BioMath

Ecological Footprint: What's My Impact?

Student Edition

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Ecological Footprint: What's My Impact?

In this unit we will examine the impact that humans have on the environment. In particular, we will focus on the impact that humans have on the environment's ability to sustain life.

People often think of humans as being separate from the environment. Wrong! Humans depend on the environment and in turn the environment's ability to sustain humans depends on what humans do. In this unit we develop a mathematical model for quantifying one aspect of the relationship between humans and their environment. The purpose of this mathematical model is to help us determine what our ecological impact is. Once we can measure our impact, we can use that information to make decisions about how to live our lives—decisions that take the environment's ability to meet our needs into account.

Humans and the environment are mutually dependent, locked in a circle of mutual cause and effect that ultimately involves the Earth's **carrying capacity**—its ability to sustain life, and human life in particular.

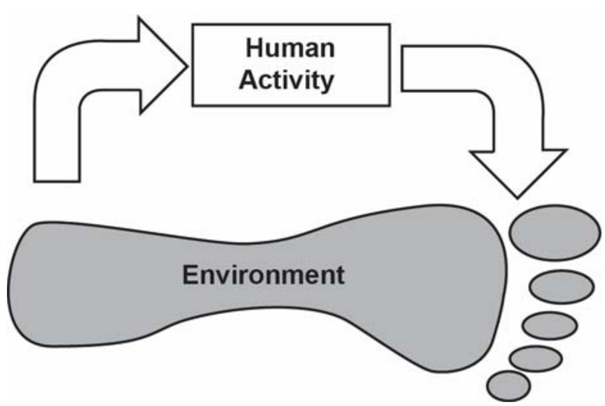
How long can the earth sustain our current level of resource use?

Is there enough of the earth left for other (nonhuman) species to flourish?

This unit shows that our dependency on the environment is much greater than we realize—perhaps too great to be sustained indefinitely.

The unit introduces and discusses the following important topics.

- Biologically productive land
- Ecological footprint
- Sustainable
- Environmental impact
- Biocapacity or carrying capacity
- Dimensional analysis—converting one unit of measure into another
- Conversion factors or conversion ratios
- Overshoot



Unit Goals and Objectives

Goal: Students see themselves, in particular, and the human population, in general, as much more dependent upon the environment than is often apparent in everyday life.
Objectives:

- Identify many of the hidden inputs and byproducts that are required to produce some object or carry out some activity.
- Explain how any given object or activity ultimately depends upon one fundamental resource: biologically productive land.

Goal: Students convert objects and activities into the amount of biologically productive land required to produce the object or sustain the activity.
Objectives:

- Explain how an object or activity can be converted into an area of biologically productive land.
- Use dimensional analysis (converting from one or more units of measure to other units), simple formulas, and tables of conversion factors to convert objects and activities into areas (hectares) of biologically productive land.

Goal: Students use ecological footprinting as a mathematical tool for assessing our dependence on the environment.
Objective:

- Explain the ecological footprinting model.

Goal: Students see human products and activities in terms of their ecological footprint and find ways to reduce human impact on the environment.
Objectives:

- Use simple ratios and interpret graphs to compare the levels of sustainability of objects, activities, lifestyles, and countries and assess the degree of overshoot of the earth's capacity to sustain human life.
- Define and apply concepts of density, scale, and biodiversity to individual, community, population, and ecosystem levels of environmental activity.

Goal: Students analyze the sustainability of an aspect of their lives (personal, school, community) and identify the most ecological alternatives.
Objective:

- In small teams, students will conduct Sustainability Case Studies.

Lesson 1 Ecology of Humans: Connecting Humans to Their Environment

Humans both depend on and alter the environment's ability to sustain life. For example, we depend upon the land to grow crops and provide food; but when we use intensive farming techniques that deplete the fertility of the soil or erode it, we are affecting the land's ability to grow more food to meet our needs in the future. Similarly, if we cut down forests for lumber or housing developments or shopping malls, we are reducing the ability of the formerly forested patch of land to sequester carbon, which in turn influences the climate. Additionally, depending on how the land is treated after lumbering, its ability to provide lumber in the future may be compromised. Clear cutting old-growth forests or rain forests depletes resources that took centuries to build up.

Resource Quest

There are many hidden or indirect dependencies that humans have on natural resources and in turn on the environment. Most of the items in our lives required energy and resources for their production or manufacturing prior to arriving in our possession. The amount of energy that goes into producing and maintaining an object, separate from the energy required for us to use or consume the object, is called **embodied energy**. The resources are called **embodied resources**.

Since energy is a resource required for most of our activities and products, we first consider our energy sources. About 86% of the world's energy needs are met using **fossil fuels**. What do you know about fossil fuels?

ACTIVITY 1-1 Fossil Fuels

Objective: Review fossil fuel facts

Materials

Handout EI-H1: Fossil Fuel Worksheet

1. Answer the following fossil fuel questions individually with no resources.
    a. What are the three main fossil fuels used today as energy sources?

    b. What fossil fuel supplies more than half of the US energy?

    c. Are fossil fuels renewable or non-renewable resources?

    d. What gas is released when fossil fuels are burned?

    e. Which fossil fuel creates the lowest amount of the gas in question d?

    f. Name two other sources of energy that are not fossil fuels.

2. Compare your answers with a partner. Decide upon one answer for each question in part 1.

3. Work with a partner to answer the following questions.
    a. Why are fossil fuels called "fossil fuels"?

    b. How does the burning of fossil fuels impact the environment?

    c. What is **carbon sequestration**?

    d. What can be done to mitigate the impact of burning fossil fuels?

4. Participate in the class discussion and make any necessary corrections and additions to your previous answers.

Sources of Our Stuff

Consider wheat grown on land in Iowa that arrives as processed grain in a box of cereal on a Wisconsin grocery store shelf. It didn't magically appear there. It required large expenditures of energy and resources to grow, harvest, process, transport, package, label and finally ship to the store. And then there are the energy and resource expenditures associated with getting it home and preparing it for consumption and finally disposing of the box. These energy and resource inputs add up to far more than the 120 or so calories our bodies extract from each serving of cereal. These resource and energy demands are hidden from us and therefore we often do not consider them when we assess our dependency on the environment.

In addition to thinking about the sources of the stuff in our lives, consider the byproducts or waste of our products. While a **source** is the place or resource used in the making of a substance or product, a **sink** is the place or process that takes the byproducts or waste that result from using the substance or product out of circulation.

ACTIVITY 1-2 The Stuff Behind Our Stuff

Objective: Identify where all this stuff in our lives comes from and where it goes?
Materials:
Handout EI-H2: The Stuff Behind Our Stuff Worksheet

Consider the following objects and activities.
Objects:
A. A potato or an apple or some other vegetable or fruit
B. A bottle of water (purchased from a store)
C. A bottle of soda or pop
D. A hamburger, chicken nuggets, or some other meat portion of a meal
E. A fish sandwich or serving of fish or shrimp
F. A pair of blue jeans, wool sweater, nylon windbreaker, or some other article of clothing

Activities:
G. Playing a video game or surfing the internet on a computer

H. Playing the violin, flute, guitar, saxophone, piano, or some other musical instrument
I. Riding on a bicycle, four-wheeler, jet ski or some other small personal vehicle
J. Attending a rock concert, or attending a professional athletic event (football, or baseball)
K. Shopping at the mall

1. Think broadly about all possible “hidden inputs” to each object or activity and think about byproducts associated with producing the object or the activity.
   a. For each object, identify and list as many of the things required for its production, use, and disposal as possible.

   b. For each activity, identify and list as many of the things as possible that are required to carry out or sustain the activity.

2. On a blank sheet of paper draw a concept map with one of the objects or activities at the center. Use arrows to connect your object or activity to the primary things listed in part 1 that make it possible. Draw lines to connect these to secondary resources or energy inputs. Continue using lines to track your primary object or activity to as many of its hidden resources and energy inputs as you can think of.

