RESOURCES

ECOLOGICAL FOOTPRINT QUIZ- www.myfootprint.org
BOBBIE BIGFOOT (Online Elementary Level Quiz)- www.kidsfootprint.org

Readings and lesson plans that trace significant events throughout history impacting Ecological Footprints.

FOOD

The Food Timeline- Culinary History Timeline (Social history, manners, & menus)
Readings, recipes, and links on food throughout history.
http://www.foodtimeline.org/food1.html

The Food Timeline- Food History Lesson plans
Lesson plans and pictures.
http://www.foodtimeline.org/food2a.html

The Plimoth Plantation- Online Learning Center
Interactive website dedicated to the First Thanksgiving.
http://www.plimoth.org/OLC/index_js2.html

American Forum- Fast Food History
9 Activities and supplemental readings that show how fast food has evolved through trade and globalization.
http://www.globaled.org/curriculum/ffood.html

Viola, Herman J. and Margolis, Carolyn. ***Seeds of Change: A Quincentennial Commemoration.*** Smithsonian Institution Press, Washington and London: 1991.

ENERGY

Wolf, Winfried. ***Car Mania- A Critical History of Transport.*** Pluto Press, London: 1996.

Hutchins, John. ***Transportation and the Environment.*** Elek Books Ltd., London: 1977.

ALL

National Geographic Theme Sets
Sets of 4 themed books that outline significant products/events and their impacts on history (Ex. Inventions Bring Change: The Reaper, The Railroad, Water-Powered Mills, The Cotton Gin; also Trade Across Time and Culture, Providing Goods, Communication Around the World) and Teacher Support Materials.

Ryan, John C. and Durning, Alan Thein. ***Stuff: The Secret Lives of Everyday Things.***
Northwest Environment Watch, Seattle: 1997.
Excerpts and curriculum available at http://www.northwestwatch.org/publications/stuff.asp.

REDEFINING PROGRESS WEB RESOURCES

http://redefiningprogress.org/newprograms/sustIndi/education/k-12lessonplans.shtml

K-12 Lesson Plans

These lesson plans have been created by Earth Day Network and Redefining Progress as an additional resource to help you in your classroom on Earth Day or any day! Click on any one of the links to download the lesson plans in PDF format. Also be sure to check out our website links for more information!

For your convenience, we have provided Picture Files as a supplement for **Food and You**, **The Trash We Pass**, and **Have and Have-Not**. Click here to access the Picture Files.

Food and You
Designed to incorporate environmental education into general math and science classes for elementary school classes (K-5th grade), this lesson encourages students to think about where their food comes from, the food production process, and the byproducts associated with their favorite foods.

The Trash We Pass
This lesson brings environmental education to middle school (4–7th grade) social studies, math, and science classes by asking students to have fun analyzing garbage and recycling options.

Have and Have-Not
This lesson incorporates environmental education in middle school (7–9th grade) social studies, geography, math, and economics classes by helping students gain a perspective on different consumption habits in developing and developed countries and the effect that mass consumption has on the ecological footprint of a country and an individual.

Sustainable Dining
Designed for lower high school (7–10th grade) economics, home economics, and general education classes, students will learn about sustainably produced groceries as a valuable and environmentally friendly option for grocery shopping.

Renewable Energy
Renewable Energy: In this lesson targeting high school history, science, and math classes, students will analyze the use of energy in their every day lives and consider the advantages and disadvantages of environmentally friendly renewable energy sources.

MATERIALS AND INITIATIVES FOR SUSTAINABILITY EDUCATION
http://redefiningprogress.org/newprograms/sustIndi/education/edParentMaterials.html

REDEFINING PROGRESS PARTNER ORGANIZATIONS

CREATIVE CHANGE EDUCATIONAL SOLUTIONS
Download curriculum and sample student work for K-12 classes on Ecological Footprints and Ecological Economics at www.creativechange.net

FACING THE FUTURE
Download curriculum and readings at www.facingthefuture.org
Wheeler, Goekler, Hibbard, Boyd, Wondra, and Bush. *Facing the Future: People and the Planet Curriculum Guide*. Facing the Future, Seattle: 2002.

HAMBURGER, FRIES, AND A COLA

WHAT DID IT TAKE TO PRODUCE THIS FAVORITE AMERICAN MEAL?

The meat came from cattle grazed initially on public or private land, and later fed grain. About 10 percent of all public lands in the western United States have been turned to desert by overgrazing, and about two-thirds of those public lands are significantly degraded. Streamside lands, where cattle graze, have been especially damaged. It took approximately 2 pounds of grain to produce that quarter pound of meat, and that grain production caused five times its weight in topsoil loss due to erosion from unsustainable farming methods. Producing that grain also took substantial amounts of pesticides and fertilizers (half of all fertilizer in the United States is applied to feed corn for animals), some of which ran off into surface water or seeped into groundwater supplies. By the time the steer was finished in the feedlot, it took 600 gallons of water to build that hamburger patty. Once slaughtered and processed, the meat was frozen, shipped by truck, kept cold, and then cooked on a grill using natural gas.

The 5-ounce order of fries came from one 10-ounce potato grown in Idaho on half a square foot of soil. It took 7.5 gallons of water to raise that potato, plus quantities of fertilizer and pesticides, some of which ran off into the Columbia or Snake Rivers. Because of that, and dams that generate power and divert water for irrigation, the Snake River sockeye salmon is virtually extinct. A number of other species are also in decline because of these production practices.

The potato was dug with a diesel-powered harvester and then trucked to a processing plant where it was dehydrated, sliced, and frozen. The freezing was done by a cooling unit containing hydrofluorocarbons, some of which escaped into the atmosphere and likely contributed to global climate change. The frozen fries were then trucked to a distribution center, then on to a fast-food restaurant where they were stored in a freezer and then fried in corn oil heated by electricity generated by hydropower. The meal was served in a fast-food restaurant built on what once was originally forest, then farmland, then converted to commercial/industrial uses as the city expanded. The ketchup in aluminum- foil packets came from Pittsburgh and was made from Florida tomatoes. The salt came from Louisiana.

The cola came from a Seattle processing plant. It is made of 90 percent water from the Cedar River. The high-fructose corn syrup came from Iowa, as did the carbon dioxide used to produce the fizz, which is produced by fermenting corn. The caffeine came from a processing plant that makes decaffeinated coffee. The cola can was made from one-third recycled aluminum and two-thirds bauxite ore strip-mined in Australia. It came to Washington state on a Korean freighter, and was processed into aluminum using an amount of energy equivalent to a quart of gasoline. The energy came from some of the same dams mentioned earlier that have contributed to a 97 percent decrease in the salmon runs of the Columbia Basin.

The typical mouthful of food consumed in the United States traveled 1,200 miles for us to eat it. Along the way, it required packaging, energy, roads, bridges, and warehouses, and contributed to atmospheric pollution, adverse health effects, and traffic congestion.

Adapted from *Stuff—The Secret Lives of Everyday Things*, by John C. Ryan and Alan Thein Durning, published by Northwest Environment Watch. www.northwestwatch.org.

