activity **15**

How Much Space Do We Need?

Concept:

Every piece of land has a limited, measurable capacity to support people. The number of people that can be sustained by a given area depends on the rate at which they consume resources.

Objectives:

Students will be able to:

- Perform calculations to estimate the amount of space that they require in order to live.
- Compare how their needs for space differ from people in other countries.
- Convert measurements between the U.S. and metric systems.
- Track their consumption of water, energy, and food.
- Define the ecological concept of carrying capacity and how it relates to humans.

Skills:

Mathematical computation with integers, decimals and fractions, converting between the U.S. and metric systems, developing data to describe students' personal behavior, problem solving

Method:

Through research and analysis of their consumption of renewable resources, students measure the amount of land that they would need to support themselves.

Materials:

Calculator
Student Worksheets
Optional: Student's home water bill
Optional: Student's home electricity bill

Introduction:

It's been said that the population of the world, all seven billion of us, could fit inside the state of Texas. Technically this statement may be true: Texas is a big state, with an area of 261,914 square miles. Divided seven billion ways, each of us could claim title to a square of land with 35 foot sides, or just under .023 acres. (You may want to have your students calculate this as a preface to the activity.)

Perhaps a more significant question is whether we could survive if all of humanity lived in Texas. Every area of land has a *carrying capacity*, the maximum number of people that it can sustain. In this activity, students calculate their own personal needs for space, based on how they use resources like air, water, food, and energy. Could they survive on .023 acres, or would they need more?

Any calculations of carrying capacity must balance numbers of individuals against the resources that each of us consumes. Demographers, ecologists, and policy-makers alike grapple with these issues as they attempt to determine how to provide for the needs of a growing population. Throughout the world, rates of resource consumption of different individuals vary according to their lifestyles. So, measuring how much space you need for your lifestyle is like calculating your "ecological footprint," your impact on the Earth's resources.

Procedure:

Choose one of the following:

Short method (Students use provided data on the Student Worksheet to determine result):
Give each student a copy of the Student Worksheet to complete. Ask them to enter water use, and food and energy consumption based on the average American diet. Encourage them to estimate the local annual rainfall based on the listed numbers for some typical cities. When they have finished calculating their space needs, select a couple students to report their findings to the class. Go over the Discussion Questions with the class.

OR

Long method (Students apply personal data to determine result):
Ask students to bring in a recent copy of their family's water bill and electric bill (with parents' permission). You should also have sample bills on hand (with the name and address blacked out) that could be used by students who don't bring in bills from their own households. Hand out copies of the Student Worksheet. Using their utility bills, they can calculate their own daily use of water and electricity by dividing total use by the number of people in their household, then dividing again by the number of days in the billing period. Students can find their local annual rainfall from the National Weather Service, at *www.nws.noaa.gov/climate.html* or from a World Almanac. Students can also calculate their food consumption by tracking everything they eat for several typical days, and then computing calorie totals. Libraries, grocery stores, and even many restaurants have references on the caloric values of various foods.

Once they have calculated numbers for their personal use, they will be able to complete the rest of the worksheet. When they have finished calculating their space needs, select a couple students to report their findings to the class. Go over the Discussion Questions with the class.

Options for Completing the Student Worksheet:

Cooperative Learning: This activity could also be done in cooperative learning groups where each of four students solves one of the worksheet problems; then students combine their answers at the end of the worksheet to find out how much space they would need for all the resources required for survival. While this saves time and reduces the amount of calculations each student completes, they may not get the "whole picture" on their own ecological footprints.

Using the "How to Do It" Examples: For most of the four problems on the Student Worksheet, students are provided with examples of how to solve the problems. If you would prefer for them to come up with the processes, you may choose to cover up the examples when photocopying the worksheets.

Discussion Questions:

1. Would it be possible to divide the globe into equal-sized plots for each individual? (*No, some land is too hot or too cold, too dry or too wet, too steep, or otherwise uninhabitable.)*
2. Are there needs that you might have other than food, water, energy, and air? (*Some other things students might name include shelter, clothing, goods, or places to throw away discarded items. Our civilizations also require common spaces that are not habitat for any single individual, but provide an infrastructure for our societies. Students may think of roads, schools, businesses, churches, etc. Each of these would require additional space. Also, as a society, we have decided that some areas are worth protecting as undeveloped parkland. And, of course, there are many intangible things that we need to have a high quality of life such as love, friendship, culture, a clean and safe environment, recreational opportunities, etc.)*
3. As our population increases, does the amount of space each individual needs change? (*No, we each need the same amount of space regardless of the number of other people on the planet, unless we change the rate at which we consume resources.)*
4. If there are about 7 billion people on the Earth, and the Earth contains about 3 billion acres of cropland[9], what is each person's fair share of this land? (*0.43 acres. Many ecologists have developed their own estimates of the Earth's carrying capacity. Most of these estimates fall between 7.7 billion or .4 acres/person and 12 billion or .26 acres/person.[10])*
5. What will happen to each person's fair share of cropland as the Earth's population continues to grow? (*It will get smaller.)*