3. After you have identified a large number of hidden resource and energy inputs for an object or activity, go back and trace these hidden resources to even more basic resources. Annotate these resources and inputs on your concept map.

4. Identify as few fundamental *sources* as possible that account for everything on your concept map. Our goal is something to use as a basis for a model of human impact.

5. Now consider the byproducts, or anything else that is required at any point in the production of the object or activity that do not end up in the final object or activity. The ultimate resting place of these byproducts or discarded resources is called a *sink*. For example, potatoes might be packaged in a paper bag; ultimately, where did the bag come from and where does it wind up? Trace these byproducts to their sources and sinks. Determine the most basic sinks for everything on your concept map.

6. Reflect on your work in parts 3 and 4. Identify two or more of the most basic concepts that can serve as both sources and sinks for your object or activity. Then try to trace these basic sources and sinks to a single “most” basic concept. Note that different answers are possible, but think about which sources and sinks are the most basic or connected to most everything. We want to base our model on something flexible. What did you choose as your most basic concept?

7. Why do you think this source/sink is the “most” basic? In answering this question, consider issues such as its abundance, the control humans have over it, and how adaptable it is to being related to everything on your concept map.

A Common Denominator

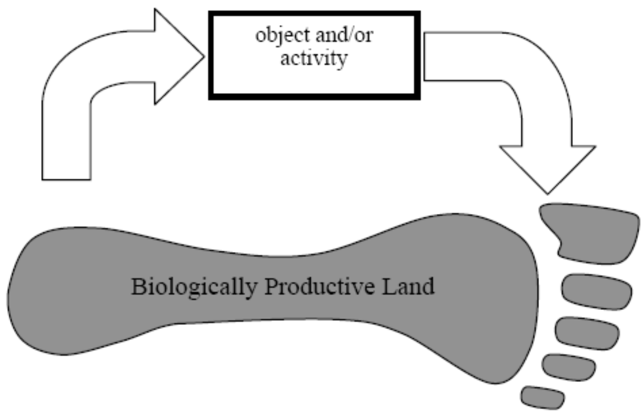
Some of the most common basic sources and sinks are listed below. Included are notes about each resource. Which of these appears to be the "most" basic source/sinks that we can use to build a mathematical model of ecological impact?

Energy	Most of our energy resources come from fossil fuels. Fossil fuels are sources only and don't serve as a sink for wastes or byproducts. Fossil fuels are finite and are non-renewable. Fossil fuels take millions of years to form and we are using them at a much faster rate than new ones are being made. Burning fossil fuels results in carbon dioxide that eventually ends up in a sink.
Water	Water is a finite, but renewable resource. Only 3% of the earth's water is in a usable state. Water is used in many products and activities. All living things require water. Water has to exist somewhere (it covers up land!). Water is also a sink as we pour significant amounts of waste and byproducts into our water either directly or indirectly.
Air	Air is another finite resource. The earth's atmosphere is thin and fragile. Although it is a sink for many byproducts and wastes, it is not particularly useful to think of air as a source of many of the things on the concept map.
Sunlight	The sun is a source for energy and a driving force of photosynthesis. Solar power is renewable, but it requires that we intercept the sun's rays and convert them into a useful form. Photosynthesis does this naturally, but we need a tool like photovoltaic cells to convert sunlight into usable energy. We have to manufacture these photovoltaic cells and then install them somewhere. The problems with solar power include cloudy days, type of current produced, and safe disposal of used solar cells.
Land	Land is a finite resource. In 2007 the largest areas of land in the United States were allocated to forest-use (30%), grassland pasture and range use 27%), and cropland use (18%). Urban areas accounted for about 3% of land. About 14% of land is used for Federal and State parks, wildlife refuges, and related protected areas.[1] While land is mainly used to grow our food, support our livestock, and provide wood, it is also the site on which most everything must exist or take place. We only have 1 planet Earth! Underneath our land, rich fossil fuels exist. Land is also the sink for most of our waste and byproducts. Even many forms of air pollution wind up on the land when they literally "rain" to earth with precipitation.

Environmental scientists want a "common denominator" for assessing human ecological impact: one good choice is **biologically productive land**. Biologically productive land is that which is sufficient to support crops, forest, plants or animals. This unit develops the idea of land as a "meter stick" for measuring ecological impact. All that is required is some work in converting resources and energy consumption into the amount of land needed to produce or sustain a given object or activity and all its hidden resource and energy needs.

Needs Versus Luxuries

All life, and human life in particular, requires food & water, air, shelter and energy. All these needs can be reduced to a footprint on the surface of the earth: an **ecological footprint**. An ecological footprint is the amount of biologically productive land required to produce and dispose of some object, or to sustain an activity for an individual or a population for a period of one year. The portion of that footprint that results from the need for carbon sequestration of the burning of fossil fuels is the **carbon footprint** for that object or activity.



Humans use many resources for things that are not needed for life. We may use them for recreation, convenience or simply pleasure. From a biological standpoint, anything not necessary for life is a luxury. Some uses of our resources may pose possible health risks. For example, soda can cause cavities, weight gain, and hyperactivity. Given that soda pop is mostly water, we could hydrate more efficiently and cheaper from a drinking fountain! Add to this the issue of bottle disposal or recycling. Today many of us consider cell phones a necessity, but they too cause a disposal problem with their short lives and the potential for leaching of toxic substances into the environment. Cell phones contain both metals and plastic that can be recycled and reused. In 2009, only about 8% of 141 million mobile devices at the end of their life cycle were recycled.[2]

ACTIVITY 1-3 I Need That!

Objective: Distinguish between necessities of life and luxuries
Materials: Paper

Brainstorm with a partner to find 5 examples of each of the following. Write your list on a separate sheet of paper. Be prepared to share with your class.

1. Needs
2. Conveniences
3. Luxuries

Ultimately, once we move beyond basic biological needs, the distinction between needs, conveniences and luxuries is a matter of degree and circumstance. What is a convenience to one person might be a luxury to someone else. The reduction of luxuries and conveniences can help us reduce our footprints so that future generations can meet their basic needs. The increase in efficiency of our use of energy and other resources in meeting our basic needs will also reduce our footprints.

You might notice that most of the luxuries and conveniences are material in nature. Our modern society advocates a level of materialistic consumption that can displace time and attention to non-materialistic aspects of life. Perhaps it is possible to reduce luxuries and increase efficiency without reducing our quality of life. In the pursuit of having more things we may spend more time working to obtain these things and then worry more about keeping them. Consider the lists you made in the activity. Which of the items listed could you give up without reducing the quality of your life?

Lesson 2 Ecological Footprint Conversion Factors

In Lesson 1 we chose land as a "common denominator" or "meter stick" for assessing environmental impact. Now we examine the impact of our products and activities in terms of the amount of land each depends upon. Eventually we want to sum the impact of all of the products and activities in our life to determine our own individual ecological footprint.

Think about the units of land that we might use in our calculations. Some units of area that may be familiar to you are square feet or square yards or square miles. Using the metric system you may measure area using square meters or square kilometers. Another type of land measure is a **hectare**. A hectare is 10,000 square meters or a square patch of land that measures 100 meters on each side.

Identifying Footprint Conversion Factors

What type of conversion factors are needed to convert objects and activities into the areas of land they depend upon? Remember that different objects and activities might have different components that require several different types of conversion factors. For now, do not worry about the exact numbers needed to make the conversion; just focus on the units.

Consider trying to measure the footprint of an apple. Here are some of the possible conversions factors that your might need. Can you think of some others?

