

Year	Amount of Corn Produced (bushels)	Energy Content of Corn (Calories)
1945	32	3,427,200
1954	41	4,132,800
1964	68	6,854,400
1970	81	8,164,800

Analysis

There are many ways to evaluate the productivity of the farm. One method requires the measuring of the amount of corn produced during different years. Another method requires the comparison of the energy used to produce the corn with the amount of food energy harvested at the end of the growing season.

You may use percentages to express the change in corn production. For example:

ERIC Full Text Provided by ERIC

1945 = 32 bushels
1954 = 41 bushels

$$\text{Percentage Increase} = \frac{\text{amount of increase}}{\text{original amount}} \times 100$$

$$\text{Percentage Increase} = \frac{9}{32} \times 100 = 28\%$$

From this example you can conclude that the corn production in 1954 was 28% greater than the corn production in 1945.

1. What was the percentage increase in the corn production during the 24 years following 1945?

You may also use numerical ratios to express the change in corn production. For example:

1945 = 32 bushels
1954 = 41 bushels

$$\text{Production Ratio} = \frac{\text{1954 production}}{\text{1945 production}}$$

$$\text{Production Ratio} = \frac{41}{32} = 1.28$$

From this example you can conclude that the corn production in 1954 was 1.28 times greater than the corn production in 1945.

2. How much greater was the corn production in 1970 than in 1945?

Note: The "energy input" used in the ratio is not all of the energy input. Efficiencies can't be greater than 100%.

You may also compare the energy used to grow the corn with the food energy produced. This comparison can be expressed as a numerical ratio called an energy efficiency ratio. For example:

1945 Energy Input = 925,500 Calories
1945 Energy Yield = 3,427,200 Calories

$$\text{Energy Efficiency Ratio} = \frac{\text{Energy Yield}}{\text{Energy Input}}$$

$$\text{Energy Efficiency Ratio} = \frac{3{,}427{,}200 \text{ Calories}}{925{,}500 \text{ Calories}}$$

$$\text{Energy Efficiency Ratio} = 3.70$$

From this example you can conclude that the energy yield in 1945 was 3.70 times greater than the energy used to produce the corn.

3. What was the energy efficiency ratio for corn production in 1954, 1964, and 1970?

4. What has happened to the energy efficiency of corn production during the 25 years following 1945?

Activity 5 - More and More May Be Less and Less: The Law of Diminishing Returns

Introduction

To feed the people is one of the primary tasks of any economic system. One of the achievements of twentieth century American agriculture is the production of enough food to feed almost one-sixth of the world's population at a relatively low price.

This achievement has not been without costs. In previous lessons you have learned that increasing amounts of energy in the form of fertilizer, herbicides and fuel for machinery have been used. This use of fuel has become an increasingly serious problem as the price rises and the fuel becomes unavailable.

This lesson discusses the use of ever increasing amounts of fertilizer to get smaller and smaller increases in total production. This is an example of the economic principle of diminishing returns.

Table I

CORN - YIELD GAINS FROM SUCCESSIVE FERTILIZER APPLICATIONS

Pounds of Nitrogen Fertilizer Applied per Acre	Corn Yield Lbs/Acre	Change in Corn Yield per Pound of Extra Nitrogen Fertilizer Applied
0	2800	-
40	3880	27
80	4400	14
120	4800	9
160	4960	4
200	5000	1

Source: U.S.D.A. - Corn Yield In Iowa, 1964.

Student Questions

TABLE I

1. What factor of production is used in increasing quantities?

2. How much is the change each time in fertilizer?

3. What resources must you assume are fixed in quantity if you are to apply the law of diminishing returns?

4. What is happening to the total production of corn?

5. What do you think will happen to the corn yield as the application of fertilizer increases above 200 pounds per acre?

6. Under what circumstances would a farmer continue to use more and more fertilizer if he gets a smaller and smaller return?

7. Aside from profit, what other factors might a farmer consider in choosing to use more and more fertilizer?

This lesson has dealt with the application of energy in the form of fertilizer. The law of diminishing returns works for all the factors of production. The following chart shows what happens when only the amount of human energy is changed. This chart assumes that all other factors have been held constant.

