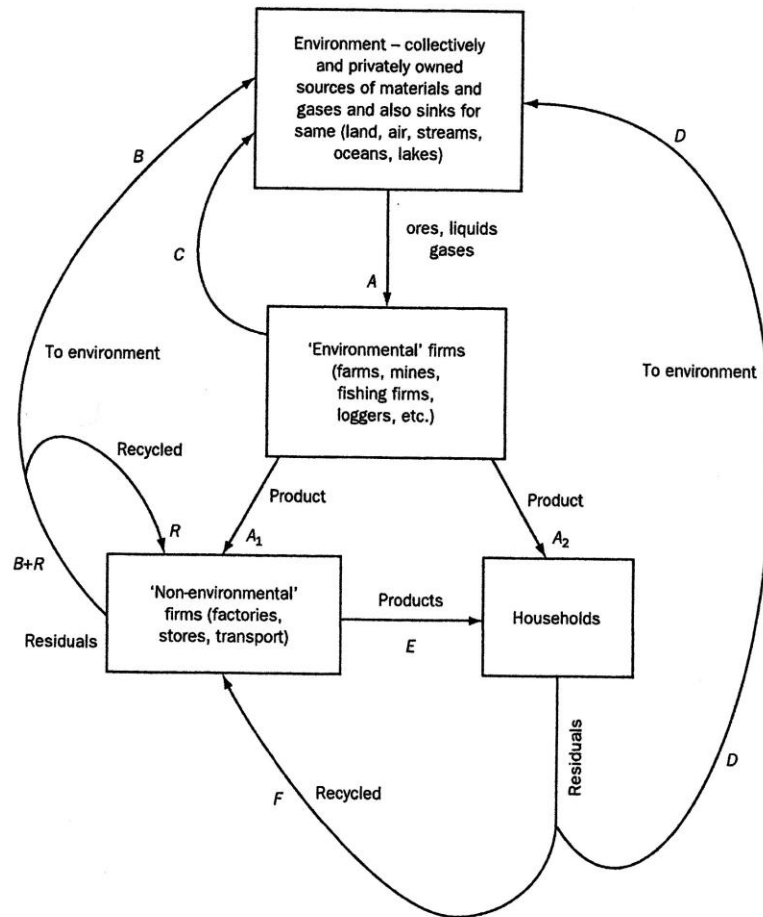


The materials balance principle



Referred to by economists as the **Law of Conservation of Mass**. It says that **matter can be neither created nor destroyed, just transformed** from one state to another.

The environment $B+C+D \equiv A$

Environmental firms $A \equiv A_1+A_2+C$

Non-environmental firms $R+A_1+F \equiv B+R+E$

Households $A_2+E \equiv D+F$

Figure 2.2 A materials balance model of economy–environment interactions
Source: Adapted from Herfindahl & Kneese (1974)