Some obvious ones: *apples/tree, trees/acre, trees/hectare*

Gasoline associated with cultivation and harvesting: *gallons/acre, liters/m*2

Gasoline associated with transportation: *gallons/mile, miles/apple*

Packing materials (paper, cardboard, wood): *pounds/apple*, kg/m^2

Pesticides, herbicides, fertilizer: *pounds/acre*

Water: *gallons/acre*, $liters/m^2$

ACTIVITY 2-1 Linking a Magazine To An Acre

Objective: Determine conversion factors that might be needed to measure the footprint of products and activities

Materials:

Handout EI-H4: Linking a Magazine to an Acre

1. Define the units (don't worry about the numbers involved) of some footprint conversion factors associated with the following items and activities. Do not worry about the exact numbers needed to make the conversion. Focus on the units or the dimensions involved.

   a. A magazine

   b. A t-shirt

   c. A pizza

   d. Going to a movie

   e. Riding a 4-wheeler (ATV)

2. Choose three different conversion factors you identified above. Explain how we could determine the actual values (or numbers) for the conversion factors, or explain how we could make measurements (or conduct experiments) to figure out what values (or numbers) should go with the units you've identified.

3. What kind of information would we need to gather about a person to calculate his or her impact on the environment—what data would we need to calculate someone's ecological footprint? Don't worry about the numbers involved, just describe the kinds of information we would need. For example, we would need to know the average number of miles the person drives over some time period and what type of car they drive.

Footprint Conversion Factor Tables

Luckily you will not have to do all of the work involved in determining the exact values of all of the conversion factors needed to calculate the footprints of various objects and activities. Environmental scientists have done much of this work for us.

Appendix B contains six tables of conversion factors for the following categories: food, transportation, housing, goods and services, stocks and wastes.

How might you use the conversion tables to determine your own ecological footprint?

Ecological Footprint Survey

Ecological Footprint analysis calculates how much of the earth is required to sustain an individual's lifestyle. A person's ecological footprint represents the area of biologically productive land and water required to support his or her consumption of a variety of products such as goods, services, transportation, fuel and food.

Answer the following items on the survey response sheet (or a blank sheet of paper). If you belong to more than one household, focus on just one of the households. You may need to ask an adult at home to assist you with portions of the survey.[3]

Food

1. How often do you eat animal-based foods (beef, pork, chicken, fish, eggs, cheese and other dairy products, etc.)?
    a. Never (vegan)
    b. Infrequently (no meat or eggs/dairy a few times a week)
    c. Occasionally (no meat or occasional meat, eggs/dairy daily)
    d. Often (meat once or twice a week)
    e. Very often (meat daily)
    f. Almost always (meat and egg/dairy in almost all meals)
2. How much of the food that you eat is processed, packaged and not locally grown (from more than 200 miles away)?
    a. Most is processed/packaged and from far away
    b. Three quarters
    c. Half
    d. One quarter
    e. Very little. Most food I eat is unprocessed, unpackaged and locally grown.

Shelter

3. How many people live in your household full time?
    a. 1 person
    b. 2 people
    c. 3 people
    d. 4 people
    e. 5 people
    f. 6 people
    g. 7 or more people
4. The average living space for a US household is around 1500 square feet. What is the size of your home?
    a. 2500 square feet or larger (4+ bedrooms)
    b. 1900–2500 square feet (3–4 bedrooms)
    c. 1500–1900 square feet (2–3 bedrooms)
    d. 1000–1500 square feet (1-2 bedroom house, 2 bedroom apartment)
    e. 500–1000 square feet (1 bedroom or efficiency-apartment)
    f. 500 square feet or smaller (one room apartment)
5. Which housing type best describes your home?
    a. Free-standing house or duplex
    b. Multi-story apartment building or condo
    c. Green-design residence

6. Do you use energy conservation and efficiency measures *throughout* your home, like florescent light bulbs, Energy Star appliances, thermal windows, etc.?
    a. No (none or only some of the above)
    b. Yes (all of the above)

Transportation

7. On average, how far do you travel on public transportation each week?
    a. 200 miles or more
    b. 75–200 miles
    c. 25–75 miles
    d. 1–25 miles
    e. 0 miles
8. The average car-driving American travels about 14,000 miles per year, or 270 miles per week. On average, how far did you go by car each week (as a driver or passenger)?
    a. 400 miles or more
    b. 300–400 miles
    c. 200–300 miles
    d. 100–200 miles
    e. 10–100 miles
    f. 0–10 miles
9. How many miles per gallon does the car you ride in get?
    a. More than 50 miles per gallon (hybrid, like a Toyota Prius)
    b. 35–50 miles per gallon (small efficient car, like a Honda Civic, Toyota Corolla, etc.)
    c. 25–35 miles per gallon (large family car like a Honda Accord, Toyota Camry, etc.)
    d. 15–25 miles per gallon (truck or SUV, or powerful sports car, like a Ford Mustang, a minivan)
    e. Fewer than 15 miles per gallon (very large SUV, truck or other vehicle)
10. How often do you ride in a car with someone else, rather than alone?
    a. Almost never
    b. Occasionally (about 25% of the time)
    c. Often (about 50% of the time)
    d. Very often (about 75% of the time)
    e. Almost always
11. Every year, Americans fly an average of 4.7 hours per person on commercial airlines. This is roughly equivalent to one round-trip flight between Washington, DC and Chicago each year. Approximately how many hours do you spend flying each year?
    a. 100 hours (approximately 10 coast-to-coast US round trip each year)
    b. 25 hours (approximately 2–3 coast-to-coast US round trips each year)
    c. 10 hours (approximately 1 coast-to-coast US round trip each year)
    d. 3 hours (approximately 1 short trip a year)
    e. I never fly.

Goods

12. Compared to people in your neighborhood, how much waste does your household generate? Think about how much trash your family puts on the curb on trash day compared to other households in your neighborhood.
    a. Much less
    b. About the same
    c. Much more

Lesson 3 The Ecological Footprinting Model

After completing your ecological footprint survey you now have a better idea of the activities and items in your life that use our world's resources. You may also have an idea of whether you are a person that carefully uses and conserves available resources or a person who hasn't really thought about your resource usage. How would you determine your impact on resources?

ACTIVITY 3-1 Gaining Some Consumption Perspective

Objective: Estimating resource usage
Materials:
Handout EI-H7: Consumption Worksheet

Estimate how much of the following products or items you or your family use in a year. Record your usage estimates and calculations. Possible calculations for the first two items are shown below

1. Apples. 1 apple per day and each apple weighs 0.2 pounds.
   0.25 lbs/day × 365 days/year = 91.25 lbs/year.

2. Pairs Cotton Blue Jeans. Own 3 pair and they last about 3 years.
   3 pair/3 years = 1 pair/year

3. Boxes of Cereal.

4. Pounds of Candy.

5. Sweatshirts.

6. Fast Food Meals.

7. Daily Newspaper.

8. Individual Water, Soda, Energy Drink Bottles.

Footprinting
The Ecological Footprinting Model in this unit has six assumptions. The motivation behind these assumptions is that we can combine and scale up individual footprints to arrive at the percentage of the earth's available land that an ecosystem depends upon. Our focus will be on humanity's ecological footprint. Consider the following assumptions.

Assumptions Behind the Ecological Footprinting Model[4]

1. We can account for most (if not all) of the resources, energy, and waste that humans consume, use, or generate. This accounting is of resource **flows** and waste flows.

2. In the end, all the resource flows and waste flows can be measured in terms of the amount and kind of land needed to maintain the flow.

3. Different types of land can be equated with each other if expressed in terms of the productivity of an average world hectare of land. For example, desert is not very productive, rich cropland is very productive, forested land is somewhere in between. Different degrees of productivity are averaged to arrive at an average global hectare of productivity.

4. Land use is largely mutually exclusive, therefore different types of land use can be added together to find a total "footprint" for our demands on nature in terms of the number of average world acres required. For example, land being used to raise cotton is not also going to be used to supply the building resources for the factory where cotton is made into cloth, and both of these are distinct from the forest land that sequesters the carbon generated by the fossil fuels used in producing and transporting the cotton.

5. The sum of our demands on nature—our ecological footprint—can be compared with the environment's available land. The result is an indication of whether our use of the environment is sustainable.

6. Area demanded can exceed area supplied if demand on an ecosystem exceeds that ecosystems regenerative capacity. This is called **overshoot**.