Table II

LABOR AND DIMINISHING RETURNS

Number of Workers	Total Product	Increase
1	100	100
2	220	120
3	270	50
4	300	30
5	320	20
6	330	10
7	330	0
8	320	-10

Student Questions

TABLE II

1. What happens to the total product?

2. Which additional worker makes the greatest difference in output?

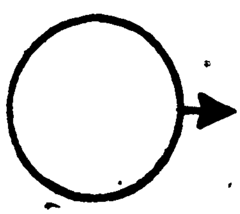
3. Which additional worker reduces the total product?

4. Why might this happen?

Activity 6 - Comparing the Flow of Energy in Two Agricultural Societies

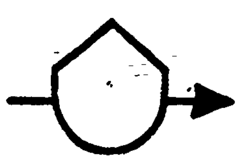
Figure 1 Tracing Energy Flow

Symbol — Definition



Energy Source

Represents source of energy from outside the agriculture system which will supply an unlimited amount of energy. An example would be sunlight.

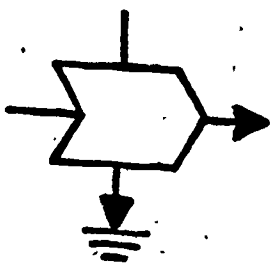


Energy Storage

Represents energy stored within the agricultural system (only in limited amounts) and when drawn upon can be exhausted. An example would be seeds.

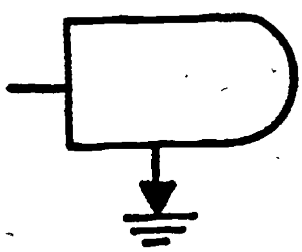
Heat Sink

Represents the heat loss from the agricultural system each time energy is changed from one to another (second law of thermo-dymanics). Examples would be the heat given off when sunlight is converted into food energy or when gasoline is converted into energy to drive a tractor.



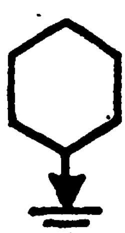
Work Gate

Represents the interaction of two or more energy flows (inputs) in an agricultural system. The net result is different from the inputs. For example, sunlight interacts with nutrients and water in a corn plant which results in corn kernels.



Green Plant

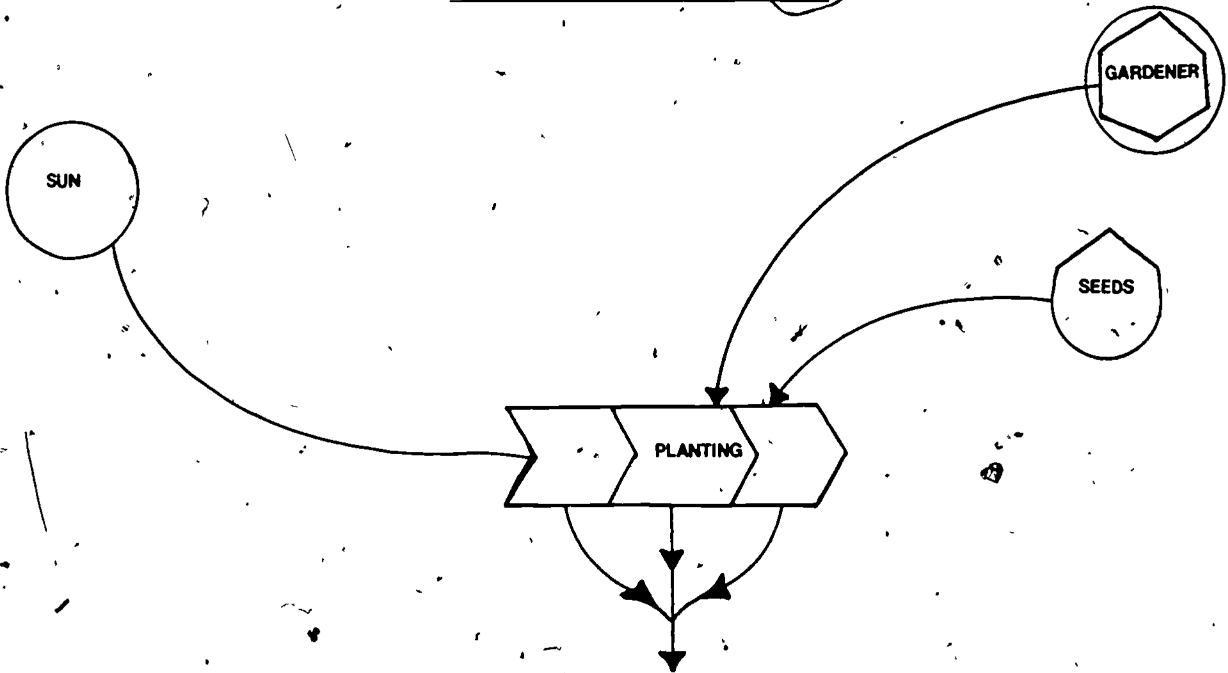
Represents the photosynthesizing (food-making) of green plants.



