Human carrying capacity and the ecological footprint

In this topic we will

- Review the concept of carrying capacity
- Describe the concept of an ecological footprint
- Calculate ecological footprints for data

And we will discuss several processes

- Factors affecting human carrying capacity and limits to growth
- The difficulty in applying the concept of human carrying capacity
- Affect of reuse, recycling and remanufacture on carrying capacity
- Differences between ecological footprints for different regions
- The effects of development policies on population growth
- The effects of technological development on population growth

DH La Chat 2004 modified JR Oakham 2005

Review of carrying capacity

Draw a sigmoid growth curve for an animal population.
Label the phases of growth and indicate the carrying capacity.

Carrying capacity is defined as the maximum population of a given species that can be supported indefinitely in a particular habitat without permanently damaging that habitat.

Can the concept of carrying capacity be applied to local human populations? (3.7.1)

In 1798, when the human population was about one billion, Thomas Malthus, and economist, wrote, 'The power of the population is infinitely greater than the power of the earth to produce subsistence for man'. In 1976, when the population was 3.5 billion, an environmentalist, Paul Ehrlich warned of 'famines of unbelievable proportions' and that feeding six billion (passed in 1999) would be 'totally impossible in practice'. So far these predictions of disaster have been wrong and human carrying capacity may continue to increase. It may not be possible to extrapolate (predict) any maximum human population.

Read the following paragraph and highlight the various ways in which local human populations can exceed the natural carrying capacity of the area in which they live.

By examining carefully the requirements of a given species and the resources available, it might be possible to estimate the carrying capacity of that environment for the species. This is problematic in the case of human populations for a number of reasons. The range of resources used by humans is usually much greater than for any other species e.g. fossil fuels and minerals. Furthermore, when one resource becomes limiting, humans show great ingenuity in substituting one resource for another e.g. replenishables for nonrenewables or substituting manufactured capital for some form of natural capital that might run out e.g. textiles. Resource requirements vary according to lifestyles, which differ from time to time e.g. pre- and postindustrial and from population to population e.g. housing in a tropical region compared to Europe. Technological developments give rise to continual changes in the resources required and available for consumption e.g. advances in energy storage. For example, if we learn to use energy and materials twice as efficiently, we can double the population or the use of energy without necessarily increasing the impact ('load') imposed on the ecosphere. Human populations also regularly import resources from outside their immediate environment which enables them to grow beyond the boundaries set by their local resources and increases their carrying capacity. People are able to trade with other regions so that an energy-poor agricultural country can trade food for petroleum from another country with lots of oil but little domestic agriculture. While importing resources in this way increases the carrying capacity for the local population, it has no influence on global carrying capacity. All these variables make it practically impossible to make reliable estimates of carrying capacities for human populations. Some economists therefore argue that there are no practical limits to economic growth and the carrying capacity concept does not apply to human beings.

Factors affecting human carrying capacity

Reuse, recycling, remanufacturing (3.7.2)

Human carrying capacity is determined by the rate of energy and material consumption, the level of pollution, and the extent of human interference in global life support systems. Reuse, recycling, remanufacturing and absolute reductions in energy and material use can affect human carrying capacity.

List two examples of reuse, recycling and re-manufacturing.

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-
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How can these initiatives increase human carrying capacity?

Case study: aluminum recycling.

Read the following information and highlight five examples of environmental impact reduction.

It takes about 15 kWh of electricity to produce 1 kg aluminium from its ore, bauxite. Much of this energy is supplied by burning fossil fuels, which when converted to electricity is at best 40% efficient. Hydroelectricity can be generated at 90% efficiency. Hydropower is under-used as a power source in the developing world at the present but it would be possible to transport aluminium to another country for processing. It takes only 5% as much energy to produce liquid aluminium from remelted cans as the original ore. Also aluminium does not change its chemical composition during heating. Used cans are easily crushed and they are not brittle like glass. Many countries and organisations now encourage people to recycle aluminium cans etc and take them to recycling centres rather than separate aluminium from domestic waste.

Unfortunately the advantages of reductions in resource use, i.e. increased carrying capacity are often eroded by population increase.