Note that these assumptions focus on biologically productive land—land that is capable of yielding some kind of biological product or activity. We are not considering barren desert, the arctic, or other unproductive spaces. Some land is already built upon (houses, factories, roads, cities, power plants, etc.) and is no longer biologically productive. There are roughly 415 million acres of built-up land, or 0.06 acres per person worldwide.

Estimates of our ecological footprints will most likely be *underestimates* because we can't take into account *every* hidden resource or byproduct. By determining our ecological footprint we can begin to see our impact on resources in terms of the area of land required to sustain our activities and products. We can use the list below to think about the different kinds of land and its finite availability.[5][6]

Land Type	Worldwide Area (2007)	Description
Forest	3.9 billion hectares	moderately productive – timber and fuel
Arable	1.6 billion hectares	very productive – food, fiber, feed, oil crops, rubber
Pasture	3.4 billion hectares	less productive – raising livestock
Sea	2.8 billion hectares	productive – continental shelf & inland fishing
Built-Up	0.167	not biologically productive
TOTAL	~11.9 billion hectares	[1 hectare = 2.47 acres]

Table 3.1: Land Types and Availability

Everything we use comes out of these 11.9 billion hectares and much of our waste and byproducts go into these acres. In 2007, with a world population of 6.6 billion people this translated to approximately 1.80 hectares (4.5 acres) of usable land per person in the world. If the human population were to use all of this available land, no land would be left for other species' needs. The figure of 1.8 hectares/person (4.5 acres/person) is an upper bound and one that cannot be sustained indefinitely!

Footprint Factors

A **footprint factor** is a ratio used to convert an object or an activity into the amount of biologically productive land required to produce or sustain that activity.

The true ecological footprint of an object or an activity is often much larger than we think because of the hidden inputs and wastes associated with it. One of the biggest hidden contributors to any footprint is the fossil fuel consumed. Therefore, one of the most important footprint factors is the energy per land conversion factor that determines the carbon footprint. This factor is computed in terms of the amount of carbon that an area of vegetated land can sequester per year.

Fossil Fuel Footprint Factor: 40 gigajoules per acre per year

This fossil fuel footprint factor is then converted into more usable forms such as the following factor for gasoline: 113 square meters of land per year for each liter of gasoline burned per month.

How Big is its Ecological Footprint?

We use the footprint factors on the conversion tables (Appendix B) to determine the footprint of activities or items in terms of land area. With these tables, we will determine our annual footprint using our monthly usage of resources. The factor converts the monthly usage to an annual footprint. This is done because it is easier to calculate how much of a resource we use on average in a month versus how much we use over an entire year.

Example 1:
What is the ecological footprint of a 20-mile round trip commute driven 5 days a week? First we need to know how efficient the car is. Suppose it gets 25 miles per gallon. Also suppose that there is only one person making the commute.

Total miles traveled:

20 miles/day × 5 days/week = 100 miles/week

Gas used:

100 miles/week ÷ 25 miles/gallon × 4 weeks/month = 16 gallons/month

From Table B.2 we find the conversion factor of:
500 square yards/gallon

Footprint:
16 gallons × 500 square yards/gallon = 8000 square yards

In acres this is:
8000 square yards × 0.000206 acres/square yard = 1.648 acres

So relative to the 4.5 acres this person has available for his or her needs, 36% of it is taken up by this commute. That's 36% of the person's share of the earth that can't be used for anything else. Also note that this is an underestimate, as we didn't factor in the footprint of the car itself or the maintenance of the car.

What is the effect of car-pooling? If two people share this commute, each of their commuting footprints is cut in half! The reduction is from 1.65 to .82 acres and from 36% to 13%. If three of more people shared the commute, the reductions would be even greater.

Example 2:
What is the ecological footprint of a 5kg computer that lasts 6 years?

Convert to monthly rate of use:
5 kg/6 years × 1 year/12 months = .069 kg/month

From Table B.5 we find the monthly conversion factor of:
2440 m^2/kg

Footprint:
.069 kg × 2440 m^2/kg = 168.4 m^2

In hectares this is 168.4 m^2 × 1 ha/10000 m^2 = 0.017 ha.

Without factoring in the electricity to run the computer, the computer alone represents .017/1.8 or .9% of a person's 1.8 hectares of land during its useful life. When it is discarded, or better yet recycled, its footprint will be increased. See Table B.6 for recycle factors.

Questions for Discussion

1. Consider a 4 lb food blender (a small appliance).
   a. What assumptions would you make to determine the blender's footprint?

   b. What conversion factor would you use to calculate the footprint?

   c. Calculate the blender's footprint in square meters.

2. Consider a polyester (synthetic) sweatshirt that weighs 0.5 kg.
   a. How many of these types of sweatshirts do you own? (Assume you have at least 1)

   b. What assumptions would you make to determine the sweatshirt(s) footprint?

   c. What conversion factor would you use to calculate the footprint?

   d. Calculate the sweatshirt(s) footprint in square meters per month.

Calculations based on these conversion factors or ratios are estimates. In most cases, they are underestimates. Even so, ecological footprinting is a useful mathematical model as an accounting tool that helps to determine if a population's use of its resources is sustainable.

Practice

Use the Tables of Ecological Footprint Conversion Factors to find the ratio needed to calculate the footprints of the following objects and activities. Then determine the footprint in terms of land area. Remember to convert to monthly rates of use (4 weeks/month, 30 days/month, 52 weeks/year, 12 months/year) prior to multiplying by the footprint factor.

1. Receiving a 0.45 kg (1 lb) newspaper daily *and recycling it.*

2. Eating three one-quarter pound hamburgers per week

3. A 12 kg metal bicycle that lasts 5 years

4. A 1 lb (.45 kg) pair of cotton blue jeans that lasts 3 years

5. A 6 hour round-trip economy class airline flight twice a year

6. A family of four eating a gallon of ice cream each week

Lesson 4 Environmental Sustainability and Carrying Capacity

Environmental scientists use the formula $I = P \cdot A \cdot T$ to represent the environmental *I*mpact that results from a *P*opulation living at a given level of *A*ffluence and possessing a given level of *T*echnology. It represents a direct variation. In general, the more people there are, and the higher their standard of living is, and the more advanced their technology is, then the greater will be their impact on the environment. These values are multiplied together because A and T represent average per person values.

For example, if the affluence of a population increases because everyone now owns two cell phones, the impact increases since we multiply the population by the number of cell phones per person. The impact would further increase if each cell phone becomes even more advanced and makes use of new technology that requires even more resources to produce.

For our purposes, we combine the A and T factors into one. We will simply use the formula $I = P \cdot F$ where F represents the average ecological footprint of the members of a population. Often, this value is called per person consumption. The more we consume, the greater our footprint will be, and the greater our environmental impact will be.

Of course, if we find ways to be more efficient, it is possible that our impact can be reduced without reducing our consumption—and if that happens, then new footprint conversion factors would need to be calculated. But efficiency is a tricky concept! Often when something becomes more efficient it just means that *more* people wind up using even *more* of it, and in the end our environmental impact is even greater than it was when something was hard to produce. Solving the sustainability problem requires wisdom.

Environmental Sustainability

Environmental sustainability refers to a relationship between a population and its environment that allows the current population to meet its needs without reducing the environment's capacity to meet future population's needs.

Each pair of graphs below represents the trend of a population's size, and the trend of the population's per person consumption—the ecological footprint per person. In each case we are interested in whether the scenario is sustainable if the indicated trends continue. Remember! There is just one finite planet that can support the population.