Consumer

Represents anything with the ability to consume, grow, or reproduce from it. For example one animal, or a whole lot of animals. People are consumers.

Worksheet 1: GARDEN ENERGY FLOW CHART



Use the correct symbols to complete the energy flow system growing peas in your garden. Include energy requirements in preparing the soil, planting and watering the peas, fighting pests, cultivating, harvesting and preparation for consumption.

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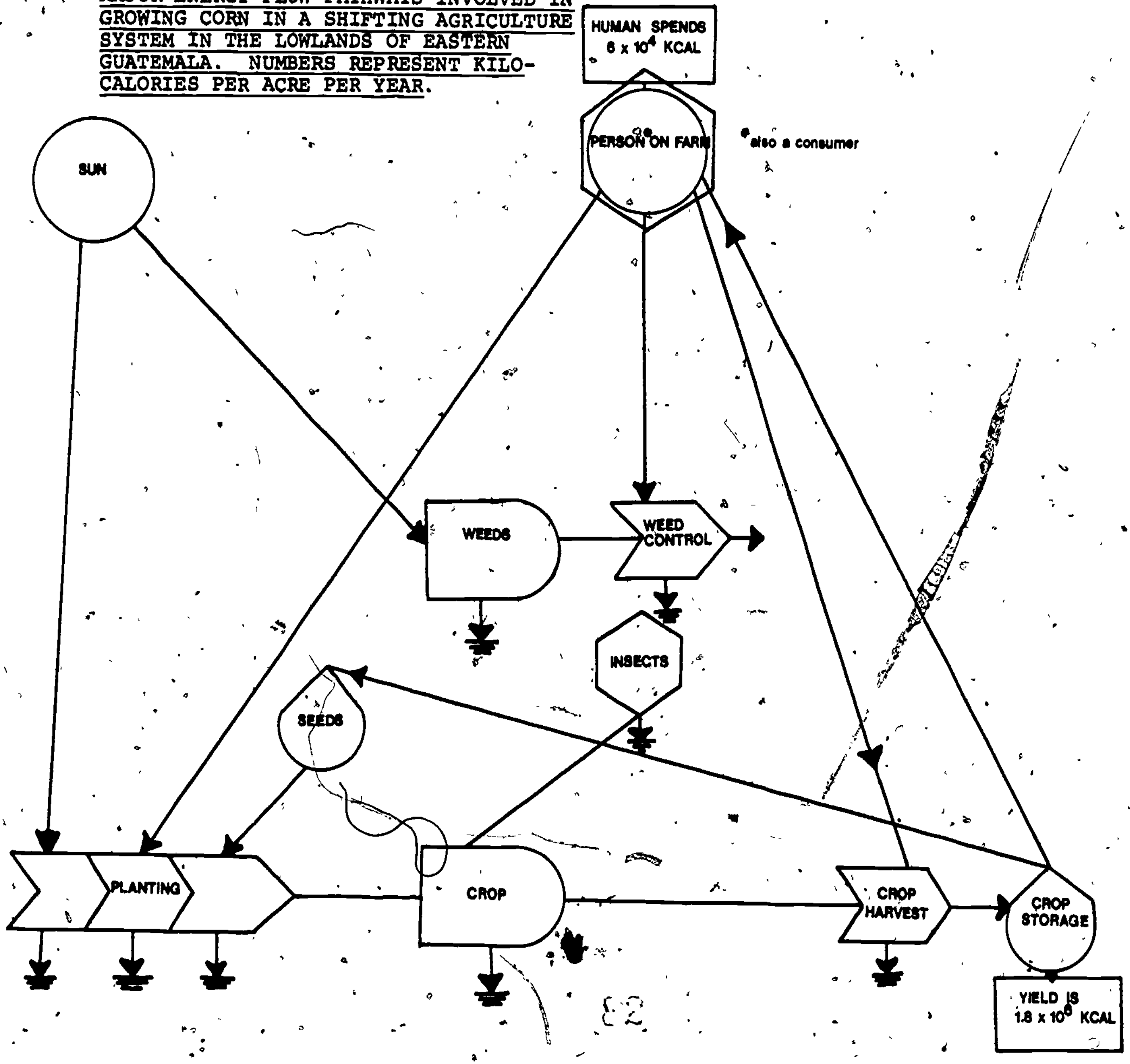
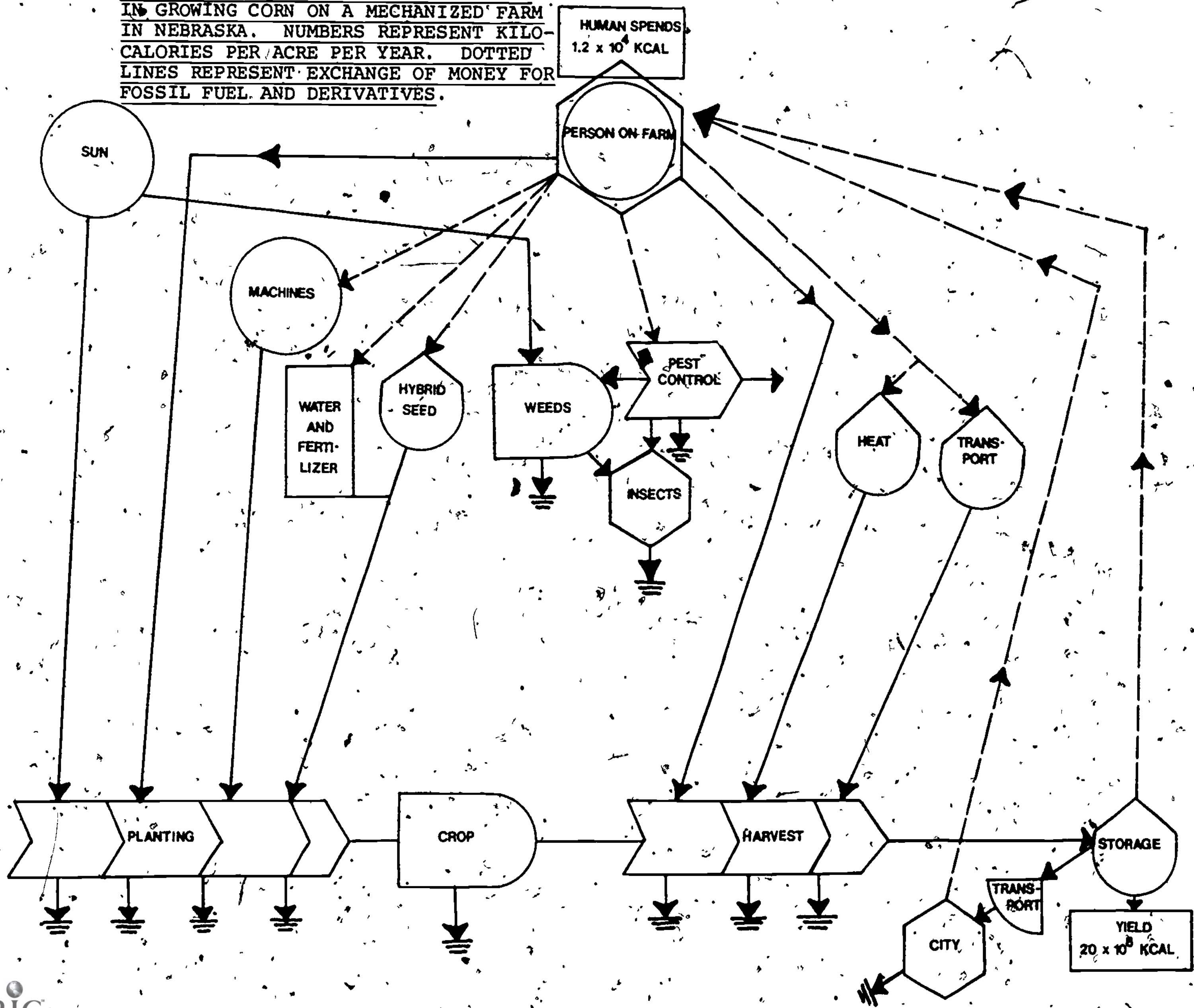
Worksheet 2: MAJOR ENERGY FLOW PATHWAYS INVOLVED IN GROWING CORN IN A SHIFTING AGRICULTURE SYSTEM IN THE LOWLANDS OF EASTERN GUATEMALA. NUMBERS REPRESENT KILO-CALORIES PER ACRE PER YEAR.