FOOD TIMELINE

- 10,000 BC Beginning of Agriculture (wheat and lentils) and herding (pigs and sheep)
- 1492 Columbus discovered the new world
- 1493 Admiral of the Ocean Sea returned to Hispaniola with empire building ships
  - mixture of culinary cultures
  - Introduced horses, cows, pigs, wheat, barley, sugarcane
    - Led to land degradation
- 1500 Renaissance
  - Spices highly sought after and valued
- 1505 First enslaved Africans reached the New World
  - Rainforests in Monserrat replaced by sugar plantations
    - Indigenous population and vegetation disappeared
- 1621 First Thanksgiving
  - Mixture of Native American and European foods
- 1800s Kola nut introduced to the United States
  - Only grows in Africa and the Caribbean, must be imported
  - Main ingredient in Coca-Cola
- 1846-1850 Great Irish Famine
  - Potatoes exported from Ireland in mass quantities
  - Millions of Irish people starved to death
- 1880 Industrial Revolution
  - Mass production techniques
  - Fossil fuel use increased exponentially
- 1918 World War I ended
  - Global trading and competition ensued
    - Food imported to Great Britain (out of season tropical fruits, etc.)
- 1950s Construction of the major American highway system
  - Development of suburbia
  - Post World War II Baby Boom
- 1950s Green Revolution
  - More food grown on larger amounts of cropland
  - Fertilizer and pesticides were introduced, causing runoff into water sources
  - Irrigation projects drained lakes and rivers and pumped some aquifers dry
  - Soil erosion and depletion damaged land, causing less productivity
- 1950s Fast Food establishment growth explodes
- 1990s Reversion to famine in developing nations, particularly Africa
  - Soil heavily eroded; therefore land became less productive
  - Civil wars impede relief supplies

Frequently Asked Questions

1) How Accurate is the Ecological Footprint Quiz?

The quiz is based on national consumption averages and is meant to give an idea of Ecological Footprint size relative to other people in the country you live in. It is not highly detailed, but should give most people an idea of where they stand. If you already live a sustainable lifestyle, do not be discouraged by your results. There are some portions of your Footprint that are not the direct result of your consumption habits. For example, each resident of a city is 'responsible' for a portion of the city's infrastructure, such as roads, schools, and government offices, regardless of whether the resident uses those services. In addition, some options that could make your Footprint smaller are not available to you as a result of choices on the part of local decision makers, such as reliable and efficient public transportation as an alternative to driving. Therefore, an important path to reducing your Footprint is to advocate for more sustainable decisions at all levels of government. This will make it easier for you and many others to reduce Ecological Footprints.

2) How is the Ecological Footprint measured?

The Ecological Footprint measures the amount of nature's resources an individual, a community, or a country consumes in a given year. The analysis is primarily based on data published by United Nations agencies and the Intergovernmental Panel on Climate Change. We use official statistics tracking consumption and translate that into the amount of biologically productive land and water area required to produce the resources consumed and to assimilate the wastes generated using prevailing technology. Because people use resources from all over the world, and affect faraway places with their pollution, the Footprint is the sum of these areas wherever they are on the planet.

Ecological Footprint calculations are based on five assumptions:

- It is possible to keep track of most of the resources people consume and many of the wastes people generate. Much of that information can be found in existing official statistics.
- Most of these resource and waste flows can be converted into the biologically productive area that is required to maintain these flows.
- These different areas can be expressed in the same unit (hectares or acres) once they are scaled proportionally to their biomass productivity. In other words, each particular acre can be translated to an equivalent area of world-average land productivity.
- Since these areas stand for mutually exclusive uses, and each standardized acre represents the same amount of biomass productivity, they can be added up to a total—a total representing humanity's demand.
- This area for total human demand can be compared with nature's supply of ecological services, since it is also possible to assess the area on the planet that is biologically productive.

Conservative Estimates
The results underestimate human impact and overestimate the available biological capacity by:

- Counting each area only once, even if the area provides two or more ecological services at once.
- Choosing the more conservative estimates when in doubt.
- Including current agricultural practices as if current industrial yields would not cause any significant long-term damage to the soil productivity.
- Leaving out some human activities for which we have insufficient data.
- Excluding those activities that systematically erode nature's capacity to regenerate. They consist of:
    - The uses of materials for which the biosphere has no significant assimilation capacity (e.g. plutonium and other radioactive elements associated with nuclear energy production, polychorinated biphenyls (PCBs), and chlorofluorocarbons (CFCs)).
    - Processes that irreversibly damage the biosphere (e.g. species extinction, aquifer destruction, deforestation, and desertification).

2) What are the units used in measuring footprint size?

Footprint results are expressed in global acres (or global hectares in metric measurement). There are approximately 2.5 acres in a hectare. Each of those acres (hectares) corresponds to one acre (hectare) of biologically productive space with world-average productivity. Today, the biosphere has 26.7 billion acres (or 10.8 billion hectares) of biologically productive space corresponding to less than one-quarter of the planet's surface. These 26.7 billion acres (10.8 billion hectares) include 5.7 billion acres (2.3 billion hectares) of productive ocean and 21 billion acres (8.5 billion hectares) of productive land.

Biologically productive land is land that is fertile enough to support forests, agriculture and / or animal life. All of the biologically productive land of a country comprises its biological capacity. Arable land is typically the most productive area.

3) What about population?

- Population is one factor in the global EF, along with consumption and the type of environmental impacts of technology.
- Consumption is critical because 1 person living at a US lifestyle has a footprint of 9.57 hectares (23.6 acres). That figure is more than 4 times the footprint of someone living at the level of the average 2.3 hectares (5.75) acres.
- A more equitable distribution of resources worldwide would provide better access to education and health care for women in the 'developing' world. This is the most effective way to reduce population growth rates.

4) How does technology play a role in footprint size?

The world's Ecological Footprint changes in proportion to global population size, average consumption per person, and the resource intensity of the technology being used. Technology can alter the productivity of land, or the efficiency with which resources are used to produce goods and services. The footprint calculations are conservative estimates of human impact since insufficient data are available on some uses of the biosphere. Also, the calculations assume that the technologies used in resource exploitation are the average of those prevailing in the world today, and do not make distinctions between the use of more sustainable exploitation in some places and less sustainable exploitation in others. This may distort the size of some countries' footprints, but does not affect the global result.

5) The US and the developed world has all the conveniences--cars, air conditioning, etc. Why should we suggest to developing countries that they not develop along the same lines?

The countries with the largest per capita footprints have a leadership responsibility in this regard. They can use their technological, economic, and political power to promote development the improves quality of life in environmentally sustainable ways. Energy and the impacts of fossil fuels is a critical example. Countries such as the US could support a rapidly-growing country such as China to 'leapfrog' over fossil fuels and transition to renewable energy.

That said, the Ecological Footprint does not necessarily suggest that people with large per capita footprints should eliminate consumption and wealth to equalize the global distribution. Rather, people can become aware of their purchasing power and the environmental and social implications of each decision. They can then make choices that support sustainable practices and technologies, or they can choose not to buy unnecessary items.

FREQUENT DEBATES

Perception: Population growth is the problem.

Questions raised: "Why look at consumption? What about population? Isn't that the real problem?"

Response talking points:

- Population is one factor in the global EF, along with consumption and the type and environment impacts of technology.
- Consumption is critical because 1 person living at a US lifestyle of 9.57 hectares has a footprint 4.35 times bigger than someone living at the level of the average 2.2 hectares .
- Reducing our EF is not about abandoning all cars and electricity. It's about considering *how we can live well with a smaller impact*. For example, walking more might not only be good for the EF, but be good for our health as well. Connections like this help us understand the relationship between our own well-being and that of the planet.
- Finally, a more equitable distribution of resources worldwide would provide better access to education and health care for women in the 'developing' world. This is the most effective way to reduce population growth rates.