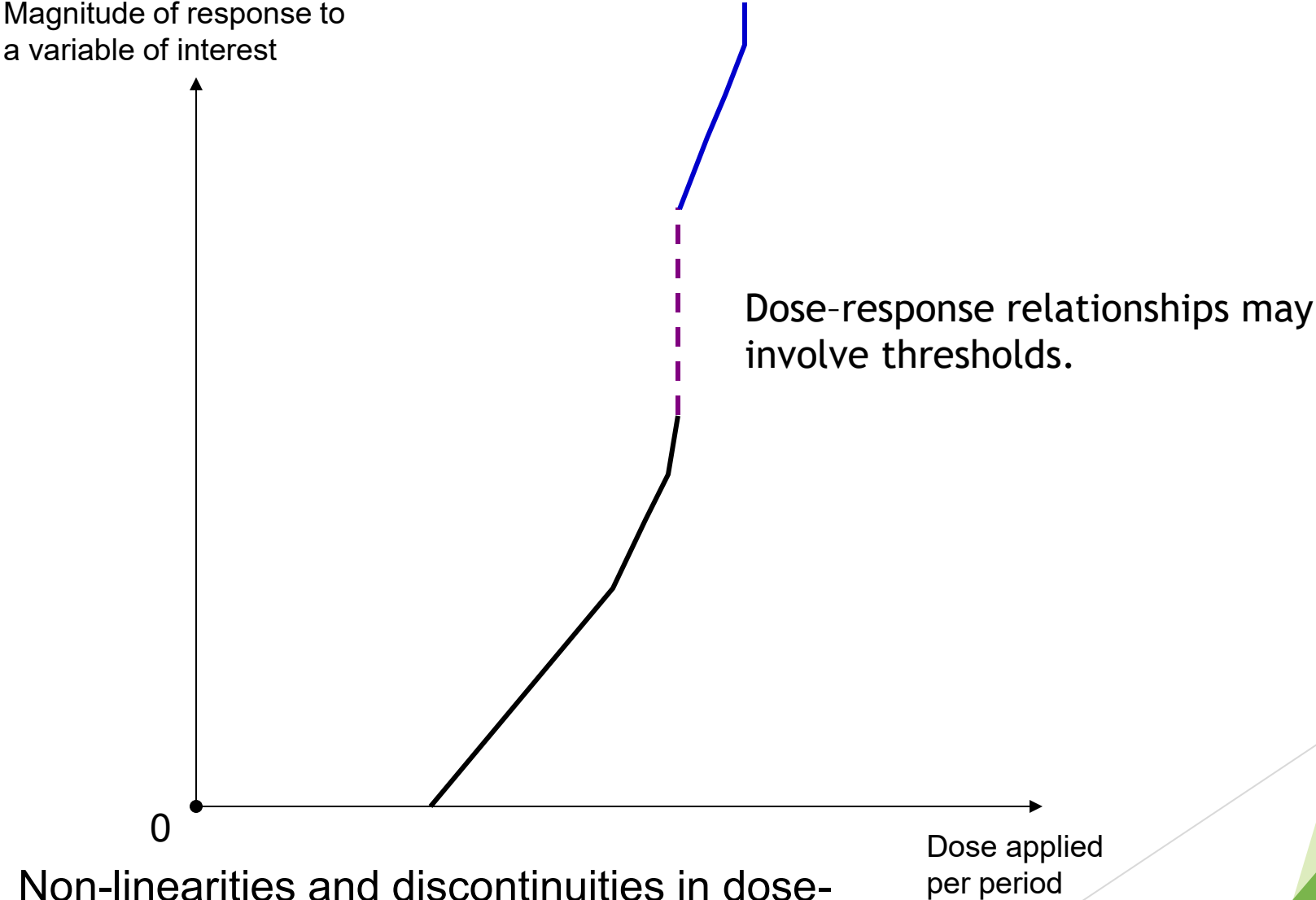
In terms of mass, and ignoring lags due to accumulation in the economy, environmental extractions equal insertions, resource input equals waste flow.

Stability and resilience

Holling (1973, 1986)

- ▶ **Stability:** a property of a population comprised in an ecosystem
 - ▶ Is the propensity of a population to return to some kind of equilibrium following a disturbance.
- ▶ **Resilience:** a property of the ecosystem
 - ▶ Is the propensity of an ecosystem to retain its functional and organizational structure following a disturbance.
- ▶ The fact that an ecosystem is resilient does not necessarily imply that all of its component populations are stable.
 - ▶ A disturbance can result in a population disappearing from an ecosystem while the ecosystem as a whole continues to function in broadly the same way, so exhibiting resilience.

Stability and resilience



Non-linearities and discontinuities in dose-response relationships

Ecological footprint

- ▶ Measures the ecological impact of the human species.
- ▶ According to Wackernagel and Rees (1997) it is:
 - ▶ *“the aggregate area of land and water needed to produce all the resources consumed, and to absorb all the wastes generated on a continuing basis, using prevailing technology.”*
- ▶ It varies with technology as well as with levels and patterns of production and consumption.

Ecological footprint

- ▶ Wackernagel *et al.* (2002) estimated that it would require 1.2 earths, or one earth for 1.2 years, to regenerate what humanity used in 1999.
- ▶ <https://www.footprintnetwork.org/> currently humans use as many ecological resources as if we lived on 1.75 Earths.



Ecological footprints



<https://www.footprintcalculator.org/home/en>



SUMMARY FACT AND FIGURES HOW DO YOU FEEL EXPLORE YOUR DATA SOLUTIONS


RESULTS


Your personal Earth Overshoot Day is:

01. Apr

If everyone lived like you, we would need

4 Earths



Why can't I get my Footprint score within the means of one planet? 