Worksheet 3: MAJOR ENERGY FLOW PATHWAYS INVOLVED IN GROWING CORN ON A MECHANIZED FARM IN NEBRASKA. NUMBERS REPRESENT KILOCALORIES PER ACRE PER YEAR. DOTTED LINES REPRESENT EXCHANGE OF MONEY FOR FOSSIL FUEL AND DERIVATIVES.



Comparing Two Agricultural Systems

Worksheets 2 and 3 both outline agricultural systems which grow corn. Follow the energy flow in both, then answer the questions.

1. What is the unlimited energy source in both systems?

2. Where does each system draw upon stored energy?

3. Where is energy (in the form of heat) lost in each system?

4. How do the following interact in a gardening agricultural system to produce a corn crop? Use Worksheet 1 or 2 to locate the interaction.

   Sun's energy
   Seeds
   Soil
   Work done by the farmer
   Weeds.
   Collecting and storing corn

5. Which system gives the largest yield? By how much? How many times greater?

6. Compare the two systems in terms of the human energy needed per acre per year. Which is the greater? By how much? How many times greater?

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7. Complete this statement. The yield of the mechanized farm is approximately ________ times greater than that of the gardening system. While the farmer on the mechanized farm did only about ________ times as much work to produce the crop.

8. In making your comparisons, why wouldn't it be quite fair to compare only the energy expended directly by each farmer?

9. Calculate the output in kilocalories for each one (1) kilocalorie of input. Do this for each system, mechanized and gardening. You will need to know that, in addition to human energy input in the mechanized system, there is also 7.14×10^6 kilocalories of fossil fuels.

$$\frac{\text{(output) yield}}{\text{(input) labor + fossil fuel}} = \text{ratio of output to input}$$

10. The above calculations show that mechanized farming is less efficient relative to energy input/output. Why are many of the areas that formerly used a gardening system introducing more mechanized farming?

Activity 7 - Organic Farms?

A WORKSHEET

Introduction

This worksheet provides some information and data concerning the use of fertilizer on the farm. A comparison is made between the use of organic and conventional (inorganic) fertilizers. After reviewing the background information and the available data, you should be able to answer the questions.

Background Information

Farmers who grow large quantities of corn (and other crops) must apply large amounts of nitrogen fertilizer to the soil. Without the use of fertilizers, crops will not mature completely.

The farmer has two sources of nitrogen fertilizer: inorganic and organic. The production of inorganic nitrogen fertilizer requires the use of a large industrial facility where nitrogen is combined with hydrogen under high pressure and temperature. This process requires approximately 5,000 Calories of fossil fuel energy for each pound of fertilizer produced. The fertilizer is then shipped to the farm and applied to the soil.

The organic fertilizer sources include animal manure and legume crops. Legumes (alfalfa, soybeans, peanuts, vetch, etc.) are plants that are capable of forming nitrogen compounds from the nitrogen in the air. A fall planting of a legume that is plowed under in the spring adds nitrogen fertilizer to the soil. Approximately 625 Calories of fossil fuel energy per acre are needed to plant and plow under a legume crop.

Farmers must choose the type of nitrogen fertilizer that they will use. Their principal concern is with the cost and quality of each.

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Available Research Data

You can use the information in this section to compare the use of organic and inorganic fertilizers. The information was collected from a study conducted by Washington University in St. Louis, Missouri. The following data were developed by comparing the productivity of 14 commercial sized organic farms, that used neither inorganic fertilizers (other than phosphate rock) nor chemical pesticides, with 14 conventional farms that used both.

