TUTORIAL:
ECOLOGICAL FOOTPRINT

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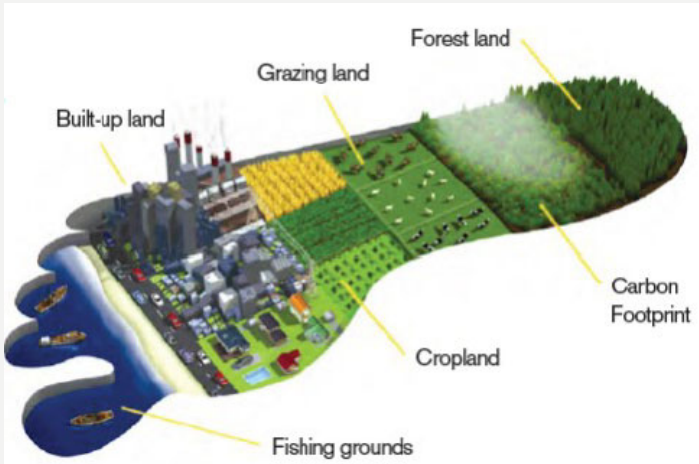
- **What is "Ecological Footprint"?**
  - method to measure **human demand on natural capital**, i.e. the *quantity of nature it takes to support people or an economy*. It tracks this demand through an ecological accounting system.
  - A measure of how much **area of biologically productive land and water** that an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates.
  - The Ecological Footprint of a person is calculated by adding up all of people's demands that compete for biologically productive space, such as:
    - cropland to grow potatoes or cotton
    - forest to produce timber
    - to sequester carbon dioxide emissions
  - Measured in global hectares (gha).



EQUIVALENCE FACTOR

- A productivity based scaling factor that converts a specific land type (such as cropland or forest) into a universal unit of biologically productive area, (i.e. global hectare).

Table 1: Equivalence factors (From "Ecological footprint calculators: technical background paper" by EPA Victoria, 2005)

Component	Equivalence factor
Cropland	2.17
Forest	1.35
Permanent pasture	0.47
Built-up land	2.17
Energy land	1.84
Marine (fishing ground)	0.06

Ecological Footprint (gha) = Physical land area (ha) x Equivalence Factor

- **Ecological Footprint = Energy Land + Built-up Land**
- **EF > 1 when:** Land types (e.g., cropland) have a productivity higher than the average productivity of all biologically productive land and water area on Earth.
- **EF < 1 when:** Land types (e.g., grazing lands) have a lower productivity.

REMINDER

- Energy Land:
  - The land needed to sustainably manage our energy demands. This is different from forest land
    - E.g. offset the release of CO2 from fossil-fuel burning by setting aside land for growing trees which reabsorb, or sequester, the carbon emissions.
- Built-up land:
  - Productive capacity has been largely lost by development – roads, buildings, etc.

12.55 **metric tons = 1 hectare**

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1 hectare = 10,000 m^2: 1 GWh = 1000 MWh = 1000,000 kWh: 1 GJ = 1000 MJ = 1 KJ

QUESTION 1:

1. Australian consumption of bananas per person is 10 kg/year (fresh banana and banana derived products). The average banana yield is 12 tonne/ha.year and the current population of Australia is 21 million people. If only cropland footprint is considered, calculate the **banana ecological footprint for Australia.**

We know that: Ecological Footprint = Physical Land Area (ha) * Equivalence Factor

Therefore, we need to calculate for the Physical land area required for Australian banana consumption.

a) $Banana\ consumption = \left(10\,\frac{kg}{year}\right)(21 * 10^6\ persons) = 21 * 10^7\,\frac{kg}{year} = 21 * 10^4\,\frac{\text{tonne}}{\text{year}}$

Because 1 kg = 0.001 tonnes

b) Required physical land for Australian banana consumption:

$$Land = \frac{consumption}{banana\ yield} = \frac{21 * 10^4\,\frac{tonne}{year}}{12\,\frac{tonne}{ha.year}} = 1.75 * 10^4 ha$$

c) $\boldsymbol{Ecological\ Footprint = Land * 2.17(cropland) = (1.75 * 10^4) * 2.17 = 37.975\ gha}$

QUESTION 2:

The American Wind Energy Association estimates that the embedded energy required for producing and maintaining a wind turbine is 27 MWh per GWh of energy produced per year. Assume that this embedded energy is from a mix of fossil fuel and that the footprint of this energy is 161 gha/GWh.

The built-up land for wind power is 0.6 ha per GWh produced per year. Calculate the **ecological footprint of wind power**.