Perception: US is the model for the world; They should be like us.

Questions raised: "The US lifestyle is a model for developing countries; they're trying to get what we have. Hasn't all our technology made life better? People are living longer than ever."

Response talking points:

- We have the opportunity, now that we've seen the results of developing economies around the use of fossil fuels and other non-renewable resources, to help developing nations build strong economics based on sustainable use of renewable resources.
- Health care and nutritional advances have increased life expectancies over the past century. Diseases of affluence (obesity, heart disease, diabetes) are on the rise around the world, in part because of the increased consumption of convenience and processed foods in 'developing' countries. Real advances in quality of life would involve not only living longer, but also healthier.
- Meanwhile, 800 million people are malnourished and tens of thousands of people die from preventable causes such as malaria and water-borne diseases. According to the UN, the cost of providing clean water and sanitation is estimated to be $2 billion, yet world military expenditures exceed $900 billion per year. Similarly, the US and Europe spend $17 billion on pet food each year, while the annual cost of providing basic health care and nutrition for everyone is $13 billion.

Issue: Equity: "We have it all; who are we to say they shouldn't?"

Questions raised: "The US and the developed world has all the conveniences--cars, air conditioning, etc. Isn't it a bit arrogant for us in rich nations to suggest to developing countries that they not develop along the same lines?"

Response talking points:

- First, it's important to distinguish between 'development' (an improvement in the **quality** of life) and 'growth' (an increase in quantity of economic output). Although the words are often used interchangeably, in reality, growth and development do not always go hand in hand. For example, a holistic look at environment and social indicators shows that since the 1980s, overall quality in these areas has decreased even as economic growth as increased. Thus, 'more' is not always better.
- Given that, the real question is, *How can all countries make real, qualitative improvements in ways that don't contribute to environmental overshoot?*
- The countries with the largest per capita footprints have a leadership responsibility in this regard. They can use their technological, economic, and political power to promote real development in environmentally sustainable ways. Energy and the impacts of fossil fuels is a critical example. Countries such as the US could support a rapidly-growing country such as China to 'leapfrog' over fossil fuels and transition to renewable energy.

EATING UP THE EARTH: HOW SUSTAINABLE FOOD SYSTEMS SHRINK OUR ECOLOGICAL FOOTPRINT

by Diana Deumling, Mathis Wackernagel, and
Chad Monfreda; Condensed by Diana Abellera.

The Earth provides a perpetual bounty as long as we don't destroy its self-renewing capacity with our appetites. Today, however, we are eating up the planet.

Our global food system, with its resource-intensive production and distribution, is using almost half the planet's ecological capacity and is slowly degrading our natural resource base. To assure our well-being, we must close the gap between human demand and ecological capacity. Sustainable food systems offer viable opportunities to shrink humanity's food Footprint to a size the Earth can support.

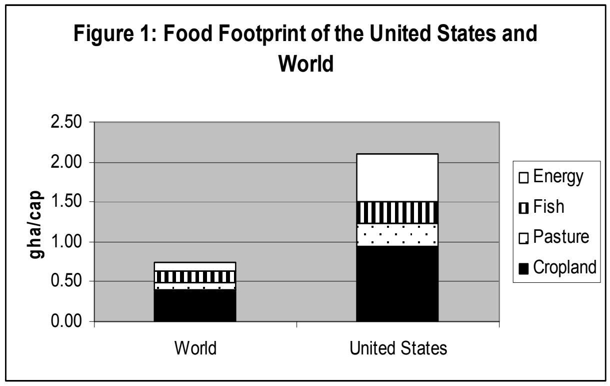
1. AGRICULTURE TAKES A BIG BITE: THE ECOLOGICAL FOOTPRINT OF THE GLOBAL FOOD SYSTEM

After air and water, food is the most essential resource people require to sustain themselves. Yet the way the food system provides food often severely damages the health of the biosphere through soil and aquifer depletion, deforestation, aggressive use of agrochemicals, fishery collapses, and the loss of biodiversity in crops, livestock, and wild species.[1]

We use Ecological Footprint analysis to document the current food system's demand on the biosphere. Ecological Footprint accounts track the area of biologically productive land and water needed to produce the resources consumed by a given population and to absorb its waste.

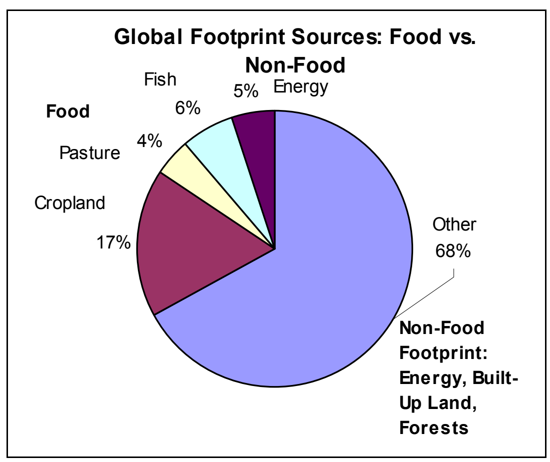
All Footprints are measured in a common unit called a "global acre," an acre with a global average biomass productivity. Figure 2 compares the average American food Footprint (5.2 global acres per person) to the world average (1.9 global acres per person). The dramatic differences in every component of the food Footprint reflect drastically different consumption patterns between the U.S. and the rest of the world.

The global food Footprint is steadily increasing. In 1961, the food system occupied 27 percent of the Earth's biocapacity. Today, the food system requires 40 percent of the Earth's biologically productive area,[2] or 47 percent if unharvested crop areas and non-edible crops, such as tobacco and cotton, are included. While the remaining biological capacity may seem like ample territory for the expansion of food production, this extra area lies mostly in the world's forests and grasslands, which provide other products and critical ecosystem services and harbor much of the Earth's biodiversity.



FOOTPRINTS BY SECTOR

The food Footprint consists of four components: **cropland**—on its own more than half the Footprint—**pasture**, **fisheries**, and **energy**. These four components account for all of the meat, fish, grain and vegetables that are consumed directly by humans, as well as all of the meat, fish, grain and energy that is used to feed, harvest and ship food products to consumers.



- **Cropland** production is highly intensive in many places around the world, degenerating the productivity of the land. The intensification of farming, using agrochemicals, irrigation, and monoculture cropping has slowed the expansion of cropland: the cropland Footprint grew by less than 10 percent over the last 40 years, while the world population doubled. But these gains have ecological costs: a swollen energy Footprint and increased demands on neighboring ecosystems to cope with nutrient loading, soil erosion, toxicity, and water shortages.

- While the **pasture** and grassland Footprint has not grown as rapidly as the consumption of animal products, this is due to the increased use of fertilized pastures for grazing, breeding, and managing livestock from cropland production. A third of the world's harvested cropland grows feed and forage for animals.