Follow-up Activities:

1. Have students measure out the land they would need for survival in the school gym or athletic field.
2. Have students calculate their space needs using data supplied for the modern industrialized country in Europe (Sweden) or the developing country in Africa (Ethiopia). This will allow students to compare the "ecological footprint" of residents of these countries.

Sources/notes:

[1] *University of Georgia, Dept. of Forestry: www.forestry.uga/docs/for96-39.html. Other estimates varied over a wide range.*

[2] *Estimate based in part on:* Laboratory and Field Manual of Ecology. *Richard Brewer and Margaret McCann. New York: Saunders College Publishing, 1982.*

[3] Beyond Oil: The Threat to Food and Fuel in the Coming Decades, *3rd Ed. John Gever, Robert Kaufmann, David Skole, and Charles Vorosmarty. Niwot, CO: Univerity Press of Colorado, 1991.*

[4] Recommended Dietary Allowances, *10th Edition, National Research Council, 1989, pp.26-28.*

[5] *Estimate based on average conditions. Actual electricity production will vary depending on the amount of sun the photovoltaic cell receives.*

[6] *Domestic figures from EIA International Energy Database 1995. U.S. Energy Information Agency. Washington, DC, 1995. International figures from* World Resources 1998-1999: A Guide to the Global Environment. *World Resources Institute. New York: Oxford, 1998.*

[7] The World Almanac and Book of Facts 2010. *William A. McGeveran, Ed. Mahway, NJ: Funk & Wagnalls, 2010.*

[8] World Development Report 1997. *The World Bank. New York: Oxford, 1997.*

[9] World Resources 2000-2001: People and Ecosystems. *World Resources Institute. New York: Oxford, 2000.*

[10] *Survey of carrying capacity estimates found in:* How Many People Can the Earth Support? *Joel E. Cohen. New York: W. W. Norton & Sons, 1995.*

Name__________________________________ Date____________________________

How Much Space Do We Need?
Student Worksheet # 1

In order to survive, we all depend on some basic resources that the Earth provides:

1) Oxygen to breathe (produced from the Earth's vegetation)
2) Food
3) Energy (from renewable and nonrenewable resources)
4) Water

In the following math problems, you will be calculating how much land area you require to meet your needs for these essential things.

Problem 1: How much space in square meters (m^2) do you need for generating oxygen to breathe?

Data: One acre of trees generates enough oxygen each day for the needs of 18 people.[1] One acre is equal to 4046.9 m^2.

How to do it:

Divide 4046.9 m^2 by 18 people to determine the number of m^2 needed for oxygen production =__________________.

Problem 2: How much space in square meters (m^2) do you need for growing food?

Data: It takes roughly 1 m^2 to grow 1,000 calories worth of food over a year.[2] Animals use an average of about 16 calories of grain, soybeans, etc. for every calorie they produce as meat or other animal products.[3]

Refer to the chart below to find your recommended caloric intake per day.[4]

	Recommended Daily Calories
Males	
Age 11-14	2500 cal/day
Age 15-18	3000 cal/day
Females	
Age 11-18	2200 cal/day

How to do it:

Step 1: Tally your individual needs:

Calories: How many calories do you consume each day? ___________.

Food source: Approximate the percentage of the calories in your diet that are made up of meat and animal products? _________.

Convert this percentage to a ratio (express in decimal terms). ___________.

Step 2: Figure out how many calories you need to grow daily to maintain your diet:

Multiply your proportion of vegetable calories by the number of calories you consume daily. Add to this the proportion of meat and animals calories, multiplied by 16, multiplied by the number of calories you consume daily.

EX: for a person who consumed 2500 cal/day, 10% of which was meat and animal, the equation would look like this:

(.9 veg)(2500 cal/day) + (.1 meat)(16)(2500 cal/day)

or

(2250 veg cal/day) + (4000 meat cal/day)

or

(6250 total cal/day)

= ____________________________.

Name______________________________________ **Date**________________________________

Student Worksheet # 2

Step 3: Figure out how much land you need to grow the calories you want:
Multiply your total calories/day by 365 days to get total cal/year. Divide this figure by 1000 cal/m^2 to get the number of square meters that you would need.