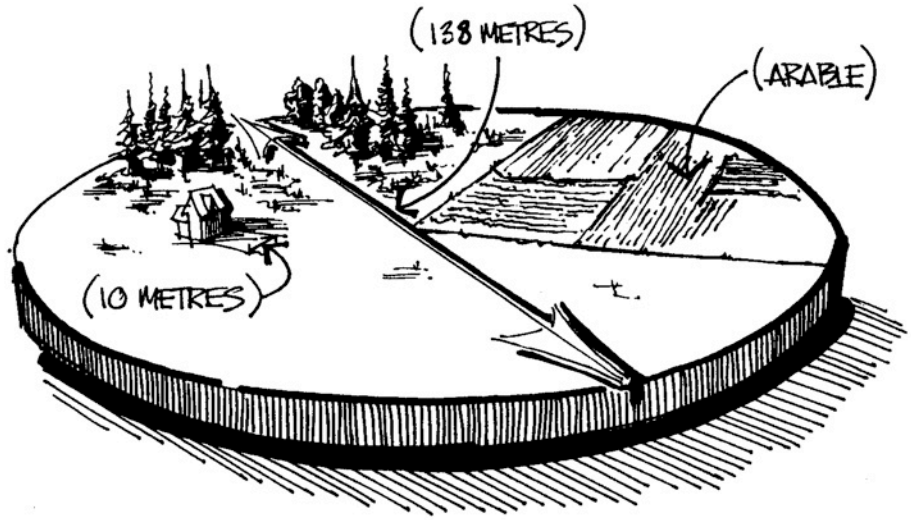
Human carrying capacity and ecological footprint (3.8.1)

Carrying capacity is the **maximum number** of a particular species that a specific ecosystem can sustainably support. As we have seen humans can exceed their local carrying capacity by several means including trade to import resources. Thus human carrying capacity can also be viewed as the **maximum load** (rate of resource harvesting and waste generation) that can be sustained indefinitely without reducing productivity and functioning of ecosystems wherever those ecosystems are. Thus human carrying capacity is better viewed not so much as population size but as areas of land that support that population. An ecological footprint is the area required to sustainably support a given population rather than the population that a given area can sustainably support. An ecological footprint is therefore the inverse of carrying capacity and provides a quantitative estimate of human carrying capacity.

The ecological footprint of a population is an area of land (and water) that would be required to sustainably provide all of a particular population's resources and assimilate all its wastes. How does the cartoon on the front page suggest this?

Personal ecological footprint

The diagram shows a fair Earthshare for one person. A fair Earthshare is the amount of land each person would get if all the ecologically productive land on Earth were divided evenly among the present world population.



How large is it?

What resources does it contain?

List the products and services your fair Earthshare provides you with.