CORN CROP PRODUCTION

	Conventional		Organic	
	1974	1975	1974	1975
Value per Acre of Corn	$172	$193	$159	$169
Production Costs per Acre	$ 46	$ 54	$ 28	$ 34
Net Income per Acre	$126	$139	$131	$134

ENERGY USE IN CORN PRODUCTION

	Conventional		Organic	
	1974	1975	1974	1975
Calories per $(income)	4,325	3,750	1,800	1,650

Student Questions

After reading the introduction and reviewing the available data, you can complete the following:

1. How can you explain the smaller value of the corn yield on the organic farm?

2. Since the energy requirement for the production of inorganic fertilizer is approximately eight times that of organic fertilizer, why are the production costs for a conventional farm and an organic farm so drastically different? What contributions to the costs of organic and inorganic farm fertilizer use?

3. Suppose you want to farm organically. What might you have to consider before using this method?

4. How does the average income per acre in the years 1974-75 compare on both farms?

5. How do you think an energy shortage would affect the choice between organic farming and conventional?

6. How much energy in calories per acre could be saved if all corn was produced by organic farm methods? Use 1975 figures.

7. What additional information would be valuable if you had to decide whether or not to go into organic farming?

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Activity 8 - Put the Horse Back in Horsepower? The Man Back in Manpower?

TABLE I
Indexes of Selected Farm Inputs

Year	Farm Labor	Horses and Mules	Value of Farm Real Estate[1]	Use of Mechanical Power and Machinery	Tons of Fertilizer And Other Agricultural Chemicals[2]
1910	100	100	100	100	100
1920	107	102	98	160	133
1930	102	78	99	200	183
1940	92	59	100	210	233
1950	68	31	101	415	500
1960	46	14	96	475	833
1970	29	NDA	95	505	1830
1975	27	NDA	92	530	2262

1 - Includes service buildings and improvements on land.
2 - Includes fertilizer, lime and pesticides.
NDA - No Data Available
Source: "Changes in Farm Productivity and Efficiency", USDA #233

TABLE II
Indexes of the Prices of Farm Resources

Year	Farm Wage Rates	Farm Real Estate	Farm Machinery	Fertilizer
1950	100	100	100	100
1955	121	131	113	108
1960	148	171	138	106
1965	171	214	154	106
1970	255	286	194	103

Source: "Changes in Farm Productivity and Efficiency", USDA #233

Student Questions

<u>TABLE I</u>

1. What conclusions can you draw from Table I about changing factors of production used in farming?

2. Which factors of production have declined in use? Which have increased? Which have stayed about the same?

3. As the use of farm labor, horses and mules has declined, what factors of production have taken their place?

4. Which of the factors of production are most energy-intensive?

5. What factors explain why there have been changes in the type of farm inputs?

TABLE II

1. Which prices have increased, decreased, or stayed about the same?

2. Which prices have increased the most?

3. How have the increases in the costs of the factors of production on the farm affected their use?

4. What reasons can you give for different rates of increase in the cost inputs?

5. In 1973 the cost of oil and natural gas nearly quadrupled. What effect might this have on the relative price of fertilizer?

Activity 9 - Crop Drying: How Does It Use Energy Directly?

A WORKSHEET

Introduction

This worksheet provides information and data on the use of a fossil fuel in drying corn. When you finish reading the background information and the available data, you should answer each question, listed below the readings.

Background Information

Modern On-the-Farm Crop Drying

Corn can be harvested as soon as it matures or it can be allowed to stand in the field after it matures, for several weeks, before it is harvested. However, if corn is left to dry in the field too long, a significant portion of the crop may be lost to weather damage, bleaching, mold, fungi, birds and rodents. It has also been demonstrated that automatic corn pickers operate more efficiently if the corn has not been allowed to dry in the field.

If corn is harvested as soon as it matures, crop losses will be reduced significantly. However, the moisture content of the corn must be reduced from 30% to 13% before it can be safely stored. Historically, corn has been harvested and naturally dried in ventilated cribs. It is now common practice to harvest the moist corn and dry it using heaters. The principal fuel for the grain dryers is LP (liquid petroleum) gas.