- Most **fisheries** operate near or over capacity and have experienced declines or collapses in populations. Industrial scale fisheries are rapidly changing the ecology of ocean ecosystems, while an increasing number of studies document the damaging effects of aquaculture and farmed fish. Wealthy nations like the U.S. and Japan eat a disproportionate amount of the ocean's primary productivity by consuming more fish per capita at higher trophic levels. Poorer fish-dependent countries like the Philippines, where people get more than 40 percent of their animal protein from fish, are left with fewer and less desirable fish. As a result, the average Japanese has a fisheries Footprint of 2.0 global acres per person, compared to the average Filipino fisheries Footprint of 0.7 global acres.

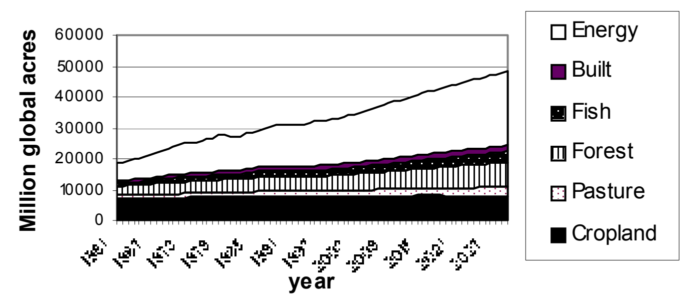
- **Energy** plays a major role in the global food system due to high fossil fuel consumption and corresponding carbon dioxide emissions. We use 10 percent as a conservative placeholder for calculating the global food energy Footprint until more detailed studies are undertaken.[3] This 10 percent includes the energy used in food production, for inputs like fertilizers, pesticides, and irrigation, and in post-production. Post-production, which accounts for 80-90 percent of the food system's fossil fuel use, includes processing, packaging, transportation, storage, and retail.[4] An average food item in the U.S. travels 1500 miles, with 90 percent of vegetables grown in the San Joaquin Valley of California.[5]

As we have seen, the global food Footprint represents a significant portion of the Earth's total biomass production, yet even this is a conservative underestimate of the true area required for food production. Several other factors without comprehensive datasets could be included, such as pesticide toxicity, climate change, and fresh water shortages. Such problems certainly contribute to footprint size but cannot be measured at this time.

FUTURE SCENARIOS

What will the world's food footprint look like in 30 years? That depends on the choices we make today.

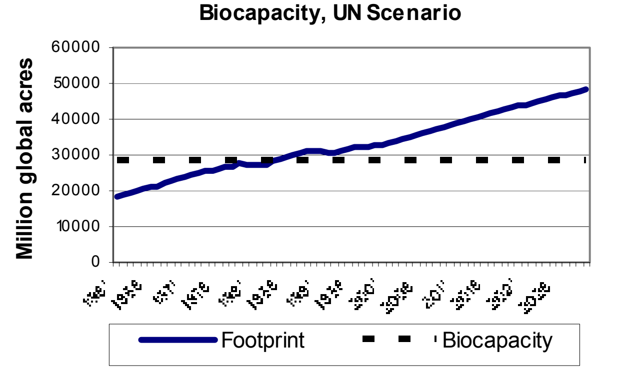
Figure 3: World Ecological Footprint Projection



A recent study estimates that growing enough food for the 9 billion people expected by 2050 would require converting an area larger than the size of the U.S., including Alaska,[6] into cropland and pasture. By then, additional natural habitat will already have been lost to development to support the increasing population.

Can we grow more food on less land? Crop yield increases comparable to those of the past 40 years are not yet clear, though there is evidence that grain production yields per person have already begun to decline.[7] Marginal and lower productivity land, where further expansion will mostly occur, is likely to sustain low yields. Irrigation water is increasingly limited, fertilizer runoff is already harming ecosystems, and yields may become more susceptible to pests and disease due to monoculture production.

Figure 4: World Ecological Footprint vs. World Biocapacity, UN Scenario



2. SHRINKING OUR FOOD FOOTPRINT: A WHOLE SYSTEMS APPROACH

Environmental problems are often addressed sector by sector. However, the solution to one problem sometimes generates a new problem. Although some unintended consequences are unavoidable, we can prevent many through whole systems thinking. The Ecological Footprint helps quantify overall limits to human activities, identifying the tradeoffs of different policy choices.

Closing the gap between human demand and ecological supply therefore will depend on four areas—**population, consumption, technology, and maintaining natural capital**. Sustainable agriculture offers us opportunities to simultaneously encourage progress on all four fronts.

- **Population**: One of the most cost-effective and humane opportunities for sustainability is to make safe, effective and affordable family planning widely available, thereby decreasing population growth rates and the demand for food.

- **Consumption**: The choices we make about the food we eat have a direct effect on other people and the land. A sustainable food system looks beyond labels of organic versus conventional farming, or meat-eater versus vegetarian, to the whole food system. Sustainable food is grown by a local farmer, at a scale appropriate to the area with minimal ecological disruption and processing, under healthy working conditions, and low on the food chain.

- **Technology**: Increased efficiencies in food production, processing, and transportation, and a shift to renewable fuel sources, can substantially reduce our food Footprint while yielding the same output.

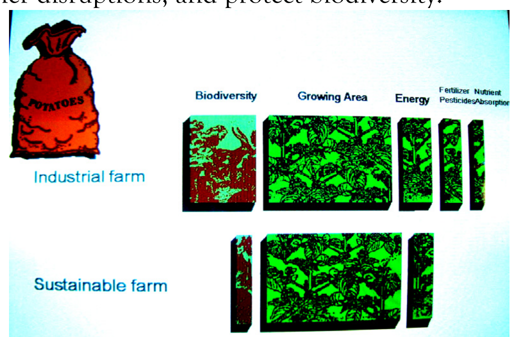
- **Maintaining natural capital**: Sustainable farming methods protect soil, water, and wildlife. There are many ways to build natural capital through farming, including maintaining or even creating habitat for wildlife, using conservation tillage to restore soil carbon, reducing water pollution, and farming with natural flood cycles.[8]

By following the food chain from farm to table, we can point the way toward smaller-Footprint alternatives that will transform agriculture.

3. A DOWN TO EARTH EXAMPLE: POTATOES-INDUSTRIAL OR SUSTAINABLE?

Industrial agriculture appears highly productive, yet it is startlingly inefficient.

The figure below compares the Footprint areas of two potato farms: one using conventional practices that rely heavily on inputs, the other working with nature to close resource loops, increase soil fertility, control pests and other disruptions, and protect biodiversity.



Adding up all the Ecological Footprints associated with industrial farming leads to a substantially larger Footprint per pound of potatoes. Even if we assume that the industrial farm's cropland Footprint is slightly smaller due to potentially higher yields, the smaller growing area is overshadowed by the areas used by other environmentally degrading activities.

Growing area: Studies comparing the yields of organic and conventional farms indicate comparable or slightly lower yields in organic systems on average, but show organic systems consistently outperforming conventional systems in stressful conditions.[9]

Energy: Fossil fuel energy from agriculture is in the form of indirect energy consumption (the energy it takes to produce chemical fertilizers and pesticides), direct diesel fuel, and other uses such as irrigation.[10] Sustainable farming substitutes organic nutrient sources, such as cover crops and animal manure, for chemical fertilizers. Pesticides are replaced by integrated pest management techniques. Small-scale agriculture typically requires less energy to operate than industrial systems,[11] and fueling equipment with alternative fuels can further minimize energy demands.

Nutrient pollution: Nitrogen fertilizers damage aquatic ecosystems through nutrient loading and contribute to changes in atmospheric composition. Organic fertilizers and reduced tillage can substantially reduce nutrient losses and increase nutrient use efficiency.