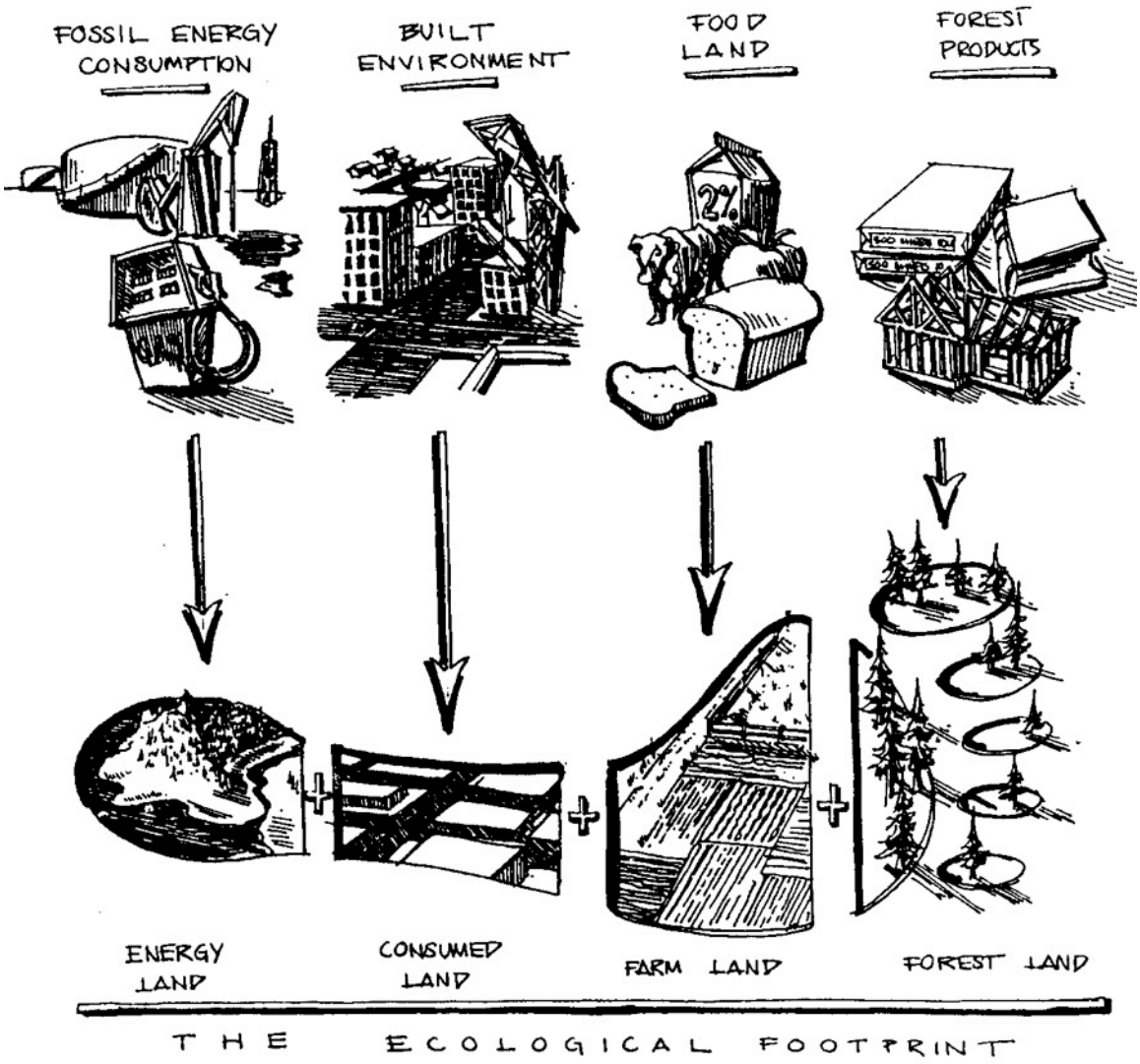
Do you think yours is larger? The average person in the United States consumes 9.6 hectares, in Canada 7.2 hectares and in Europe 4.5 hectares. We are a long way from

planetary equality and even further from a sustainable civilisation which would require consumption levels below 1.4 hectares – even before accounting for population changes.

Calculating ecological footprints (3.8.2)

Ecological footprinting converts various kinds of consumption and waste production into a land area needed to produce or service it.

Look at the diagram below. What four areas would need to be estimated for a full ecological footprint?



Ecological footprints are stated as the land area in hectares needed by a particular population e.g. a country or community, or as a per capita per annum of that population. Ecological footprints will always be conservative estimates. Why is this so?

Internal assessment: An ecological footprint investigation

You are expected to be able to calculate data ecological footprints for specified populations from collected data. The formulae needed to calculate ecological footprints are given below with worked examples. You are going to choose an investigation from suggestions given to you by your teacher. You will write up your ecological footprint investigation as part of your internal assessment. You can collaborate on this for personal skills.

Ecological footprint formulae

Food Land

This is the total crop and pasture for plant and animal food in the country (plus overseas land used for imported food items).

Calculation: area of cropland and pasture / population. Units w ha.cap^{-1}.

Consumed Land

This is land consumed for houses, factories, roads, sports grounds etc.

Calculation: area of consumed land / population. Units x ha.cap^{-1}.

Energy Land

This is land to absorb CO_2 from the combustion of fossil fuels.

Calculation: fuel used in GigaJoules / population x energy area. Units y ha. cap^{-1}.

If the volume in litres is known the GJ equivalent can be calculated.

Forest Land

This is the forest area needed to produce sawn wood, paper and other wood products.

Calculation: wood products (mass or volume) / population x productivity. Units z ha. cap^{-1}.

Ecological footprint of India

As a practice example we will calculate the ecological footprint of an average Indian person.

Use the following data to calculate w, x, y and z. Add them together to find the total average ecological footprint for a citizen of India.

Population	1,000,000,000
Cultivated area	250,000 km^2
Covered land	25,000 km^2
Fuel used	13,500 PJ
Energy area: fuel	6000 l. = 1 ha. yr^{-1}
Energy area: energy	200 GJ = 1 ha. yr^{-1}
Wood products	300,000 m^3
Wood mass to volume	1 tonne = 1.8 m^3.
Productivity (volume)	2.3 m^3 ha^{-1} yr^{-1}.
Peta = 10^{15} Giga = 10^9	1 PJ = 10^6 GJ
1 hectare = 10000m^{-2}	1 km^2 = 100 ha.