1. Do the trends below represent a sustainable scenario? Why or why not?

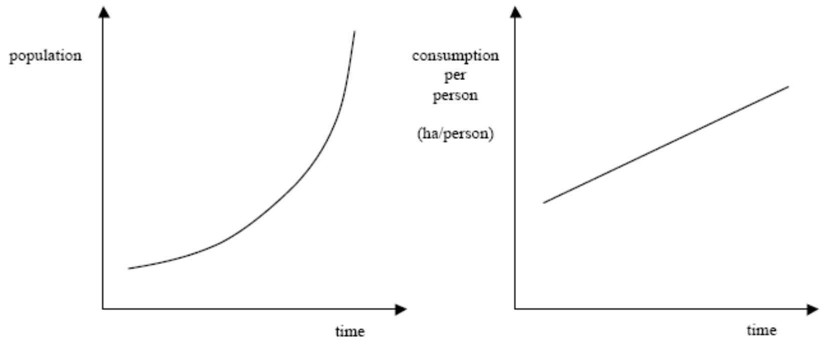


Figure 4.1:

2. Make up a story that explains the trends in the population and its per person footprint graphs represented below. What might have happened?

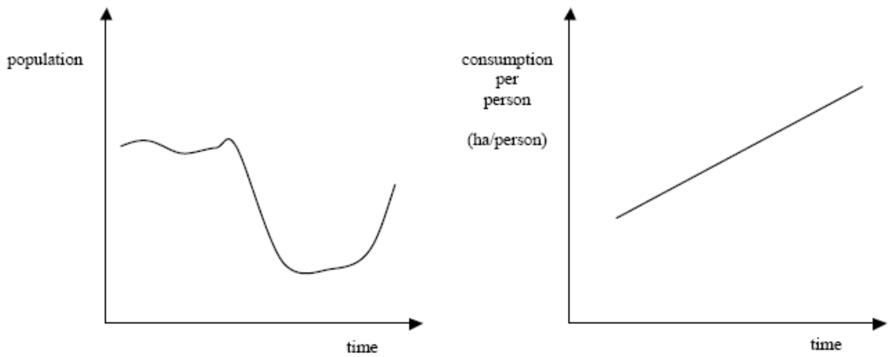
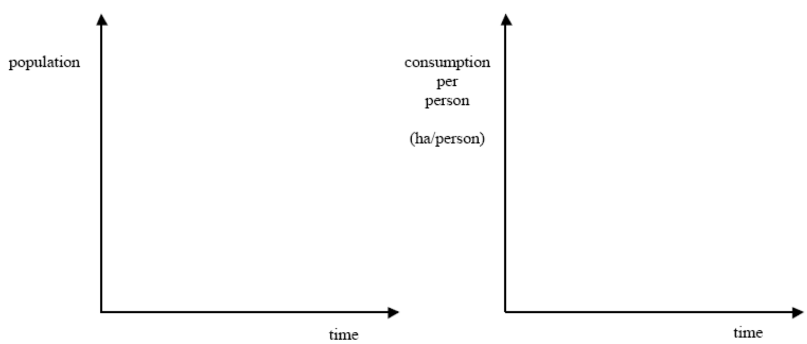


Figure 4.2:

3. Sketch a pair of graphs that represent a population and its per person consumption (or footprint) that are sustainable.



Carrying Capacity

We live on a finite earth with finite resources. Population and consumption cannot continue to grow indefinitely. The maximum possible combinations of population and consumption levels that can be sustained determine an environment's carrying capacity. You can think of this as the product of population and sustainable per person consumption. An environment can sustain any combination of population and consumption that does not exceed its carrying capacity. A large population with low levels of consumption might be as sustainable as a small population with higher levels of consumption. In all cases, it is the ability of the environment to meet a population's needs that determines how large the combination of population and per person consumption levels can be.

Reflecting on Our Personal Footprints

Think about your own consumption. If everyone on earth had the same footprint as yours, would this situation be sustainable? In other words, if we took the product of our current population and your footprint would it be less than earth's available surface area or more than earth's available surface area? Within your class, do you think you have one of the smaller or one of the larger footprints?

If you completed the Ecological Footprint Survey after Lesson 2, your teacher may have the results to share today. Remember your ID number in order to see your footprint in comparison to other students in your class.

Questions for Discussion

1. Did you correctly predict your relative footprint size?

2. What do you think contributed most to your footprint?

3. What changes could you make to decrease your footprint?

Practice

For each choice of two items below, first predict which of the options is more sustainable. Then use the Footprint Conversion Factor Tables in Appendix B to find the footprint. Show your calculations and explain which option is more sustainable.

1. Burgers: 1 lb of hamburger or 1 lb of tofu (made from 1/3 lb of dry soybeans).
Prediction:

2. A cotton sweater (or sweatshirt) or a wool sweater of half the weight. Use "w" to represent the weight of the sweater (in kg).
Prediction:

3. A 100-watt incandescent bulb or a 20-watt fluorescent bulb (the fluorescent bulb generates a brightness equivalent to a 100 watt incandescent bulb) turned on for one hour.
Prediction:

4. Choose two other alternatives of your own and compare their footprints. Be sure to choose alternatives that are represented in the Tables of Conversion Factors.
Prediction:

Lesson 5 Individuals, Communities, Populations, and the Scaling of Impact

As you have seen in the previous lesson, you use natural resources in every aspect of your life. Imagine the collective impact on resources when you consider the usage by everyone in your community or in your country or in the world. As we begin to examine the bigger picture of sustainability, we consider the amount of land available to populations in various parts of the world.

Population Density

Consider a country *A* with population *y* and area *x* hectares.

Questions for Discussion

1. What is the meaning of population density?

2. How would you determine the population density of a particular city or country?

Definition:
Population Density: a measurement of population per unit area or unit volume.

3. Four countries, *A*, *B*, *C* and *D*, are plotted on the graph shown in Figure 5.1. All countries have equal average ecological footprints. Note that the vertical axis shows population and the horizontal axis shows available land area.

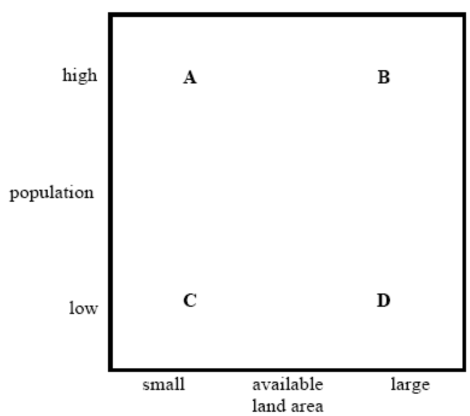


Figure 5.1:

a. Rank each country's population density from least to greatest.

b. Describe in words each country's population density.

c. Describe the countries in terms of their relative sustainability.

d. How does sustainability relate to population density?

Human Carrying Capacity of Earth

As was seen in Lesson 3, it is the product of *people* and *per person consumption* that measures a population's impact on the environment.

In symbols: Impact = Population × Average Footprint per Person. Or: $I = P \times F$

On a finite earth, the product of the population and the average amount of land required per person must be less than the amount of land available. So there is a maximum sustainable value of I. In the equation below we use I_{max} to represent this maximum sustainable impact. The line plotted on the graph is the carrying capacity of the earth. With the units in place, our equation becomes:

$$I_{max}\ \textit{hectares} = P\ \textit{persons} \times F\ \textit{hectares per person}$$

Determining this upper limit is a difficult task, but currently environmental scientists and economists believe that there are roughly 12.13 billion hectares (about 30 billion acres) of biologically productive land available on the planet (www.footprintnetwork.org/en/index.php/GFN/page/footprint_data_and_results/.) So with this maximum value for I, our equation now looks like:

$$12{,}130{,}000{,}000\ \textit{hectares} = P\ \textit{persons} \times F\ \textit{hectares per person}$$

Questions for Discussion

4. Find and interpret three combinations of values for P and F that will make the equation true?

5. How are P and F related? Find an equation for P in terms of F and for F in terms of P and describe their relationship.

6. The figure below shows a possible graph of the carrying capacity of the earth. Justify why this may be the graph of the equation $12{,}130{,}000{,}000 = P \times F$.