Biodiversity: Industrial agriculture has devastated both crop and wild biodiversity. Expansive monocultures and forest clearing have eliminated wildlife habitat, with high-tech seeds threatening many native crop varieties. Sustainable farms work to preserve biodiversity by protecting wildlife habitat, avoiding toxic pesticide applications, and preserving soil and water quality.

4. THE ROAD AHEAD

CAN SUSTAINABLE AGRICULTURE FEED THE WORLD?

Unfortunately, no form of agriculture—conventional or sustainable—can feed the world if we bank on continuous expansion of human demands. Feeding an ever-increasing population with its ever-increasing consumption habits cannot last.

Yet sustainable agriculture is the ***best*** chance we have to feed the world. Today's industrial food system not only occupies an exorbitant amount of the biosphere's regenerative capacity, it also degrades the productivity of ecosystems that are the very basis of our food supply. Ecological Footprint accounts, by identifying the ecological constraints of food and other human demands, underline why planning for resource and food security are essential strategies for a socially just and ecologically healthy world.

> When the Soviet Union collapsed, Cuba was forced to transform its export-based, highly industrialized agricultural system, implementing sustainable agriculture on a massive scale. Without chemical fertilizers, pesticides, and fuel, the country invested in alternative farming techniques like polycropping, biofertilizers, biological pest control, and widespread urban farming. Out of a severe crisis blossomed a model of sustainable agriculture.

THE BURDEN ON PEOPLE

While agricultural output has increased over the last decades, distribution has become more unequal. For much of the world's population, food is harder to purchase. Costly production inputs and middlemen have squeezed millions from the world's farmers, who spend more to farm yet receive less income. It is a sad irony when those who grow the world's food can't afford food for themselves or their families.

Even though food has become cheaper for wealthy people monetarily, hidden costs mask other consequences. It is difficult to calculate the true price of fossil fuel consumption, soil and water degradation, farm worker injuries and exposure to toxic chemicals, health problems from eating overly processed products from aggressive use of agro-chemicals, and exposure to toxic residues.

OPPORTUNITIES FOR SUSTAINABLE FOOD SYSTEMS

There is nothing inevitable about unsustainable food systems. They are the product of past choices, social forces, and special interests. Alternatives abound for every dimension of the current food system. Making them a reality depends on overcoming special interests, providing recognition and financial support, and restructuring the current incentive system that subsidizes and encourages unsustainable behavior. Transforming agriculture will require an economy that corrects today's price distortions and perverse incentives; phases out our addiction to fossil fuels; supports local economies; and pays farmers and farm workers a fair share of every food dollar.

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[1] For a comprehensive overview of the devastating social and ecological effects of industrial agriculture, see *Fatal Harvest: The Tragedy of Industrial Agriculture,* Andrew Kimbrell, Editor (Island Press, 2002). The link between various forms of agriculture and deforestation is described in Michael Williams, *Deforesting the Earth: From Prehistory to Global Crisis* (Chicago: University of Chicago Press, 2003).

[2] Our most recent calculations are consistent with the Ecological Footprint results published in *Living Planet Report 2002,* World-Wide Fund for Nature International (WWF), UNEP World Conservation Monitoring Centre, Redefining Progress, and Center for Sustainability Studies (Gland, Switzerland: WWF, 2002).

[3] For U.S. estimates see M. Heller and G. Keoleian, Life-Cycle Based Sustainability Indicators for Assessment of the U.S. Food System, *Report No. CSS00-04* (Ann Arbor: Center for Sustainable Systems, University of Michigan, 2000); and J. Hendrickson, Energy Use in the U.S. Food System: A Summary of Existing Research and Analysis, In *Sustainable Farming*, REAP-Canada 7: 4 (1997).

[4] Heller and Keoleian; Hendrickson.

[5] Halweil; Matthew Hora and Judy Tick, *From Farm to Table: Making the Connection in the Mid-Atlantic Food System* (Washington D.C.: Capital Area Food Bank, 2001); R. Pirog, T. Van Pelt, K. Enshayan, and E. Cook, *Food, Fuel, and Freeways: An Iowa Perspective on How Far Food Travels, Fuel Useage, and Greenhouse Gas Emissions* (Ames, Iowa: Leopold Center for Sustainable Agriculture, Iowa State University, 2001); *The Practical Farmer* 9: 3, Fall Issue (1994); and J. Barton, *Transportation and Fuel Requirements in the Food and Fiber System*, Agricultural Economic Report No. 444 (Economic, Statistics and Cooperative Service, USDA, 1980).

[6] Tilman et al., Forecasting agriculturally driven global environmental change, *Science* 292: 281-284 (2002).

[7] David Tilman et al., Agricultural sustainability and intensive production practices.

[8] Redefining Progress, *Sustainable Agriculture and Common Assets: Stewardship Success Stories*, Paige Brown, Editor (2002).

[9] See Mäder et al., Soil fertility and biodiversity in organic farming, *Science* 296: 1694-1697 (2002); J. Reganold, J. Glover, P. Andrews, and H. Hinman, H., Sustainability of three apple production systems, *Nature* 410: 926-930 (2001); L. E. Drinkwater, P. Wagoner, and M. Sarrantonio, Legume-based cropping systems have reduced carbon and nitrogen losses, *Nature* 396: 262-265 (1998); and D. Lotter, Organic agriculture, submitted May 2001 to *Ecological Economics*.

[10] Heller and Keoleian.

[11] Lotter.

ENERGY FOOTPRINTS

By: Diana Abellera

REDEFINING PROGRESS

Although the entire human population exists on just one planet, we act and consume as though we have multiple earths at our disposal. Ecological Footprint accounts break down how humanity's actions degrade bioproductive land, leaving future generations without the resources we currently utilize and enjoy. Perhaps we should begin to reduce the global ecological footprint with its biggest source: the fossil fuels sector, a factor with important environmental, sociological, and political implications. Decreasing or even eliminating dependence on fossil fuels and turning towards renewable energy sources offer a great opportunity to shrink humanity's footprint to a size the earth can support.

FOSSIL FUEL FOOTPRINTS: LARGER THAN LIFE

The widespread transition to fossil fuels (coal, oil, and natural gas) from pre-industrial to industrial times has resulted in global overshoot, or overstepping natural boundaries by extracting resources and creating waste at rates that exceed the earth's capacity. Despite radical local and regional ecological changes from pre-industrial societies, the human economy only surpassed global limits when fossil fuel use exceeded ecologically sustainable rates and induced the expansion and intensification of extractive industries like agriculture and forestry.

The burning of fossil fuels creates greenhouse gases such as carbon dioxide that contribute to the worsening problem of climate change. Assuming that the primary problem with fossil fuel use lies in the rate at which the earth can absorb carbon dioxide emissions, we can measure in terms of how much land we would need in order to absorb emissions. If we deduct the amount absorbed in the oceans and use a generous sequestration rate of 0.95 tons carbon per hectare per year, a reforested area of over 6 billion global hectares (gha) would be needed to balance current emissions. Over half of our land would have to be used for carbon dioxide absorption, as the total bioproductive land mass amounts to only 10.6 billion gha. However, since we still need land for other uses, such as agriculture and development, our fossil fuel use seems unsustainable.