[See Details](#)

The image shows the results page of the Ecological Footprint calculator. It has a dark teal background with a starry pattern. At the top, there are navigation tabs: 'SUMMARY' (highlighted in orange), 'FACT AND FIGURES', 'HOW DO YOU FEEL', 'EXPLORE YOUR DATA', and 'SOLUTIONS'. The main heading is 'RESULTS'. Below it, it says 'Your personal Earth Overshoot Day is: 01. Apr' with an information icon. Then it says 'If everyone lived like you, we would need 4 Earths' with another information icon. Below this text are four small 3D globes of Earth. At the bottom, there is a question 'Why can't I get my Footprint score within the means of one planet?' with an information icon, and an orange button labeled 'See Details'.

Ecological footprint

Humanity's Ecological Footprint by land use

Key

- Grazing land footprint
- Forest product footprint
- Fishing grounds footprint
- Cropland footprint
- Built-up land footprint
- Carbon footprint

Humanity's Ecological Footprint by activities

Key

- Food
- Housing
- Personal transportation
- Goods
- Services

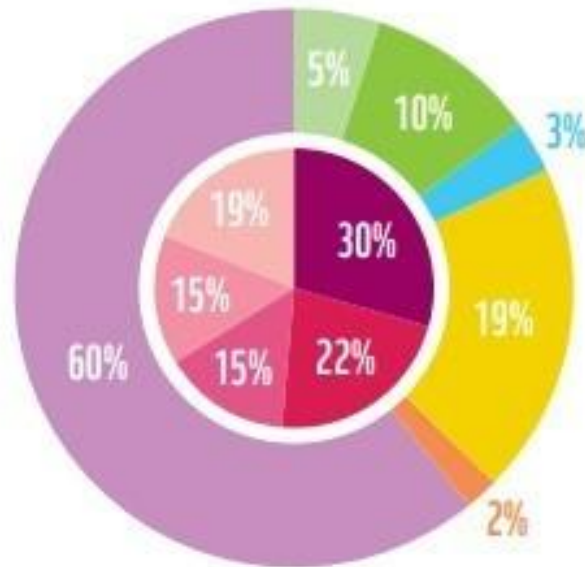
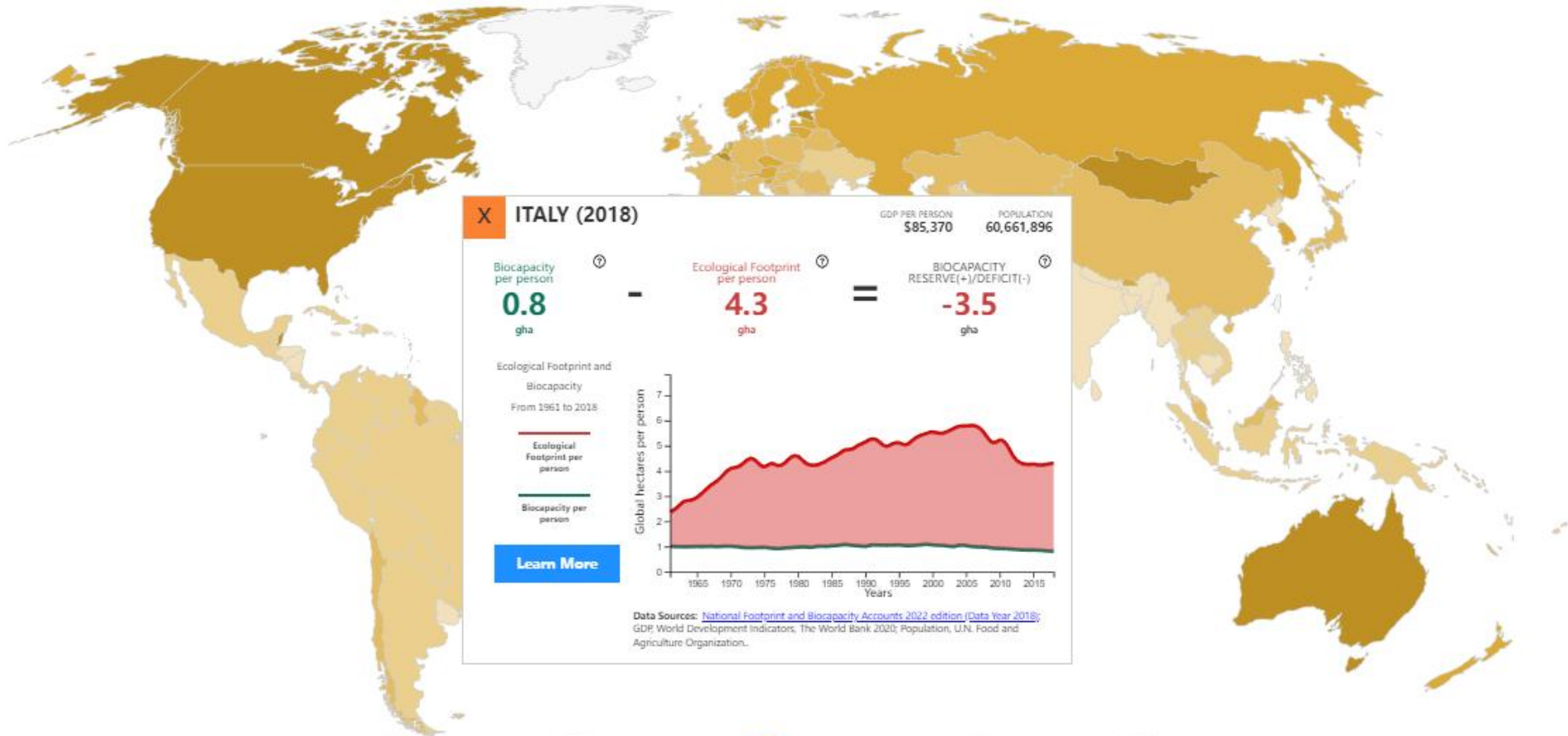