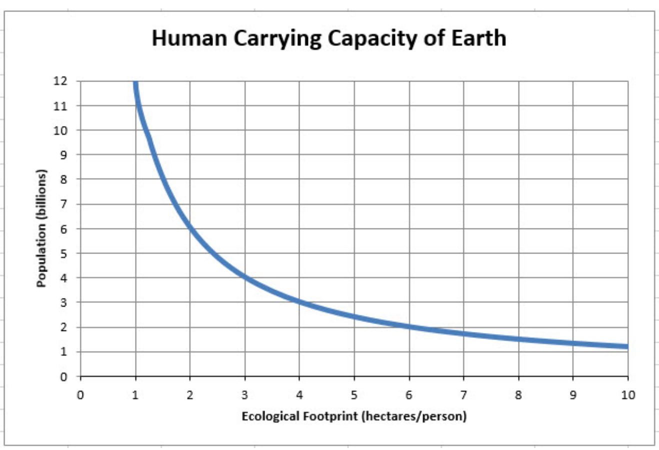


Figure 5.2: Carrying Capacity of The Earth

7. Describe what happens in a situation where a point falls on or below the carrying capacity curve?

8. Describe what happens in a situation where a point falls above the carrying capacity curve?

9. What happens if there are innovations in technology, energy resources or manufacturing?

The carrying capacity equation in Figure 5.2 is an inverse relationship whose graph is the hyperbola: P = 12,130,000,000/F. In more familiar algebraic symbols, it would be $y = k/x$ where k is the constant of variation.

Any point that falls above the curve represents an unsustainable population. Such a population is said to **overshoot** the carrying capacity of the environment. Such a population can exist temporarily because of stockpiles of resources such as rich arable land, fossil fuels, large forests, and fresh water. The population is unsustainable in the long run because it is using resources faster than the environment can renew them.

This state of affairs is precisely the environmental challenge our planet faces: almost all vital resources are being used up faster than they can be renewed. Our collective average footprint is currently unsustainable. This environmental challenge is tied closely to a human rights challenge. Who is going to decide who gets to live at what standard of living? Today a small minority of the human population consumes a vast majority of the resources. As the poorer majority of the population tries to follow in the steps of the well-off minority, the human impact on the environment will only worsen.

A Tour of World Footprints

Comparing a country's per person footprint with the country's per person biocapacity reveals whether that country's population is living sustainably within its borders—whether the population is within the carrying capacity of the country itself.

ACTIVITY 5-1 Population and Biocapacity

Objective: Examine data of population and biocapacity to develop an understanding of a country's ecological footprint and how its footprint compares to the country's biologically productive land area (its biocapacity).

Materials:

Handout EI-H8: Population and Biocapacity Worksheet

The table below shows the population, biocapacity and average ecological footprint per person for 14 countries and the earth as a whole. The unit of "global hectare" refers to a hectare of land with the global average biological productivity. The biocapacity is the available productive land per person within the county's borders. (Note: There may be some discrepancies due to rounding.)

A Tour of World Footprints

Region	Population (millions)	Biocapacity (millions of global hectares)	Ecological Footprint (global hectares per person)	Biocapacity per Person (global hectares per person)	Ecological Surplus/ Deficit (global hectares per person)	Total Ecological Footprint (millions of global ha)
World	6,739.6	12,130.00	2.7			
Argentina	39.7	281.87	2.7			
Australia	21.5	313.90	6.7			
Austria	8.3	27.40	5.3			
Bolivia	9.6	176.64	2.6			
Brazil	191.5	1838.40	2.9			
Canada	33.3	496.17	6.4			
Denmark	5.5	26.40	8.3	4.8	-3.5	45.65
Finland	5.3	64.66	6.2			
Ireland	4.4	14.96	6.2			
Mongolia	2.7	41.31	5.5			
New Zealand	4.3	43.86	4.3	10.2	5.9	18.49
Russian Federation	143.2	945.12	4.4			
Sweden	9.2	87.40	5.7			
United States	305	1189.50	7.2			

Table 5.1: World Footprints

Table Data: 2008 Data from Global Footprint Network Oakland, CA
www.footprintnetwork.org/en/index.php/GFN/page/footprint_data_and_results/

1. Consider that New Zealand has ___hectares of biologically productive land available per person and its citizens have a per person footprint of __hectares. If we subtract the footprint from the biocapacity, we see that there are 5.9 hectares of biological productivity per person that is not needed to meet the needs of New Zealand's 4 million people. This land can be used to meet the needs of non-human species. New Zealand, when viewed in isolation, is:

_____ living within its carrying capacity.
_____ overshooting its carrying capacity.

2. On the other hand, Denmark's 5.5 million people have an average footprint of hectares per person, but there is only hectares of productive land per person. Subtracting the footprint from the biocapacity yields hectares per person. Denmark, when viewed in isolation, is

_____ living within its carrying capacity.
_____ overshooting its carrying capacity.

3. What role does population density play in the different situations of New Zealand and Denmark?

4. How do you determine the missing values for:

a. Biocapacity per Person?

b. Ecological Surplus or Deficit?

c. Total Ecological Footprint?

5. Fill in the missing values in the table.

Practice
Use your completed table from Activity 5-1 to answer the following.

1. Each person in Bolivia uses 2.6 ha/person. How many hectares are available per person, but not used?

2. The United States has a biocapacity of 3.9 ha/person, but each person uses 7.2 ha.
   a. How much extra land is required per person?

   b. Where does the excess land come from to support people in the US?

3. Look at Brazil's data.
   a. What is Brazil's population?

   b. What is Brazil's ecological footprint per person?

   c. How much biologically productive land is required to support their population?

   d. Does Brazil have enough land to support their population? Calculate the surplus or deficit. Show all work.

4. What happens to the World's entire ecological surplus?

5. Which country is using the least of its biocapacity? Explain.

6. Which country is most living beyond its biocapacity means? Explain.

Scaling Up

The world's population and its footprint combine the data from all countries. Now consider if the entire population of the earth lived as the populations of Australia, Brazil or the United States. To determine what this would be like, we scale up each of the three countries' data to the global population of 6.7 billion.

For example, the population of Australia is 21.5 million. To scale up Australia's population to that of the world we multiply 21.5 by 313. We then multiply Australia's per person ecological footprint to obtain a total scaled up ecological footprint of 6.7 x 21.5 x 313 = 45,088 million global hectares.

Similarly, we can scale up Brazil's and the United State's data to obtain the equivalent amounts if everyone of earth lived as those in these countries.

Brazil: Scale factor = 35.19
Scaled up ecological footprint = 2.9 × 191.5 × 35.19 = 19,545 million global hectares

United States: Scale factor = 22.1
Scaled up ecological footprint = 7.2 × 305 × 22.1 = 48,531 million global hectares

We can plot these three situations on our Carrying Capacity of the Earth graph as shown below. This graph uses a logarithmic vertical axis so that we can easily see the differences in the points. The graph shows Australia (A), Brazil (B) and the United States (U) in isolation by plotting their individual populations against their individual ecological footprints. Additionally, the points A', B' and U' show the respective positions of each country's scaled up data.

