Problem-Based Inquiry Series in Mathematics

Global Population and Ecological Footprints

Essential questions:

- What is unique about our current era of human civilization?
- What is an ecological footprint and when will humanity reach carrying capacity on Earth?
- What can be done to reduce per capita ecological footprints?
- What is the relationship between standard of living, population, land area, and a nation's ecological footprint?

This inquiry leads through an exploration of global human population growth, historical and projected, and the implications. The problems in this document are designed to be pursued in conjunction with a supplemental presentation and teacher coach.

Part I - Global Population Growth

Inquiry # 1: Exploring Global Population and Critical Thinking

1. Read the conversation with Zeek and Minny.

2. Reflect and Discuss

1. Were Zeek and Minny being good critical thinkers? Why or why not?

2. How can you find out for sure if there is a population problem or not?

3. Math to the Rescue!

Zeek and Minny were arguing about whether or not the earth would get so crowded that we would "fall off the earth someday..." The real question is: How fast is population growing? How soon will it become a real problem? Math can help us see things more accurately. To explore the difference between how we see things and how they really are, make a guess about the answer to the problem below, and then solve it with the tools provided. You just might be surprised!

Population Brain Twister

How many years will it take for the world population to increase to the point where there is one person on every square foot of the Earth's surface (the point where people would be "falling off the earth")?

NECESSARY FACTS:
1) The Earth has 57,300,000 square miles of land surface. (Rounded to three significant digits. This includes the North and South Poles.)
2) 5280 feet= 1 mile
3) The current population of the Earth is approximately 8 Billion people.

In order to solve this problem we will need some more information about population and create a mathematical tool that models the growth of population.

1. World Population

Shown below is a data table from the Encyclopedia Britannica of the historical population of the world. In order to see and understand the way population has grown through the years, make a graph of the data and connect the data points.

Historical Population of the World

Year	World Population
1650	500,000,000
1750	725,000,000
1800	900,000,000
1850	1,175,000,000
1900	1,600,000,000
1914	1,810,000,000
1920	1,810,000,000
1939	2,230,000,000
1950	2,490,000,000
1982	4,531,000,000
1995	5,734,000,000
2007	6,500,000,000
2012	7,060,000,000
2024	8,000,000,000

2. Analyze the graph, and answer/discuss the following:

a) How long does population take to double in size after 1650?

b) The above is called the “doubling time” of a quantity. Does the doubling time of population stay the same over history? What is happening to it?

c) Use the graph to make an estimate of what the doubling time is today. Another way to think of this is—how long ago was the world population one half of what it is today?

3. Do the “Best Paycheck Deal” activity to develop a function for doubling growth pattern (optional)

4. Use the exponential growth function and current population doubling time to solve the Population Brain Twister.

5. Reflection and Analysis

   a) Why will the effects of increasing population growth be felt long before we have 1 person on each square foot?

   b) How can society adapt to exponential population growth?

Inquiry #2: If the history of the earth was to be modeled by a 10 meter long timeline, where on the model would the following be placed (in distance from the present)?

A) The appearance of humanity on earth.

B) The moment when global human population numbers first passed the 1 billion mark.

C) Let the 10 meter timeline represent the history of humanity on earth. How far from the present would the moment when global human population numbers first passed 1 billion be placed?

Part II -- Ecological Footprints and Carrying Capacity

An "ecological footprint" is the amount of land area necessary to provide the materials (food, air, shelter, etc) and absorb the waste (carbon dioxide, garbage, etc.) for a particular person or species. It is generally measured as a land area (hectares or acres) per capita.

The "carrying capacity" for a species in relation to their environment is the maximum number of individuals that their can be support sustainably. Carrying capacity is a function of the ecological footprint of the species and the usable land area of the environment.

Refer to the fact sheet to calculate the following:

1. How many hectares is all of humanity using on Earth? (Use the global average footprint value).

2. What does it mean that the value in #1 above is different from the given value for amount of biologically productive land?

3. What global population number has a footprint that is within the amount of biologically productive land? What does this mean?

4. How long will it be until global population reaches 9 billion? (Assume the growth rate will remain constant for this problem).

Part III -- Footprints of Nations and Carrying Capacity

Examine and discuss the relationship between the footprint of nations and their populations. Calculate the following using the exponential growth function and the current doubling time

1. If everyone in the world lived like the people in India, how long would it take to reach global carrying capacity?

2. If everyone in the world lived like we do in the United States, how long would it take for humanity to reach the carrying capacity of Earth?