One could approach fossil fuel sustainability as though fossil fuels were renewable resources similar to water or light. In those terms, we would need one hundred global hectares per person every year to have enough land to regenerate fossil fuels at humanity's rate of consumption. With a global population of 6 billion, current fossil fuel consumption rates would be 50 times the earth's biocapacity. This method provides a footprint 100 times greater than the aforementioned carbon sequestration method, proving that the amount of and control over fossil fuel supplies is even more problematic than the pollution emitted. Thus, fossil fuels are indeed non-renewable as we will deplete the supply completely if we continue to rely on them as a major resource.

IN A GLOBAL CONTEXT: IS THE U.S. CONSUMING MORE THAN ITS FAIR SHARE OF FOSSIL FUELS?

Illustration 1: Sources of Global Footprint in 2000

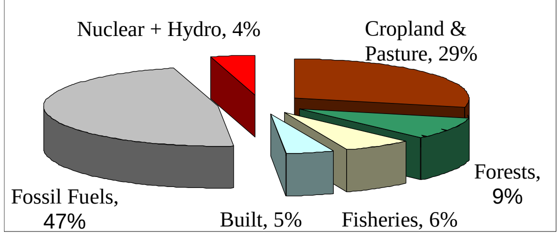


Illustration 2: Lower Income Countries: Sources of Footprint 2000

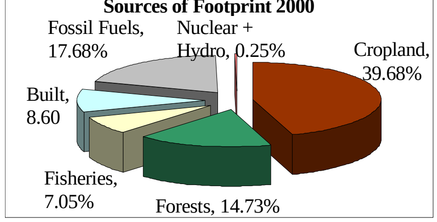


Illustration 3: Middle Income Countries: Sources of Footprint 2000

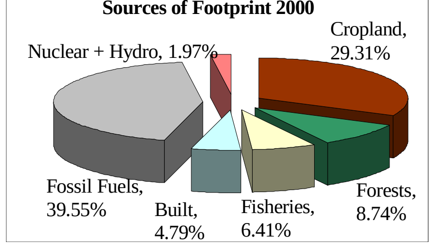
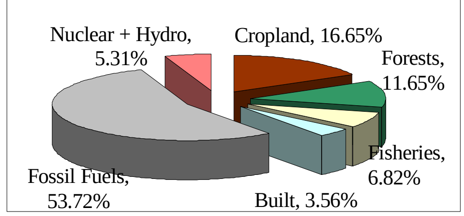


Illustration 4: Higher Income Countries: Sources of Footprint 2000



On a global scale, the burning of fossil fuels accounts for the largest portion of the Ecological Footprint. The very high amounts of coal, oil, and natural gas consumption in the wealthier regions of the world heavily influence this global pattern. In contrast, nearly half of the Footprint in lower income countries is attributable to the utilization of cropland, not fossil fuels (Illustrations 1-4).

Is there a correlation between Ecological Footprint and economic income/consumption? In looking at countries in 2000, the answer seems to be yes.[1] This is not surprising given that gross domestic product (GDP) and energy use tend to be highly correlated, and globally Footprints are dominated by fossil fuel consumption. Thus, highly industrialized countries must be held accountable for a large portion of the fossil fuel footprint and therefore the global footprint.

Illustration 5 shows the skewed ratio of the United States' energy production and consumption versus its share of world population. Comparisons to other regions of the world are exhibited in illustration 6.

Illustration 5: U.S. Share of the World, 2002

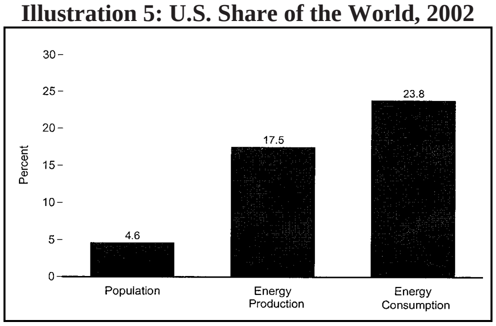
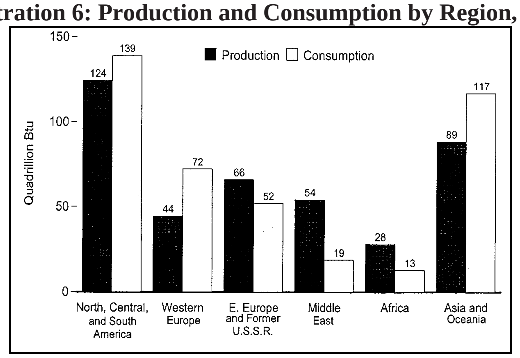


Illustration 6: Production and Consumption by Region, 2002

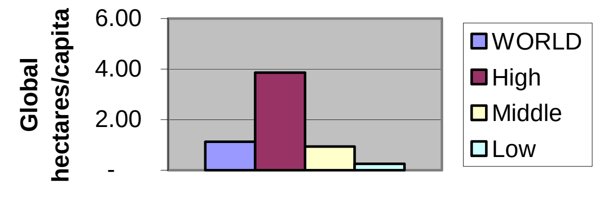


Although the US represents less than 5% of the world population, it consumes nearly one quarter of the world's energy. The whole world suffers the consequences as the pollution emitted affects everyone on a global scale. Balancing this disproportionate relationship must begin by re-evaluating fossil fuel consumption rates.

In policy terms, this analysis suggests two directions.

First, international cooperation in many areas is clearly important in addressing the distribution inequalities in global Footprints. Illustration 7 exhibits energy footprints by income group, accentuating the disparity between the rich and the poor.

Illustration 7: Energy Footprints by National Income Level



High income countries have per person footprints sixteen times those of low income countries. While it is important that all nations work together to stabilize fossil fuel emissions and to lessen the threat of global warming, the burden rests on higher income countries. The United Nations' Kyoto Protocol stands as the major initiative to reduce global greenhouse emissions, focusing on developed countries.

THE KYOTO PROTOCOL

On February 16, 2005 128 nations became legally bound to the Kyoto Protocol. The voluntary treaty asks countries to work together to reduce greenhouse gas emissions on a global scale. By the year 2012 developed nations must reduce combined emissions to below their 1990 levels and can trade allowances in order to meet their goals. The only industrialized nations that have yet to sign the treaty are Australia, Liechtenstein, Monaco, and the United States. Australia and the U.S. have claimed they have no plans to participate, despite their responsibility for one-third of the industrialized world's greenhouse gases. As a leader in global issues as well as fossil fuel consumption, US ratification of the agreement would pave the way towards environmental change simply due to the sheer amount of fossil fuel emissions that would be eliminated from the atmosphere. The framework for this international treaty was modeled after the Montreal Protocol, an agreement that limited the ozone damaging greenhouse gases of chlorofluorocarbons (CFCs) and hydrochloroflourocarbons (HCFCs). The Montreal Protocol success shows that the world can work together to combat environmental issues if everyone cooperates.[2]

Second, local efforts are necessary to reduce resource use on a smaller geographic scale. Higher income communities may invest in renewable energy sources instead of relying on fossil fuels. Source reduction, or using less of a resource overall, also remains the number one method for reducing any type of Footprint. Implementing more efficient public transportation systems, offering incentives for green energy use, and investing in research and development are all methods of contributing to Footprint reduction.