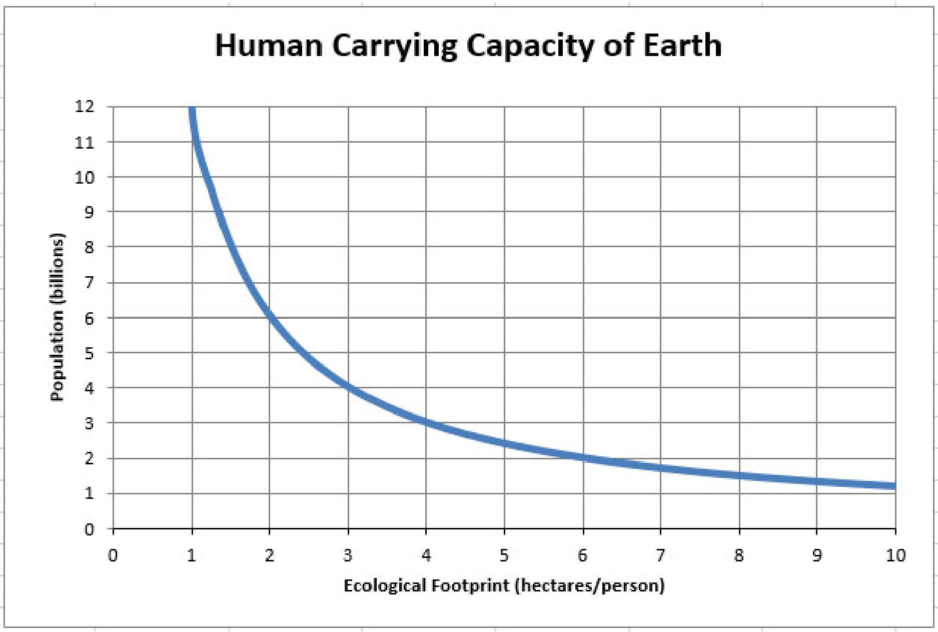


Figure 5.3: Plotting Countries' Footprints-Logarithmic Graph

Note the difference! Smaller populations can have larger footprints and be sustainable by using the surplus of other populations. But, if we scale up to the global population there simply isn't enough biologically productive land available.

In comparing A', B', and U' note that since they are all based on the same population value, it is only the footprint that determines how sustainable the population is. Even if we all lived as they do in Brazil we would be overshooting the carrying capacity of the earth.

Finally, plot the World data onto the graph above. This is the point (6.7, 2.7) and it lies just to the right of Brazil's. This point represents our current unsustainable population.

Questions for Discussion

9. What is the meaning of the area to the top right of the graph in Figure 5.3?

10. If the world currently contains 6.7396 billion people and there are 12,130,000,000 hectares of available biologically productive land. How many hectares could each person on the planet "have" if everyone got the same amount? Show all work.

11. How does this value compare to the table of global hectares/person for other countries listed on the country footprint data table?

12. Looking at the data table, what country that has a footprint that is closest to the value you found in question #2?

13. Look at the plots on the Human Carrying Capacity of Earth logarithmic graph of the US, Australia and Brazil data. Which country by itself is the closest to crossing that sustainability line?

14. Look at the plots on the Human Carrying Capacity of Earth logarithmic graph of the US, Australia and Brazil as if everyone in the world is living with the same ecological footprint of these countries. Order the lifestyles from least overshoot to most overshoot.

15. How many Bolivians could live on the footprint of 1 American? Show your calculation and include the proper units.

16. Demographers predict the world population might reach 10.1 billion by the year 2100. How many hectares of biologically productive land would be available per human being if this occurs, and if there is no change in the efficiency of our use of resources?

Where Do We Go From Here?

Confronting the unsustainability of our current way of life can be disturbing. It is especially disturbing to realize that this unit has had at its core the assumption that humans can appropriate the entire planet for themselves. Such an intense use of resources by one species leaves very little room for biodiversity. One way or another and sooner or later, humans have to come to terms with the fact that they are not separate from the rest of nature. Human ecology is inextricably linked to the global ecosystem.

Perhaps the first best step we all can take is to study the environmental problems and understand our role in them—both how we affect and are affected by them. Then we can all engage in spreading awareness of the problems. And finally we can all begin taking steps to reduce the degree to which we contribute to environmental degradation and exploitation.
As governments and businesses begin to focus on solving environmental problems and becoming more energy efficient and independent new careers and fields of study will open. The students of today will be the leaders in this effort.

Lesson 6 Mini-Case Study

“Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has.” —Margaret Mead

How would you begin to change the world? Perhaps you would start in your own home, neighborhood, town or city. Select an issue of local importance in your school or local community. Complete a footprint analysis of alternative solutions/situations to see which is more sustainable.

Use your own issue or choose from the following list of possible issues to address. Calculate and compare the ecological footprints of these alternatives. Present your findings either on a poster or an electronic presentation as directed by your teacher.

A. Organic vs. conventional produce
B. Coffee cups vs. reusable plastic mugs vs. reusable metal mugs vs. ceramic mugs
C. Local produce vs. cross-country produce
D. Walk vs. bike vs. public transportation vs. carpooling vs. individual car
E. Frozen vs. fresh food
F. Cornmeal vs. oats vs. processed cereal
G. Conventional grain-fed beef vs. organic grass-fed
H. Gas vs. hybrid cars
I. Conventional cotton vs. organic cotton vs. polyester clothing
J. Wood vs. plastic furniture
K. Aluminum vs. steel vs. plastic vs. carbon fiber vs. titanium vs. fiberglass vs. wood
L. Solar power vs. wind power vs. hydroelectric vs. coal vs. oil vs. gas

Appendix A: Standard and Metric Conversions.

Table A: Standard & Metric Conversions

1 hectare	10,000 square meters 107,639 square feet 2.471 acres	1 acre	4,840 square yards 43,560 square feet .4047 hectares
1 square meter	10.7 square feet	1 mile	1,609 meters 1,760 yards
1 cubic meter	35.3 cubic feet	1 yard	3 feet 0.9 meters
1 Gigawatt Hour	1,000,000 kilowatt hours 3,600 gigajoules 34,120 therms 3.4 billion Btu's 8.5 trillion calories	1 square yard	9 square feet 0.8 square meters
		1 pound	0.45 kilograms
		1 gallon	4.5 liters
		1 ton	0.9 metric tonnes

Appendix B: Tables of Ecological Footprint Conversion Factors

Use of Tables: The following conversion factors are based on monthly usage of resources. Multiply the amount of the item used per month by the footprint factor to obtain the footprint – the amount of land required (e.g. yd^2 or m^2) annually to use or consume that item. Tables B1-B6 adapted from Merkel[3]

Table B1: Food Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
Veggies, potatoes & fruit	33 yd^2/lb	63 m^2/kg
Bread and bakery products	128 yd^2/lb	235 m^2/kg
Flour, rice, noodles, cereal products	118 yd^2/lb	218 m^2/kg
Maize (corn)	85 yd^2/lb	158 m^2/kg
Beans & other legumes	252 yd^2/lb	464 m^2/kg
Milk, cream, yogurt, sour cream	118 yd^2/qt	105m^2/l
Ice cream, other frozen dairy	475 yd^2/qt	420 m^2/l
Cheese, butter	503 yd^2/lb	926 m^2/kg
Eggs (number)	28 yd^2/#	23 m^2/#
Pork	458 yd^2/lb	844 m^2/kg
Chicken, turkey	335 yd^2/lb	616 m^2/kg
Beef	1180 yd^2/lb	2171 m^2/kg
Fish	2798 yd^2/lb	5154 m^2/kg
Sugar	61 yd^2/lb	113 m^2/kg
Vegetable oil (seed and olive)	1093 yd^2/qt	966 m^2/l
Margarine	655 yd^2/lb	1208 m^2/kg
Coffee & tea	512 yd^2/lb	943 m^2/kg
Juice & wine	175 yd^2/qt	153 m^2/l
Beer	138 yd^2/qt	121m^2/l
Garden (area for food) poor soil: ave. soil: good soil:	1 yd^2/yd^2 2 yd^2/yd^2 3 yd^2/yd^2	1 m^2/m^2 2 m^2/m^2 3 m^2/m^2
Restaurant Meal (meat eater)	83 yd^2/$	73 m^2/$
Restaurant Meal (vegetarian eater)	55 yd^2/$	48 m^2/$

Table B2: Transportation Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
Bus, around town	17 yd^2/mi	9 m^2/km
Bus, inter-city	4 yd^2/mi	2 m^2/km
Train, light rail	11 yd^2/mi	6 m^2/km
Train, inter-city	17 yd^2/mi	9 m^2/km
Taxi/rental/other's car (divide miles by number in car, exclude taxi driver & kids)	40 yd^2/mi	21 m^2/km
Gasoline (divide fuel by number of people in vehicle; exclude children)	500 yd^2/gal	113 m^2/l
Parts for repair	663 yd^2/lb	1220 m^2/kg
Airplane		
Economy Class	5216 yd^2/hr	4361 m^2/hr
Business Class	6040 yd^2/hr	5050 m^2/hr
First Class	6864 yd^2/hr	5739 m^2/hr