3. Considering the current global average footprint per capita, how long will it take for humanity to reach the carrying capacity of the Earth?

Reflection:

1. Consider why reducing population growth is not the most important factor in helping humanity stay within the carrying capacity of the earth.

2. What do humans have the most control over to deal with the effects of exponential population growth? Make a list, brainstorm, make a proposal.

Necessary Facts

Age of Earth: 4.5 billion years

Origin of humanity: 200,000 years ago

Date of 1 billion people (find this on the population chart provided):_____

Doubling time for human population currently:_____

640 acres =1 square mile

2.47 acres =1 hectare

5280 feet = 1 mile

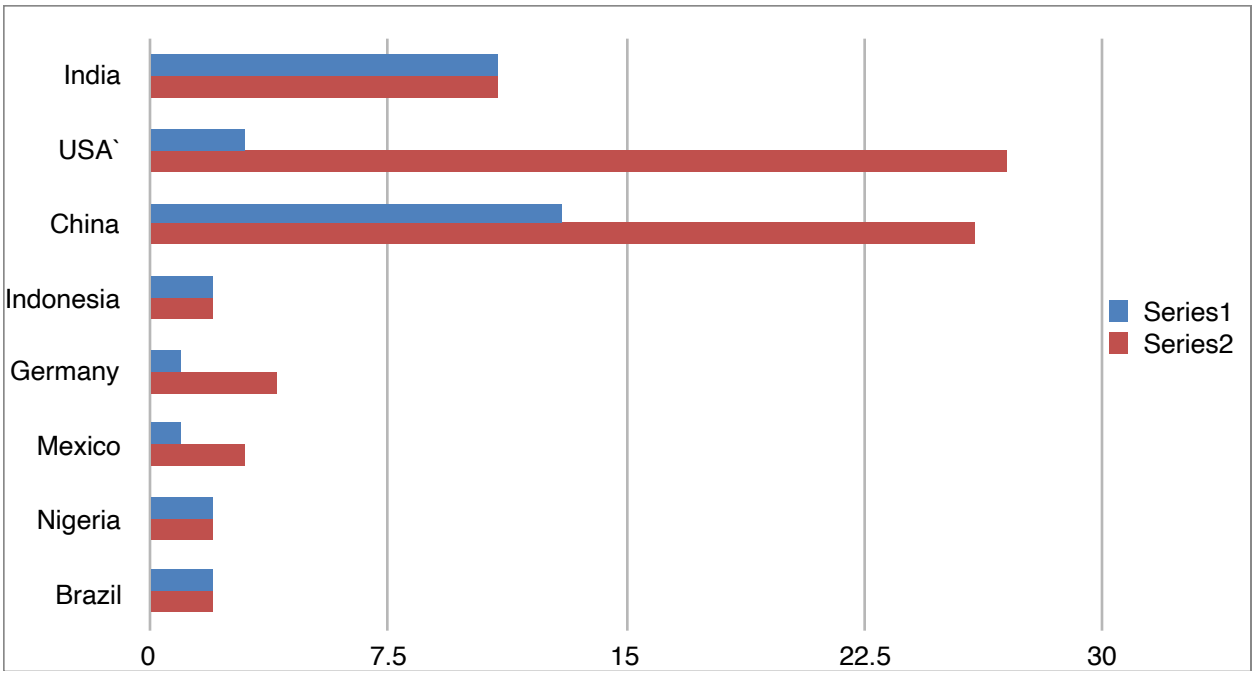
Total area of land surface on Earth = 57,300,000 square miles

Biologically productive land area on Earth = 11,200,000,000 hectares

Global per capita ecological footprint (average): 2.24 hectares/person

Per Capita Ecological Footprints of Nations

Country	**population**	**Footprint (global hectares per capita)**
China	1,334,190,000	2.1
United States	301,958,000	9.4
Germany	81,882,342	4.2
Indonesia	231,369,500	.9



Year	Billions
0	0.1
500	0.2
1000	0.4
1650	0.5
1750	0.7
1800	0.9
1850	1.1
1900	1.6
1914	1.8
1920	1.8
1939	2.2
1950	2.5
1982	4.5
1995	5.7
2007	6.5
2014	7.0
2021	7.8
2035	

Mexico	107,550,697	3.4
Nigeria	154,729,000	1.3
Brazil	192,055,000	2.4
India	1,172,720,000	.9

Footprint--Population Comparison of Nations

Blue (top) = population
Red (bottom) = total national footprint

Global Population--Past 2000 years