EVERYONE HURTS

Fossil fuel use results not only in adverse environmental problems but also social and political issues. Oil has risen in global prominence to become the largest primary energy source, causing serious debates and conflicts over resource management and control. Finite resources create tension in a world where everyone competes for their use. Stripping ourselves from dependence on oil could potentially decrease competition over resources in foreign affairs and calm debates over choices for drilling sites in domestic affairs.

High energy consumption contributes to other problems that affect individuals as well as the world. Fine particulates and gases that are emitted in the burning of fossil fuels worsen asthma and other respiratory problems. Climate change has already caused crop damage, severe weather, and increased heat strokes. The potential dangers of extreme climate change can cause disastrous effects on nature that can lead to dire consequences.

SOLUTIONS EXIST

Using electricity from renewable "green" sources like wind, solar, and small-scale hydropower substantially reduces Ecological Footprints. Exact measurements remain undetermined as technology continues to develop and renewable energy sources remain an insignificant percentage of all commercial energy. However, current estimates show that using renewable energy lessens Footprint size dramatically[3].

Alternatives to fossil fuels currently exist, each with their advantages and disadvantages. Each renewable source of energy has a reduced footprint as seen in table 1. However, barriers to large-scale implementation make viability difficult. Improved storage and distribution mechanisms are needed to alleviate logistical problems; moreover, the idea of changing infrastructure (such as converting pipelines to transport new sources of energy) increases resistance. Technology advances and further understanding of the benefits make renewable energy sources a strong possibility for the future. One example, photovoltaic power, can reduce energy Footprints dramatically.

Actions needed to reduce energy consumption and CO2 emissions:

- Increase the use of energy-saving technologies; eliminate wasteful energy consumption in transport, industry, and the home.
- Increase the supply of energy from sources which reduce or eliminate pollution, especially renewable sources such as solar and wind.
- Assist lower-income countries to invest in sustainable energy technologies.
- Increase energy prices to cover the full environmental costs of energy use, and remove government subsidies on energy.
- Use energy dividends from higher prices to restore ecological and social damage caused by energy consumption.
- Stop deforestation and promote reforestation of deforested areas in an ecologically and socially appropriate manner.

Table 1: Ecological Footprints of Power Production

ENERGY SOURCE	FOOTPRINT (global hectares/megawatt)
Coal	1,903
Natural Gas	1,053
Hydroelectric	46
Wind	21
Photovoltaic	221

Photovoltaic arrays (PV), or solar power, can deliver an impressive energy output without compromising bioproductive areas. One hectare of PV panels can deliver the thermal energy contained in 100 tons of oil annually. PV arrays covering a square 160 km on each side could supply the electricity demand of the United States. With a national population of 280 million people, this amounts to 0.01 ha/cap. In order to provide energy for the entire global population, PV panels must cover 310 km, leading to a mere 0.002 ha/cap. These panels could rest atop buildings already in place or in sunny, arid regions such as deserts, thereby reducing Footprints on bioproductive land.

ICELAND'S HYDROGEN FUEL ECONOMY

Change is possible. In 2002 Iceland announced its decision to rid itself of dependence on fossil fuels by transforming the basis of its economy to hydrogen fuel. This plan, which the country expects to complete over the next 30 years, hopes to reduce Iceland's carbon dioxide emissions by up to 50%. Infrastructure will change to accommodate automobiles, and all ships in the large fishing industry will operate on hydrogen fuel. The country hopes to serve as a model for sustainability for the rest of the world. [4]

SUCCESS STORIES

Efforts have been made to implement alternative energy throughout California. California's Energy Commission is currently reviewing a bill requiring that twenty percent of the state's energy be from renewable sources by the year 2010. Los Angeles' governor has signed into action a bill of the same intentions by the year 2017.

In 2001 San Francisco voters overwhelmingly agreed to have the city match the nation in the amount of solar panels installed on rooftops annually. They approved a $100 million bond towards this project and hope to see other cities in the United States follow suit.

Table 1: California Green Schools Savings
SUMMARY OF ESTIMATED NO-COST SAVINGS

Name of District, School	Period	Kilowatt hour Savings	Dollar Savings	% Savings
Rialto Unified School District				
Bemis Elementary School	9/02 – 8/03	229,159	$38,461	30%
Myers Elementary School	9/02 – 8/03	37,530	$6,874	10%
Dixie School District				
Mary Silveira Elementary School	3/02 – 6/03	15,211	$3,277	7%
Oakland Unified School District				
Bret Harte Middle School	3/02 – 6/03	49,272	$7,540	7%
James Madison Middle School	1/03 – 6/03	27,294	$3,818	15%
Ross Valley School District				
Manor School	3/02 – 6/03	19,528	$4,418	16%
Southern California Private				
Ambassador Christian School	9/02 – 8/03	20,168	$3,758	15%
West Contra Unified School District				
DeAnza High School	3/02 – 6/03	42,975	$6,654	4%
Mira Vista Elementary School	3/02 – 6/03	12,790	$2,158	7%
TLC/North Campus	10/02 – 6/03	10,503	$1,594	7%

The California Green Schools Program, run by the Alliance to Save Energy, has already managed to save schools all throughout the state thousands of dollars in energy savings. Participating schools have boasted increased awareness on saving energy, student and teacher action, improvements to energy efficiency at the schools and the students' homes, and savings in energy bills. Students become involved in energy audits and discover ways to reduce energy costs in their schools and homes. Table 1 shows the amounts that just some of the schools in the San Francisco Bay Area saved in 2003.

CHANGE CAN HAPPEN

Ultimately, the global Footprint is comprised mostly of the fossil fuel Footprint of highly industrialized countries such as the United States. One of the most important steps societies can take towards sustainability lies in freeing themselves from dependence on fossil fuels and turning towards more sustainable resources, both in small scale ventures and in large scale economies. Using renewable resources remains a viable option we must work towards before depleting the fossil fuel supply. Technology allows us the opportunity to reduce our footprint dramatically, yet we must first understand the developments as advancements and improvements and invest in their futures. Transition to renewable energy sources can only lead to smaller footprints, healthier conditions, less strained political relations, and a better sense of stewardship towards the earth.

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[1] A strong correlation was found between per capita Gross Domestic Product and per capita Ecological Footprints for 134 countries in 2000. A bivariate regression on per capita Footprints and GDP resulted in a 0.14 adjusted R-square at a 0.01 significance level. Both findings suggest a positive relationship between economic activity measured by GDP and Footprints.

[2] For more information on the Kyoto Protocol and the status of US ratification, please visit the US Energy Information Administration at http://www.eia.doe.gov/oiaf/kyoto/kyotobrf.html

[3] Updated from Wackernagel et al., "Tracking the ecological overshoot of the human economy," *Proceedings of the National Academy of Sciences*, **99** (2002). Numbers do not add due to rounding.