Figure 13: Humanity's Ecological Footprint by land use and by activities
 The Ecological Footprint measures how much demand human consumption places on the biosphere and compares it to what ecosystems can renew. In 2020, the world average Footprint amounts to 2.5 global hectares per person, compared to 1.6 global hectares of biocapacity. The Footprint can be broken down by area categories (outer circle) or, using Multi-Regional Input-Output Assessments, by activity fields (inner circle) ^{185, 186, 187, 188, 189}.



X ITALY (2018)

GDP PER PERSON: \$85,370 POPULATION: 60,661,896

Biocapacity per person: **0.8** gha

Ecological Footprint per person: **4.3** gha

BIOCAPACITY RESERVE(+)/DEFICIT(-): **-3.5** gha

Ecological Footprint and Biocapacity From 1961 to 2018

Global hectares per person

Years: 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015

[Learn More](#)

Data Sources: [National Footprint and Biocapacity Accounts 2022 edition \(Data Year 2018\)](#); GDP World Development Indicators; The World Bank 2020; Population, U.N. Food and Agriculture Organization.

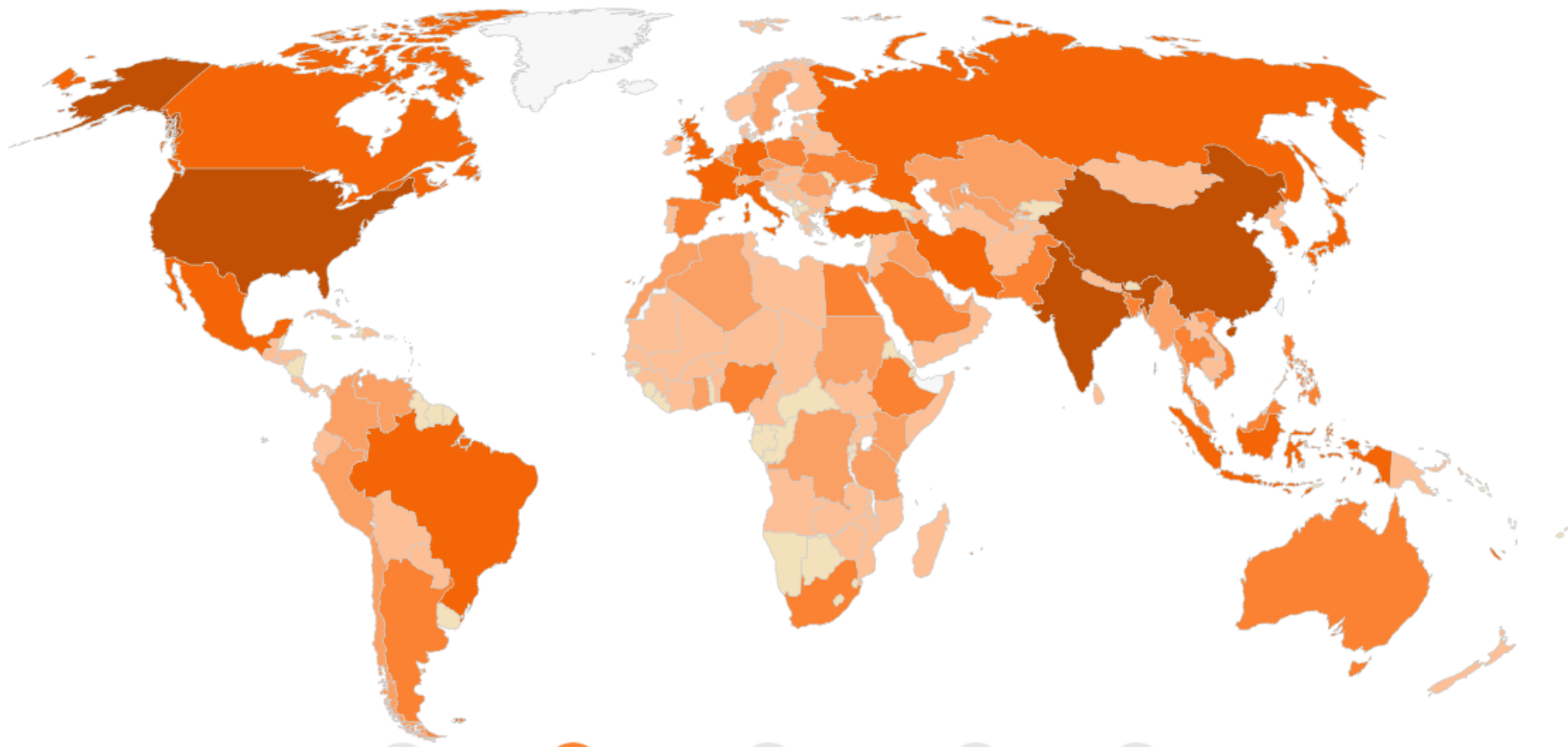
- ECOLOGICAL DEFICIT/RESERVE
- TOTAL ECOLOGICAL FOOTPRINT
- ECOLOGICAL FOOTPRINT PER PERSON
- TOTAL BIOCAPACITY
- BIOCAPACITY PER PERSON

ECOLOGICAL FOOTPRINT PER PERSON

The Ecological Footprint per person is a nation's total Ecological Footprint divided by the total population of the nation. To live within the means of our planet's resources, the world's Ecological Footprint would have to equal the available biocapacity per person on our planet, which is currently 1.6 global hectares. So if a nation's Ecological Footprint per person is 6.4 global hectares, its citizens are demanding four times the resources and wastes that our planet can regenerate and absorb in the atmosphere.

ECOLOGICAL FOOTPRINT PER PERSON OF COUNTRY'S POPULATION (in global hectares)