As the cost of LP gas increases and as the supplies diminish, farmers may have to develop new techniques for the drying of crops. These new techniques can be utilized if they are economically feasible.

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Available Data

The following information was collected from a study conducted by the University of Maryland for the United States Department of Agriculture.

1. The average price of LP gas was approximately 30 cents per gallon in 1973.
2. One gallon of LP gas will reduce the moisture content of 6 bushels of corn from 30% to 13%.
3. The value of corn at the farm in 1973 was approximately $3.00 per bushel.
4. Corn crop production averaged 80 bushels per acre in 1973.

Student Questions

Suppose you are a farmer with most of your Midwest farm acreage in corn. You must choose between using LP gas to dry your corn, or allowing it to dry by itself in the fields.

1. You have planted 25 acres of corn. How many bushels of corn can you expect to harvest?

2. It takes 1 gallon of LP gas to dry every 6 bushels of corn. How many gallons will you use to dry your total corn crop?

3. How much would the gas cost you?

4. If you choose to let the corn dry by itself in the field, you could lose as much as 5% of your total crop. What would this mean in dollars?

5. How much would the price of LP gas have to increase before it would make more sense economically for you to use nature's drying method?

6. What are some ways crops can be damaged if they are left standing in the fields? List them.

7. Suppose you must consider using other methods than LP gas to dry corn. What could you then do?

Activity 10 - Herbicides: An Indirect Use of Energy

Energy Input - Energy Output = Net Energy "Profits"

The following information was taken from a Minnesota study in 1974. You need not consider energy used directly in preparing for and planting the crop. A conventional method of preparation was used and was the same in all three methods of weed control.

ENERGY RELATIONSHIPS IN WEED CONTROL

METHOD OF WEED CONTROL	ENERGY INPUT FOR CONTROLLING WEEDS (kcal/acre)	YIELD CORN/ACRE		NET ENERGY "PROFIT" (DUE ONLY TO WEED CONTROL) (kcal/acre)
		Bushels	Kilocalories	
1. No weed control method.	0	54	------	0
2. Cultivation method.	56,005	81	------	2,665,595
3. Herbicide spraying method.	37,920	90	------	3,590,880

Student Questions

1. Suppose a farmer chooses the first method listed on the chart. Why might he decide to use weed control?

2. What is the energy difference (in kilocalories) between the two methods of weed control?

3. Why do you think there are more kilocalories used in the cultivation method?

4. The chart doesn't show how energy is consumed when manufacturers make herbicides. Energy is also consumed in other steps before it gets to the farm. List these energy-consuming steps.

5. There are 100,800 kilocalories per acre produced in the 1974 study. Write the kilocalories per bushel for each weed control method in the blanks on the chart: Which method produced the most kilocalories per bushel--no weed control, cultivation, use of herbicides? How can you prove it?

6. Net energy in kilocalories/acre as calculated from the data of the Minnesota study show the net energy "profit" due only to weed control (see Column 4, of the chart). What is the difference in net energy between the herbicide method and each of the other methods?

Activity 11 - Eating Wild Foods: Is It a Reasonable Energy Alternative?

Questions for Interview Sheet

1. What wild plants have you eaten or presently eat? What does each of the plants look like? When and where do you collect them?

2. What are the parts of each plant which you eat? What are the ways you would prepare and/or cook each plant?

3. Are there any precautions one should take in eating any of its parts? For example, are any parts poisonous or cause one to become ill? Are there only certain times during the year when a part is harmful to humans?

4. Which plants are stored (or preserved in some way) for use at a later time? How do you go about storing (or preserving) each plant?

5. Do you know of any wild plants which are good for treating an ailment? (optional question)

104

INTERVIEW SHEET

Date____________ Interviewer__________________ Person Interviewed ____________________

	NAME	DESCRIPTION	LOCATION	TIME OF YEAR	PARTS USED	PRECAUTIONS	PREPARATION FOR USE
A.							
B.							
C.							
D.							
E.							
F.							
G.							
H.							
I.							
J.							
K.							
L.							
M.							