Table B3: Housing Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
House or Apartment (living area per person)*		
Age of home: 40 years	12.2 yd^2/ft^2	109 m^2/m^2
60 years	8 yd^2/ft^2	73 m^2/m^2
80 years	6.1 yd^2/ft^2	54 m^2/m^2
100 years	4.8 yd^2/ft^2	43 m^2/m^2
120 years	4 yd^2/ft^2	36 m^2/m^2
Yard or total lot size (including buildings)	2 yd^2/yd^2	2 m^2/m^2
Hotels, Motels	136 yd^2/$	115 m^2/$
Electricity		
From the grid	31 yd^2/kWh	27 m^2/kWh
Fossil fuel and nuclear	35 yd^2/kWh	30 m^2/kWh
Large hydro	2 yd^2/kWh	2 m^2/kWh
Small hydro	0.02 yd^2/kWh	0.01 m^2/kWh
Photovoltaic (solar)	0.3 yd^2/kWh	0.24 m^2/kWh
Natural gas, city	232 yd^2/therms	76 m^2/m^3
Propane	208 yd^2/gal	46 m^2/l
Fuel oil, kerosene	389 yd^2/gal	87 m^2/l
Coal	35 yd^2/lb	64 m^2/kg
Water, sewer, garbage services	157 yd^2/$	133 m^2/$
Straw	46 yd^2/lb	85 m^2/kg
Firewood**	37 yd^2/lb	69 m^2/kg

*Dvide the total square footage of the house by the number of people sharing it for a per-person number. If there are rooms that only some people use, you need to account for this in your calculation.

** 1 cord of firewood is 128 ft^3 (4 ft × 4 ft × 8 ft) and contains roughly 3,500 pounds of wood.

Table B4: Goods and Services Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
Postal Services		
International	300 yd^2/lb	552 m^2/kg
Domestic	60 yd^2/lb	110 m^2/kg
Dry Cleaning or external laundry services	79 yd^2/$	66 m^2/$
Telephone	13 yd^2/$	11 m^2/$
Medical insurance and services	53 yd^2/$	44 m^2/$
Household insurance	110 yd^2/$	92 m^2/$
Entertainment	79 yd^2/$	66 m^2/$
Education	40 yd^2/$	33 m^2/$
Medicine	1325 yd^2/lb	2440 m^2/kg
Hygiene & cleaning products	266 yd^2/lb	488 m^2/kg
Cigarettes, tobacco products	1246 yd^2/lb	2295 m^2/kg

Table B5: Stocks Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
Construction, wood	254 yd^2/lb	467 m^2/kg
Wooden furniture	483 yd^2/lb	890 m^2/kg
Plastic & metal furniture	397 yd^2/lb	732 m^2/kg
Major appliances (stove, fridge)	994 yd^2/lb	1830 m^2/kg
Small appliances (toaster, blender)	663 yd^2/lb	1220 m^2/kg
Clothes & Textiles (if old, use 1/3 of weight)		
Cotton	1342 yd^2/lb	2474 m^2/kg
Wool	1886 yd^2/lb	3474 m^2/kg
Synthetic	133 yd^2/lb	244 m^2/kg
Durable paper (e.g. books, magazines, files, etc; and non-recyclable, e.g., toilet paper, paper towels etc.)	569 yd^2/lb	1049 m^2/kg
Metal items & tools	397 yd^2/lb	732 m^2/kg
Leather	2119 yd^2/lb	3904 m^2/kg
Plastic products & photos	331 yd^2/lb	610 m^2/kg
Computer & electric equip.	1325 yd^2/lb	2440 m^2/kg
Glass & porcelain	99 yd^2/lb	183 m^2/kg

Table B6: Wastes Footprint Factors

Item	Standard Footprint Factor	Metric Footprint Factor
Assume everything that is compostable is composted		
Household recyclables		
Paper and cardboard	194 yd^2/lb	359 m^2/kg
Aluminum	83 yd^2/lb	153 m^2/kg
Other metal	335 yd^2/lb	622 m^2/kg
Glass	69 yd^2/lb	128 m^2/kg
Plastic	98 yd^2/lb	183 m^2/kg
Garbage (all you discard)	481 yd^2/lb	897 m^2/kg

Glossary

Acre - a unit of land measurement equal to 4,840 square yards. 1 acre = .4047 hectares. 1 acre = 0.617 Irish acres

Biologically productive land - land that is sufficiently fertile to support a crop, trees, animals or some other living thing.

Biocapacity - the total amount of biological activity and the total amount of wastes and byproducts that an area of land can produce and absorb

Carbon footprint - the amount of carbon produced in the manufacture or transport of a product or in the execution of some activity due to burning of fossil fuels. This amount of carbon can be equated with an area of land needed to grow the plants that can sequester the carbon thereby removing it from the atmosphere and reducing greenhouse warming.

Carbon sequestration - the storing of carbon in plant life so that the carbon is not able to contribute to greenhouse warming through its presence in the atmosphere.

Carrying capacity - the maximum size of a population that an ecosystem can support indefinitely.

Conversion factor - a ratio that us used to convert one unit of measurement into another. A conversion factor makes use of an equivalence ratio; for example, the conversion factor for converting feet into meters is 1 ft / .3048 meters.

Dimensional analysis - the examination or breakdown of units of measurement with attention given to converting from one unit to another. Dimensional analysis involves identifying equivalent ratios and stringing them together with multiplication to change from one set of units in to another.

Ecological footprint - the amount of biologically productive land required to produce and dispose of some object, or to sustain an activity.

Ecosystem - the integrated whole of a defined area including its non-living resources, energy flows, and living organisms.

Embodied energy - the amount of energy that went into producing and maintaining an object, separate from any energy required during use of the object.

Embodied resources – the resources that went into producing and maintaining an object.

Flows: resource flow, waste flow - the movement of resources involved in the production or disposal of something, or involved in sustaining an activity.

Footprint factor - a conversion ratio used to convert resources used to produce a given object or engage in an activity into the amount of biologically productive land needed to produce or sustain the object or activity including the land needed to store or sequester byproducts (such as carbon dioxide) associated with it.

Fossil fuels – a natural fuel (as coal, oil, or natural gas) formed in the earth from plant or animal remains from a previous geological time.

Hectare - a metric unit used to measure area. A hectare (ha) is 10,000 square meters or the equivalent of a square that measures 100 meters on a side. 1 ha = 2.471 acres. 1 ha = 11,959.90 square yards. 1ha = 0.247 square furlongs.

Inverse relationship – a relationship between two quantities, represented as $y = k/x$, where as one of the quantities (x or y) gets larger, the other quantity (y or x) gets smaller. The value of k is the constant of variation. Inverse variation can be contrasted with direct variation ($y = k \times x$) where as one quantity gets larger so does the other quantity.

Joule - a unit of energy. One joule is the energy required to exert a force of 1 newton over a distance of 1 meter. A 1 kg mass falling 1 meter near the earth's surface acquires 9.8 joules of kinetic energy. In other terms, 1 joule = 1 watt second, so a kilowatt-hour is 3.6 megajoules of energy.

Overshoot - the state of an ecosystem when one part of it uses resources at an unsustainable rate, faster than they are produced; the inability of the ecosystem to meet the needs of its members.

Population density – a measure of population per unit area or volume.

Source – the origin of resources; anything or place from which something comes from or is obtained.

Sink – the final destination of a resource or item after it is used up or discarded; where things ultimately end up.

Sustainability - the ability to continue an activity indefinitely. Environmental sustainability means using resources in such a way that a population meets its current needs without reducing the environment's ability to meet future population's needs.

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