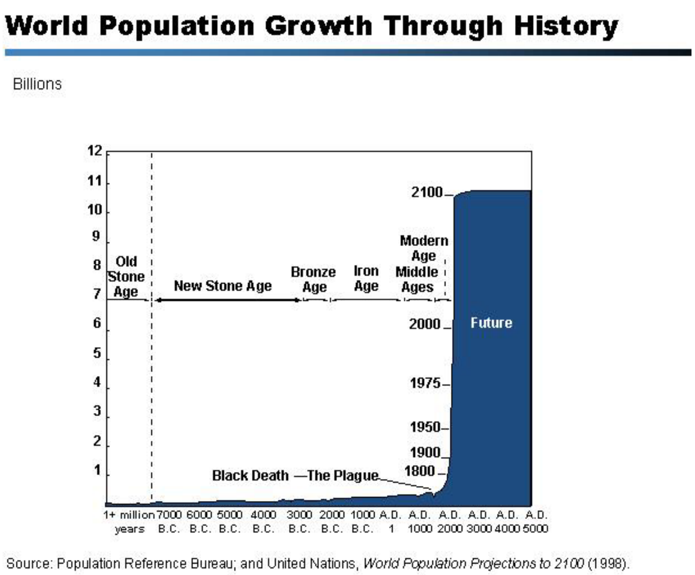
[4] BBC news http://news.bbc.co.uk/1/hi/programmes/newsnight/archive/2208013.stm

WHAT ABOUT POPULATION?

By: Diana Abellera, Dahlia Chazan, & Susan Santone
February 2005

One of the most influential environmental issues today is overpopulation. The number of humans in the world has steadily been on the rise throughout most of history, but advances in technology and improved living conditions have allowed the population to skyrocket from 3 billion to 6 billion people in the most recent 40 years (Figure 1).

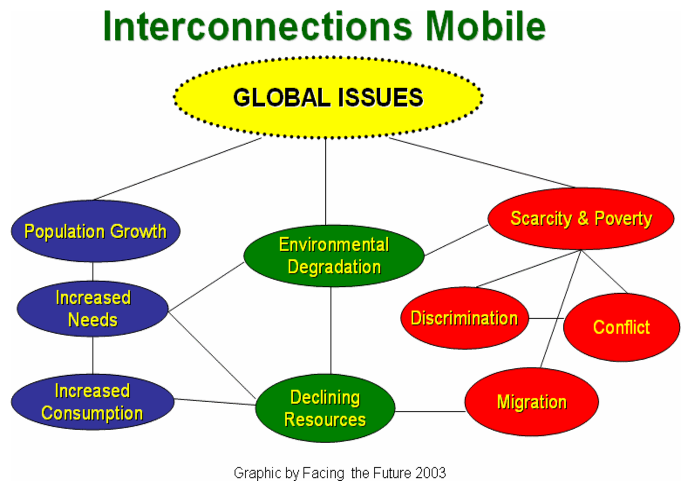
Figure 1



To calculate the overall impact of our species on the biosphere, we add up the Ecological Footprints of the Earth's entire population. As population grows, the globe's total footprint grows. However, the size of the biosphere is finite. The greater our world family, the less nature available per person.

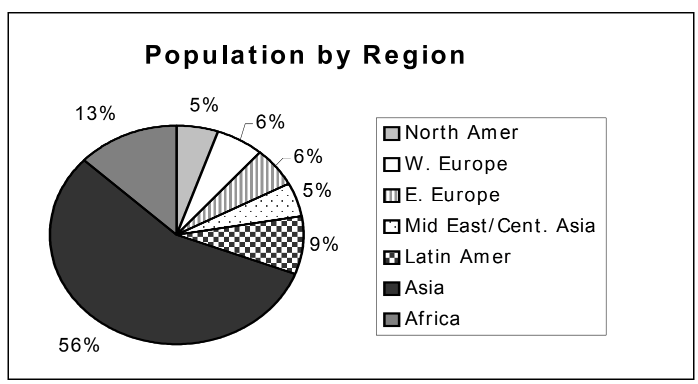
Thus, global population growth can result in a high demand for resources that exceeds the world's ability to supply them. Figure 2 demonstrates how population growth is connected to other global issues, including the decline in resource availability associated with growth demand.

Figure 2



Dividing current global population into the world's regions shows why population is quickly becoming a key issue in some parts of the world (Figure 3). Natural and economic inequities in resource distribution further deepen scarcity in developing nations with large populations. This unequal distribution of resources (both natural and through investment in human capital) stems from structural systems, such as colonial-era trade patterns, set by historical relations. Entire nations became impoverished and left behind in the industrial and technological races.

Figure 3



Without adequate health care, sanitation systems, and social security, people intentionally increase family size. More children are needed in case other children die due to malnutrition or disease. Additionally, large family size translates into more income-generating workers and support for the elderly. Even if industrialized countries succeed in reducing the size of their Footprints, global population growth rates could swamp those gains and result in an ongoing unsustainable global Footprint.

IS POPULATION THE MAIN PROBLEM?

The United Nations' data projects a decrease in population growth rates over time. But, with the large number of current residents of the planet, even a reduced rate of population increase is still enough to bring us close to the global limit of biological resource capacity.

The world's Ecological Footprint changes in proportion to global population size, average consumption per person, and the resource intensity of the technology being used. As the number of people increases, so do technological advances and the demand for natural resources. Technology can alter the productivity of land, or the efficiency with which resources are used to produce goods and services.

Total environmental impact is thus a factor of population, affluence (consumption), and technology. This is expressed in the formula:
$I = P * A * T$

How this works:	I =	P *	A*	T
Suppose that current impact is expressed as 1 using the I=PAT formula:	1 =	1	1	1
If population increases by 50% (as it's expected to), then the levels of consumption (A) or technology (T) must fall to 66% of current levels in order for environmental impact (I) to remain steady.	1= 1=	1.5 1.5	.66 1	1 .66

Although rates of consumption must decrease in developed countries such as the United States, population growth rates must decrease in all countries in order to reach sustainability and lessen the global ecological footprint.

From 1991 to 2001, per capita footprints dropped by 8% in the middle and low income countries, where population growth is highest. During the same time, the per capita Footprint in the 27 wealthiest countries (where populations are smaller) increased by 8% per person. Both situations contributed to the global ecological footprint and thus total overshoot of the earth's biocapacity.

There are 1.89 hectares (4.5 acres) of ecologically productive land available for each person on earth. However, current average usage is about 2.2 hectares (5.5 acres), resulting in 20% total overshoot. Each nation may play a role in lessening the global footprint depending on its economic situation.

LIVING WITHIN OUR LIMITS

Having passed the 6 billion mark, the task of slowing population growth seems daunting at first. However, individuals and nations can and have taken action. Developing nations can adopt policies that educate and provide incentives for limiting family size, while improving economic opportunities for their citizens. Industrialized nations have the opportunity to help not only by controlling population growth but also by investing in the development of lower-impact technologies which will contribute to a smaller global Footprint. Ultimately, population stands as a central determinant of humanity's impact on the planet because of the large number of people here right now. Reducing this pressure on our natural resources over time will improve quality of life and the distribution of economic opportunities around the world .

POPULATION POLICY IN KERALA[1]

The Indian state of Kerala reduced its fertility rate by 40 percent over the course of 25 years. Strong government commitment to social welfare allowed population rates to slow to just 1.8 percent through establishing programs like the following:

- "Fair price" stores keep costs of basic needs low
- Social security, pension, and unemployment plans aided the impoverished
- Land reform provided security by eliminating tenancy
- Grassroots groups fought for economic and political rights
- Public health expenditures and facilities increased in both rural and urban areas
- Increased education for women

Kerala now has a total fertility rate that is almost half as much as India as a whole.

[1] Goekler, John. *Population Issues, Impacts, and Solutions* (Lopez Island: Facing the Future: People & the Planet, 2000). Pg. 43.