- > 6.7
- 5.1 - 6.7
- 3.4 - 5.1
- 1.7 - 3.4
- < 1.7




 ECOLOGICAL
 DEFICIT/RESERVE


 TOTAL ECOLOGICAL
 FOOTPRINT








 ECOLOGICAL FOOTPRINT
 PER PERSON

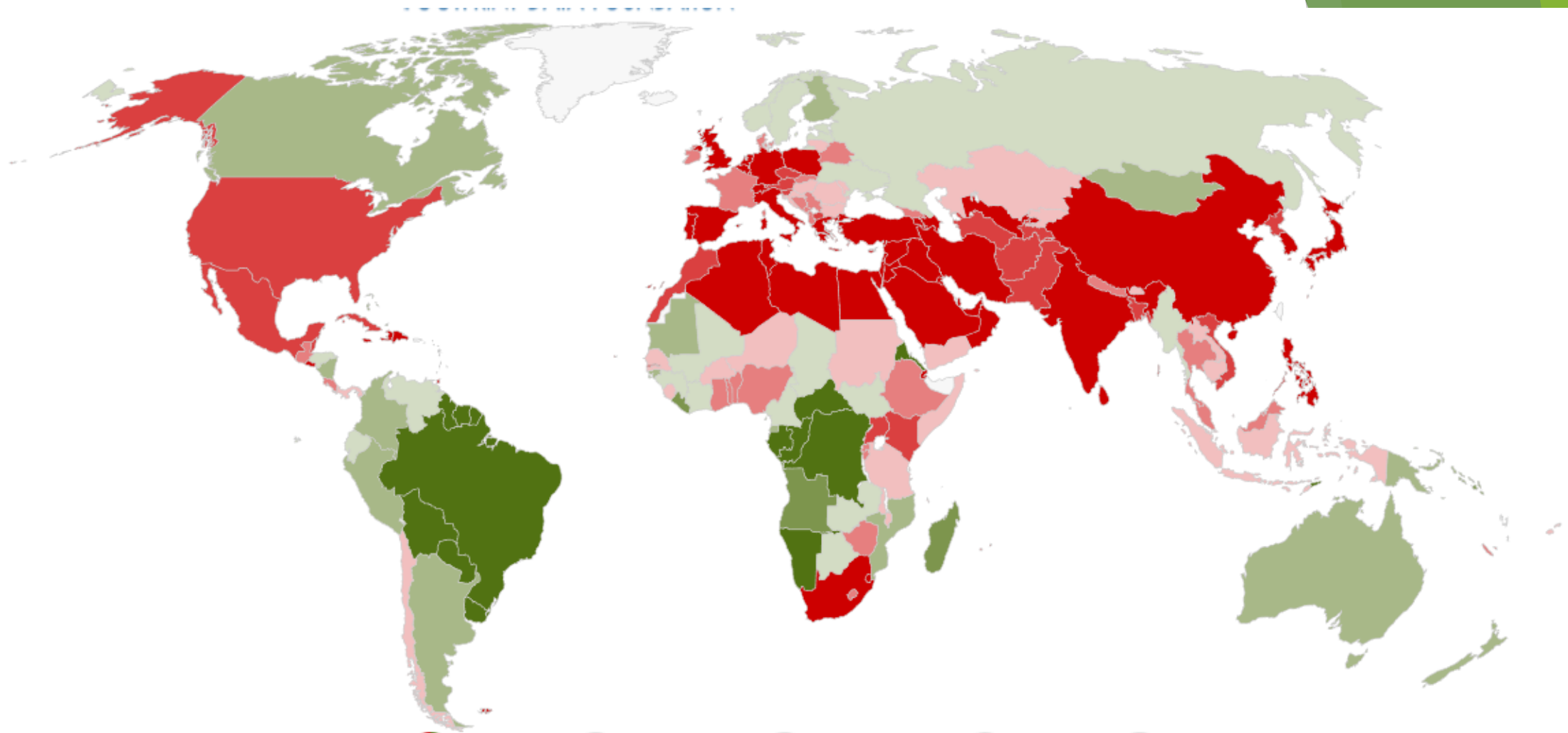

 TOTAL BIOCAPACITY


 BIOCAPACITY
 PER PERSON

ECOLOGICAL FOOTPRINT
 The Ecological Footprint measures how much demand human consumption places on the biosphere. It is measured in standard units called global hectares.

TOTAL ECOLOGICAL FOOTPRINT OF COUNTRY'S POPULATION (in global hectares)

						
> 1B	250M - 1B	100M - 250M	50M - 100M	25M - 50M	10M - 25M	< 10M



ECOLOGICAL DEFICIT/RESERVE



TOTAL ECOLOGICAL FOOTPRINT



ECOLOGICAL FOOTPRINT PER PERSON



TOTAL BIOCAPACITY



BIOCAPACITY PER PERSON

ECOLOGICAL DEFICIT/RESERVE

An ecological deficit occurs when the Ecological Footprint of a population exceeds the biocapacity of the area available to that population. A national ecological deficit means that the nation is importing biocapacity through trade, liquidating national ecological assets or emitting carbon dioxide waste into the atmosphere. An ecological reserve exists when the biocapacity of a region exceeds its population's Ecological Footprint.

BIOCAPACITY CREDITORS

BIOCAPACITY GREATER THAN FOOTPRINT



>150%



100% - 150%



50% - 100%



50% - 0%

BIOCAPACITY DEBTORS

FOOTPRINT GREATER THAN BIOCAPACITY



>150%



100% - 150%



50% - 100%



50% - 0%

Biodiversity

- ▶ *Biodiversity*: the number, variety, and variability of all living organisms in terrestrial, marine, and other aquatic ecosystems and the ecological systems they are parts of.
- ▶ Biodiversity is intended to capture two dimensions:
 1. the number of biological organisms
 2. their variability

Levels of Biodiversity

There are three levels at which biodiversity can be considered:

- ▶ **Population:**
 - ▶ genetic diversity within the populations that constitute a species, is important as it affects the evolutionary and adaptive potential of the species, and so we might measure biodiversity in terms of the **number of populations**.
- ▶ **Species:**
 - ▶ we might wish to measure biodiversity in terms of the **number of distinct species** in particular locations, the extent to which a species is endemic (unique to a specific location), or in terms of the diversity of species.
- ▶ **Ecosystems:**
 - ▶ in many ways, the diversity of ecosystems is the most important measure of biodiversity; unfortunately, there is **no universally agreed criterion** for either defining or measuring biodiversity at this level.