EX: For the above example, the person would need:
(6250 cal/day)(365 days/year)÷(1000 cal/m^2)
or
(2,281,250 cal/year)÷(1000 cal/m^2)
or
(2281.25 m^2/year)

= ______________________________.

Problem 3: How much space in square meters (m^2) do you need for collecting energy?

Energy can come from a variety of sources on Earth, both renewable and nonrenewable. Renewable sources include solar, wind, water (hydropower), nuclear and geothermal. Nonrenewable sources include fossil fuels which are in finite supply, such as coal, oil and gas. For this calculation, you will be considering how much space you need to collect energy from the sun (solar power) using solar panels. Solar panels are made up of photovoltaic cells which absorb the sun's heat.

Data: 1 m^2 of photovoltaic cells can produce an average of about 1460 kilowatt-hours (KWH) of power annually.[5]

Average energy use per person in various countries:[6]

Ethiopia: 270 KWH/year United States: 12,000 KWH/year Sweden: 6,840 KWH/year

How to do it:

Step 1: Tally your individual use:
(Look at a copy of your home power bill to see how many KWH were used during the billing cycle. Divide the KWH by the number of days to determine KWH/day. Multiply the daily figure by 365 days/year to calculate KWH/year for your house. Divide that number by the number of people in your house to calculate your share.)

EX: Consider a 3-person house that has an electrical bill for 3250 KWH, for a 30 day billing cycle.
(3250 KWH)÷(30 days) = (108.33 KWH/day)

(108.33 KWH/day)(365 days/year) = (39,541.66 KWH/year)

(39,541.66 KWH/year)÷(3 people/house) = (13180.55 KWH/person/year)

= ______________________________.

Step 2: How many solar panels will you need?
Divide the number of KWH you use a year by 1460 KWH/m^2/year

EX: (13,180.55 KWH/person/year) ÷ (1460 KWH/m^2/year)
or
(9.03 m^2/person)

= ______________________________.

Name____________________________________ Date______________________________

Student Worksheet # 3

Problem 4: How much space in square meters (m^2) do you need for collecting water?

Data: Average annual rainfall for some major U.S. cities:[7]

Chicago: 81.96 cm Houston: 121.51 cm
Los Angeles: 33.40 cm Miami: 148.66 cm
New York City: 126.21 cm

Average water use per person in various countries:[8]

Ethiopia: 6000 liters/year Sweden: 123,000 liters/year United States: 244,000 liters/year

1 Gallon = 3.785 liters 1 liter = 1,000 cubic centimeters (cm^3) 1 meter = 100 centimeters (cm)

How to do it:

Step 1: Availability: Approximate how much rain falls in your area from the above figures, or determine a more exact figure from an almanac or other appropriate reference text. Calculate rainfall per square meter by multiplying annual rainfall by 10,000 cm^2/m^2 to find rainfall in cm^3/m^2. Divide by 1000 to convert cm^3 to liters.

EX: For Chicago:
(81.96 cm/year)(10,000 cm^2/m^2) = (819,600 cm^3/m^2)(year)

(819,600 cm^3/m^2/year)÷(1,000 cm^3/liter) = 819.6 liters/m^2(year)

= ______________________________.

Step 2: Tally your individual use: Look at a copy of your home water bill to see how many gallons were used during the billing cycle. Divide the gallons by the number of days to determine gallons/day. Multiply the daily figure by 365 days/year to calculate gallons/year for your house. Divide that number by the number of people in your house to calculate your share.

EX: Consider a 3-person house that has a water bill for 32,000 gallons for a 90-day billing cycle.
32,000 gal/house)÷(90 days) = (355.55 gal/house/day)

(355.55 gal/house/day)(365 days/year) = (129,777.77 gals/house/year)

(129,777.77 gals/house/year)÷(3 people) = 43,259 gal/year/person

= ______________________________.

Step 3. Convert use to liters

EX: (43,259 gals/year)(3.785 liters/gallon) = 163,735 liters/year

= ______________________________.

Step 4. Calculate number of m^2 needed to provide a year's worth of water by dividing annual usage by available number of liters per m^2.

EX: from above we have:
(163,735 liters/year)/(819.6 liters/m2/year) = 200 m^2

= ______________________________.

Total it up:
Oxygen space: ___________m^2.
Energy space: ___________m^2.
Food space: _____________m^2.
Water space: ____________m^2.
Total space: _____________m^2.
Express in acres (4,046.9 m^2 = 1 acre): __________________ acres.
Express in square feet (1 acre = approximately 43,560 square feet): _________square feet.