- Calculate the Ecological Footprint for both land areas

  Energy Land = (27x10^-3 GWh)(161 gha/GWh) = 4.3 gha

  Built-up Land = 0.6 ha/GWh * **2.17 (Built-up Land)** = 1.3 gha

- Calculate total Ecological Footprint

  Ecological Footprint = Energy Land + Built-up Land = 4.3 + 1.3 = 5.6 gha

QUESTION 3:

Robert lives 20 km from UoW. He commutes to Uni 5 times a week to attend classes by his Holden Ute. Petrol consumption of his Ute is 9 litres per 100 km. According to the Australian Green House Office, the greenhouse emission factor for each litre of petrol is 2.36 kg of CO2. It is estimated that an additional 15% of the fuel is used to manufacture and maintain a vehicle and an additional 30% is used for the construction and maintenance of road infrastructure. The uptake of carbon by Australian forest is 1.3 tonne/ha.

Petrol consumption = 9 L / 100 km ← +15% for vehicle etc. +30% for road infrastructure
Emission factor = 2.36 kg of CO2 per L
Carbon uptake = 1.3 tonne/ha
Molecular weight CO_2 & C = 44 & 12

- Energy Land (C production)

$$= \frac{9\ L}{100\ km} x\ \left(2.36x10^{-3}\ tonne\ \frac{CO2}{L}\right) \text{x}\ (1 + 0.15 + 0.30) = 3.08\text{x}10^{-4}\ \text{tonne}\ \frac{\text{CO2}}{\text{km}}$$

$$= \left(3.08x10^{-4} tonne\ \frac{CO2}{km}\right) x\ \left(\frac{12\ C}{44\ CO2}\right) = 0.84x10^{-4} tonne\ \frac{C}{km}$$

Physical Land required to uptake this carbon

$$= 0.84x10^{-4} tonne\ \frac{C}{km} / \ 1.3\ tonne\ \frac{C}{ha} = 6.50x10^{-5}\ \text{ha/km}$$

Ecological Footprint of Energy Land = $6.50x10^{-5}$ ha/km x **1.84 (Energy land)** = **1.2x10^-4 gha**

It is estimated that cars use 86% of the 258,000 ha of road space in Australia. In total, all Australians travel a distance of 72.4 billion km by car. Calculate the ecological footprint for Robert car travel to and from Uni?

Car use = 86% of 258,000 ha road space
Total Australians car travel distance = 72.4 billion km

- Built-up Land:

$$Total\ car\ use\ land = \frac{258000\ (ha)x\ 0.86}{72.4x10^{9}(km)} = 3.1x10^{-6}ha/km$$

$$Ecological\ Footprint\ of\ Built-up\ Land = (3.1x10^{-6})(2.17) = 7x10^{-6}gha$$

- Total Ecological Footprint = EF(energy) + EF(built-up)

$= (1.2x10^{-4})+(7x10^{-6}) = 1.27x10^{-4}\ gha\ per\ car\ km\ travelled$

- Robert's Footprint

$= (1.27x10^{-4})$x(20km)x(2 times a day)x(5days a week)x(52 weeks in a year)
$= \mathbf{1.32\ gha\ per\ year}$

QUESTION 4:

On average, each year Robert consumes 48 kg of fruit and vegetable, 36 kg of bread, 48 kg of rice and cereals, 72 kg of milk, 36 kg of cheese and butter, 24 kg of white meat (pork, poultry, etc), and 24 kg of red meat (beef, lamb, etc), 12 kg of fish, 12 kg of wine, and 1 kg of tea and coffee. The following table provide unscaled footprint data for each component. Calculate the ecological footprint of Robert's diet (food only).

Component	Equivalence factor
Cropland	2.17
Forest	1.35
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Categories	Consumed (kg/yr)	Energy (m^2/kg)	Crop (m^2/kg)	Pasture (m^2/kg)	Sea (m^2/kg)	Energy (m^2/yr)	Crop (m^2/yr)	Pasture (m^2/yr)	Sea (m^2/yr)
Fruit & vegetable	48	0.5	0.6			24	28.8	0	0
Bread	36	2	2.4			72	86.4	0	0
Rice & cereals	48	1	3.6			48	172.8	0	0
Milk	72	1		20		72	0	1440	0
Cheese & butter	36	6.5		200		234	0	7200	0
White meat	24	8	22			192	528	0	0
Red meat	24	8		300		192	0	7200	0
Fish	12				550	0	0	0	6600
Wine	12	0.4	1			4.8	12	0	0
Tea & coffee	1	7.5	17.7			7.5	17.7	0	0
Total						846.3	845.7	15840	6600

- Ecological footprint = Σ (Energy, cropland, pasture, sea)

= 846.3(**1.84**) + 845.7(**2.17**) + 15,840(**0.47**)

+ 6,600(**0.06**) = 11,233 (global m^2) = 1.12 (gha)

QUESTION 5:

Data provided by a utilities company show that the distribution 1 ML of water to end users in a typical city setting will result in the emission of approximately 370 kg of CO2. The current average water consumption in Wollongong is 80 ML per day. The uptake of carbon by Australian forest is 1.3 tonne/ha. The atomic mass of C and O are 12 and 16 g/mole. Calculate the **ecological footprint of water distribution for Wollongong**?