	Results:
Cultivated area	
Covered land	
Fuel used	
Wood products	
Total	

Your investigation

You can choose to investigate the ecological footprint of:

An aspect or activity on the Oakham campus, e.g. heating, transport, paper use.

An aspect or activity of your personal life, e.g. your family home, hobby, car etc.

A person from your country of origin (or country of your choice).

A particular activity in a particular place. See example productive forest area for paper per average Canadian.

Finding Data

Global data is available from the World Resources website and some others, which are available online. Other information can be obtained by asking for information such how much fuel, paper, etc is used, or measuring things for yourself e.g. the area covered by a building etc.

Your Report

Write your report in the usual way paying particular attention to the presentation of your raw data and showing your calculations clearly.
Your report will be assessed in skills DC, DPP, PSa and PSb.

Effect of Technological Development (3.8.6)

Can technological advances allow indefinite sustainable expansion of the human carrying capacity? Many economists and technological optimists argue that human carrying capacity can be expanded continuously through technological innovation. For example, if we learn to use energy and material twice as efficiently, we can double the population or the use of energy without necessarily increasing the impact ('load') imposed on the ecosphere. However to compensate for foreseeable population growth (8 billion by 2040?) and the economic growth that is deemed necessary, especially in developing countries, various estimates have suggested that efficiency would have to be raised by a factor of 4 to 10 to remain within global carrying capacity.

a. List some examples of technological development.

b. What is the relation between technological development, resource use, carrying capacity and population growth.

c. What consequences of these can limit population growth?

Ecological footprints of more and less economically developed countries (3.8.3)

Data for food consumption are often given in grain equivalents, so that a population with a meat-rich diet would tend to consume a higher grain equivalent than a population that feeds directly on grain. Look at this data:

Population from	Per capita grain consumption kg yr^{-1}.	Local grain productivity kg ha^{-1} yr^{-1}.	Per capita CO_2 emissions from fossil fuels kg C yr^{-1}.	Net CO_2 fixation by local vegetation kg C ha^{-1} yr^{-1}.
Africa	300	6000	200	6000
North America	600	300	1500	3000

What does the high per capita grain production in North America suggest about the diet?

What does the local grain productivity suggest about the two farming methods in use?

Which population is more dependent on fossil fuels? Explain.

Why is there a difference in the net CO_2 fixation of the two regions?

These, and other factors, will often explain the differences in the ecological footprints of populations in LEDCs and MEDCs.

Calculate the per capita ecological footprint (food land and CO_2 absorption land only) for each region, using the two stated formulae.

$$\frac{\text{per capita food consumption (kg } yr^{-1})}{\text{mean food production per hectare of local arable land (kg } ha^{-1} yr^{-1})}$$

$$\frac{\text{per capita } CO_2 \text{ emission (kg C } yr^{-1}}{\text{net carbon fixation per hectare of local natural vegetation (kg C } ha^{-1} yr^{-1})}$$

State two differences you would expect between the ecological footprint of a city in a developing country and that of a city in a developed country.

It has been calculated that the ecological footprint of Singapore is 264 times greater that the area of Singapore. Explain what this mean?

Assume that in a large city with a stable population, the proportion of the population that has a vegetarian diet increases. Explain how this change might affect the city's ecological footprint.

Ecological footprint example 2: productive forest area for paper

Question: How much forest area is dedicated to providing pulpwood for the paper used by the average Canadian? (This includes food wrappings, packaging, reading materials, etc.

Each Canadian consumes about 244 kilograms of paper every year. In addition to the recycled paper that enters the process, the production of each metric ton of paper in Canada currently requires 1.8 m^3 of wood. The average wood productivity of 2.3 [m^3/ha/yr.] is assumed. Therefore, the average Canadian requires...

244 [kg/cap/yr.] x 1.8 [m^3/t] / 1,000 [kg/t] x 2.3 [m^3/ha/yr.]
= **0.19 [ha/capita] of forest in continuous production for paper.**

What is the difference between an average Canadian and Indian ecological footprint for forest products? And what is not included in this analysis?