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WILD PLANTS FOR PREPARING A "GARDEN" SALAD

PLANT	LOCATION*	PARTS USED
Asparagus	Well drained open field, woods	Tender shoots
Bulrush	Shallow water or waters' edge	White base of stem
Burdock (Great)	Roadsides, vacant lots	Peeled stalk before flowers appear
Catbriar/ Greenbriar	North Dakota east to Texas, found growing on brush and trees	Tender shoots and leaves
Cattail	Ponds, ditches, swamps	Peeled roots, young shoots, white core of stem, flowering ends before yellow pollen appears
Chickweed	Plains East and West Coast in fields and waste places	Young leaves and stems
Chicory	Plains East and West Coast in fields and waste places	Young leaves
Curled Dock	Fields, waste ground	Very young basal leaves
Dandelion	Fields, yards, waste areas	Very young leaves, white base of leaves attached to root crown
Evening-Primrose	North Dakota south to Texas and East, dry roadsides and fields	Young shoots
Grapes (wild)	Climbing in trees and brush	Tender ends in spring
Jerusalem Artichoke	Open areas	Sliced tuber

* Unless otherwise indicated found throughout the Continental United States.

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PLANT	LOCATION*	PARTS USED
Lamb's Quarters	Dry open areas	Young leaves
Onion (wild)	Open dry areas	Bulbs
Plantain (common)	Open areas and open soil	Young leaves
Purslane	Open soil	Young leaves and stalks
Pigweed (Amaranth)	Open areas, waste areas	Young tips and leaves
Raspberry	Open waste areas	Fruits, peeled young shoots
Sheep Sorrel	Open areas, gardens	Leaves
Wood Sorrel (Yellow)	North Dakota south to Texas east; woods, waste areas	Leaves, flowers and stems
Strawberry	High ground, woods, waste areas	Young leaves, fruit
Sweet Flag (Calamus)	North Dakota south to Texas east, river bays and swamps	Peeled stalks
Water cress	Spring fed streams that do not freeze throughout the United States	Young leaves
Winter cress	Plowed and open ground	Leaves of spring plant (rosette)
Violets	Woods	Young leaves and flowers

SEASONINGS

Salt	-	Ashes of sunflowers, hickory bark or coltsfoot leaves; raw stems of Samphire.
Pepper	-	Dried and crushed smart weed leaves Powdered Jack-in-the-Pulpit root Chopped fresh root of Pepperwort Crushed seeds of black mustard, charlock or rape

CONDIMENT

Fresh sliced roots of Indian Cucumber and Wild Ginger

DRESSING

Utilizing a standard formula for diluted vinegar, malt, cider or wine (never white), you can experiment with adding different combinations of the listed herbs and spices. Be creative!

Wild Ginger (roots)
Shepherd's Purse (seeds)
Greenbriar (roots)
Wild Allspice (fruit)
Mustard (seeds)
Sheep Sorrel (leaves)
Catnip (leaves)
Penny Royal (leaves)
Worm Wood
Bayberry (leaves)
Wild onion and garlic (seeds, bulbs, leaves)
Sweet Flag (roots)
Horseradish (roots)

If you would prefer to make your own vinegar then you can experiment with sweet tree saps as a prime source of vinegar. The simplest way to make your own vinegar is to start a yeast fermentation in sweet tree saps, but leave them open to the air; they are almost certain to turn to vinegar.

All Birches	Spring
Butternut	Spring
Hickory	Spring
All Maples	Spring
Black Walnut	Spring

FIELD TRIP RECORD

PLANT			Description	Location	Distance from School	Abundance
Common Name	Scientific Name	Family				
1.						
2.						
3.						
4.						
5.						
6.						
7.						

CALORIC CONTENT OF WILD AND GARDEN VEGETABLES

A

WILD VEGETABLE	food energy calories/100 g
Green Amaranth*	36
Wild Asparagus*	26
Chicory Greens*	20
Dandelion Greens*	45
Lamb's Quarters*	43
Poke Shoots*	23
Purslane	21
Watercress*	19
Curled Dock	28

Some commonly eaten domestic green vegetable for comparison.

B

GARDEN VEGETABLE	
Cabbage	24
Celery	15
Endive	20
Iceberg Lettuce	13
Leaf Lettuce	18
Green Onions	36
Green Peppers	22
Spinach	26
Swiss Chard	25

* Description and directions for use of these wild foods given in *Stalking the Wild Asparagus*, McKay, 1961.

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