Drinking water supply to Wollongong is from Avon Dam. The lake area is 10.5 km2 and the catchment of Avon Dam is 142 km2. **How does your result compare to the physical catchment required to supply drinking water to Wollongong?**

Emission = 370 kg CO_2 per 1 ML water
Consumption = 80 ML per day
Carbon uptake = 1.3 tonne/ha
- Atomic mass of C and O = 12 & 16 g/mol

Calculate the ecological footprint of water distribution for Wollongng?

- CO2 emission from 80 mL of water transmission

  = 80 tonne x 370 kg CO2 = 29.6 tonne CO2 per day x (12 mC/ 44 CO2) = 8.073 tonne C/day

  Land for Carbon uptake = $\frac{8.073\ tonne\ C/day}{1.3\frac{tonne}{ha}} = 6.21\frac{ha}{day}\ x\ 365\frac{days}{year} = 2267\frac{ha}{year}$

- Ecological Footprint = 2267 x 1.84 = **4171 gha/year** = **41.71 global km2/year**

1 hectare = 0.01 km2

QUESTION 6:

The World Energy Council reports that processing virgin paper requires 25 GJ per tonne. If this energy is from a standard mix of fossil fuel, CO2 emission is 0.2 tonne of CO2/GJ. In addition, the average energy required for the transportation of virgin paper is 69.3 kg CO2/tonne. Assume that 1 ha of forest can produce 2.6 tonne of wood. In general, it takes 1.8 tonnes of wood to produce 1 tonne of virgin paper. A typical newspaper weighs 200 g.

a. Calculate the ecological footprint of a newspaper?

$$Energy\ land\ (processing) = \frac{\left(\left(25\frac{GJ}{tonne}\right)x\left(0.2\ \frac{tonne\ CO2}{GJ}\right)x\ \left(\frac{12\ C}{44\ CO2}\right)\right)}{1.3\frac{tonne}{ha.C}} = 1.05\ ha/tonne$$

$$Energy\ land\ (transport) = \frac{\left((69.3x10^{-3}\ CO2)x\left(\frac{12\ C}{44\ CO2}\right)\right)}{1.3\frac{tonne}{ha.C}} = 0.015\ ha/tonne$$

$$Forest\ land\ (produce\ wood) = \frac{1.8\frac{tonnes}{tonne\ of\ paper}}{2.6\frac{tonnes}{ha}} = 0.69\ ha/tonne\ of\ paper$$

$$Global\ space = (1.05 + 0.015)(1.84) + (0.69)(1.35) = 2.89\ \frac{gha}{tonne}$$

$$\boldsymbol{Ecological\ Footprint} = \left(\mathbf{200x10^{-3}kg\ x\ 0.001\ \frac{tonne}{kg}}\right)\left(\frac{\mathbf{2.89\ \frac{gha}{tonne}\ x\ 0.01\ \frac{km2}{ha}}}{\mathbf{1x10^{-6}\ \frac{m2}{km}}}\right)$$

$$= \mathbf{5.78\ global\ m2}.$$

b. Recycled paper uses only 30% of the energy required for virgin paper production and transportation. Calculate ecological footprint of a newspaper made of 100% recycled paper.

Recycled paper uses 30% of energy required for virgin paper production and transportation.

Calculate the ecological footprint of 100% recycled newspaper.

- Since recycled paper is used, forest land footprint to produce wood for the production of paper is zero.

Global energy land:

$$= 0.3 \times (1.05 + 0.015) \times 1.84 = 0.59 \text{ (gha/tonne)}$$

Ecological footprint for 1 newspaper:

$$= 200\text{x}10^{-6} \times 0.59\text{x}10^{4} = \underline{1.18 \text{ (global m}^2\text{)}}$$

- $\boldsymbol{Ecological\ Footprint = \left(200x10^{-3}kg\ x\ 0.001\ \frac{\text{tonne}}{\text{kg}}\right)\left(\frac{0.59\frac{\text{gha}}{\text{tonne}}\text{x}\ 0.01\frac{\text{km2}}{\text{ha}}}{1\text{x}10^{-6}\frac{\text{m2}}{\text{km}}}\right) =}$

  1.18 global m2.