Development policies and population dynamics (3.8.5)

Many policy factors influence human population growth. Domestic and international development policies (which target the death rate through agricultural development, improved public health and sanitation, and better service infrastructure) may stimulate rapid population growth by lowering mortality without significantly affecting fertility. Some analysts believe that birth rates will come down by themselves as economic welfare improves and that the population problem is therefore better solved through policies to stimulate economic growth. Education about birth control encourages family planning. Parents may be dependent on their children for support in their later years and this may create an incentive to have many children. Urbanization may also be a factor in reducing crude birth rates. Policies directed toward the education of women, enabling women to have greater personal and economic independence, may be the most effective method for reducing population pressure.

Highlight national policies and cultural changes that might reduce population size.

Assignment and summary document

Use the information and examples in this topic to write a summary of human carrying capacity under the title:

Human ingenuity, reduction of energy and material consumption, technical innovation and population development policies all increase human carrying capacity.

Consider the following points. Give two good examples of each.

a. Define human carrying capacity. List ways in which local human populations can exceed the natural carrying capacity of the area in which they live.

b. Define and give examples of reuse, recycling and re-manufacturing. How can these lead to an increase human carrying capacity?

c. What is the relation between technological development, resource use, carrying capacity and population growth. What consequences of these can limit population growth?

d. How can national population policies decrease population size? What cultural changes can lead to decreased population growth?

Write on … your chance for a perfect answer

The diagrams below represent the area inhabited by, and the ecological footprint of, two human populations. One population is from a developed country and the other form a developing country. The diagrams are drawn to the same scale.

a. Which country is most likely to be a **developing** country?
Explain your answer.

b. State **four** pieces of information that would be necessary to calculate the ecological footprint for any human population.

c. Explain **two** ways in which the latitude of a country might affect the size of an ecological footprint.

d. Which of the populations, **A or B**, is exceeding the carrying capacity of its local area?
Explain your answer.

e. Suggest **two** ways in which food production of the two populations might differ.

f. Explain how these differences in food production could influence the **size** of the ecological footprints of these two populations.

Syllabus

3.7 Limits to Growth (2.5h)

3.7.1 Explain the difficulties in applying the concept of carrying capacity to local human populations. **3**

3.7.2 Explain how reuse, recycling, remanufacturing and absolute reductions in energy and material use can affect human carrying capacity. **3**

3.8 Environmental Demands of Human Populations (6.5h)

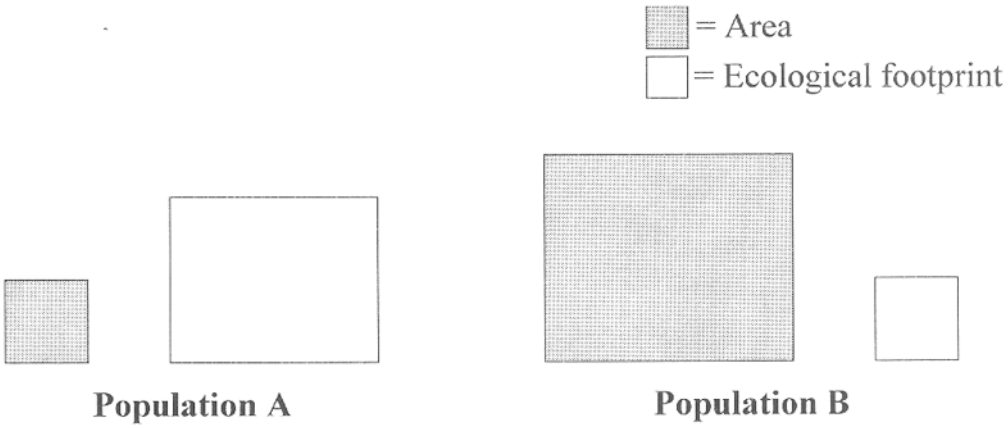
3.8.1 Explain the concept of an ecological footprint as a model for assessing the demands human populations make on their environment. **3**

3.8.2 Calculate from appropriate data the ecological footprint of a given population, stating the approximations and assumptions involved. **2**

3.8.3 Describe and explain the differences between the ecological footprints of two human populations; one from an LEDC and one from an MEDC. **2, 3**

3.8.5 Discuss how national and international development policies and cultural influences can affect human population dynamics and growth. **3**

3.8.6 Describe and explain the relationship between population, resource consumption and



technological development, and their influence on carrying capacity and material economic growth. **2, 3**