Importance of biodiversity

- ▶ Carbon cycling, soil fertility maintenance, climate and surface temperature regulation, and watershed flows.
- ▶ The diversity of flora and fauna contributes to amenity services.
- ▶ Flora and fauna are the sources of many useful products, particularly pharmaceuticals, foods, and fibers.
- ▶ Biodiversity is the basis for crop and livestock variability and the development of new varieties.

Importance of biodiversity

- ▶ Ecologists see the greatest long-term importance of biodiversity in terms of **ecosystem resilience** and **evolutionary potential**.
- ▶ Diverse gene pools represent a form of insurance against ecological collapse:
 - ▶ the greater the extent of diversity, the greater the capacity for stress adaptation and the maintenance of the ecosystem's organizational and functional structure.

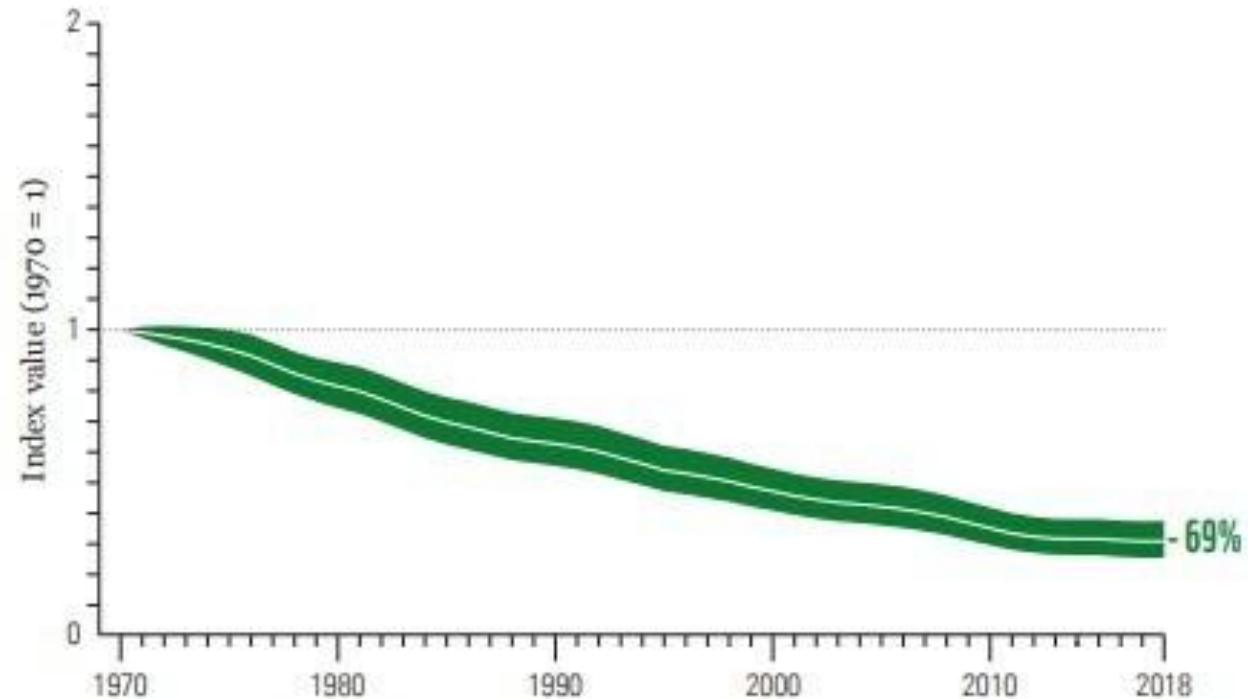
Biodiversity loss

Figure 3: The global Living Planet Index (1970 to 2018)

The average change in relative abundance of 31,821 populations, representing 5,230 species monitored across the globe, was a decline of 69%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% statistical certainty, range 63% to 75%).
Source: WWF/ZSL (2022)¹⁰⁴.

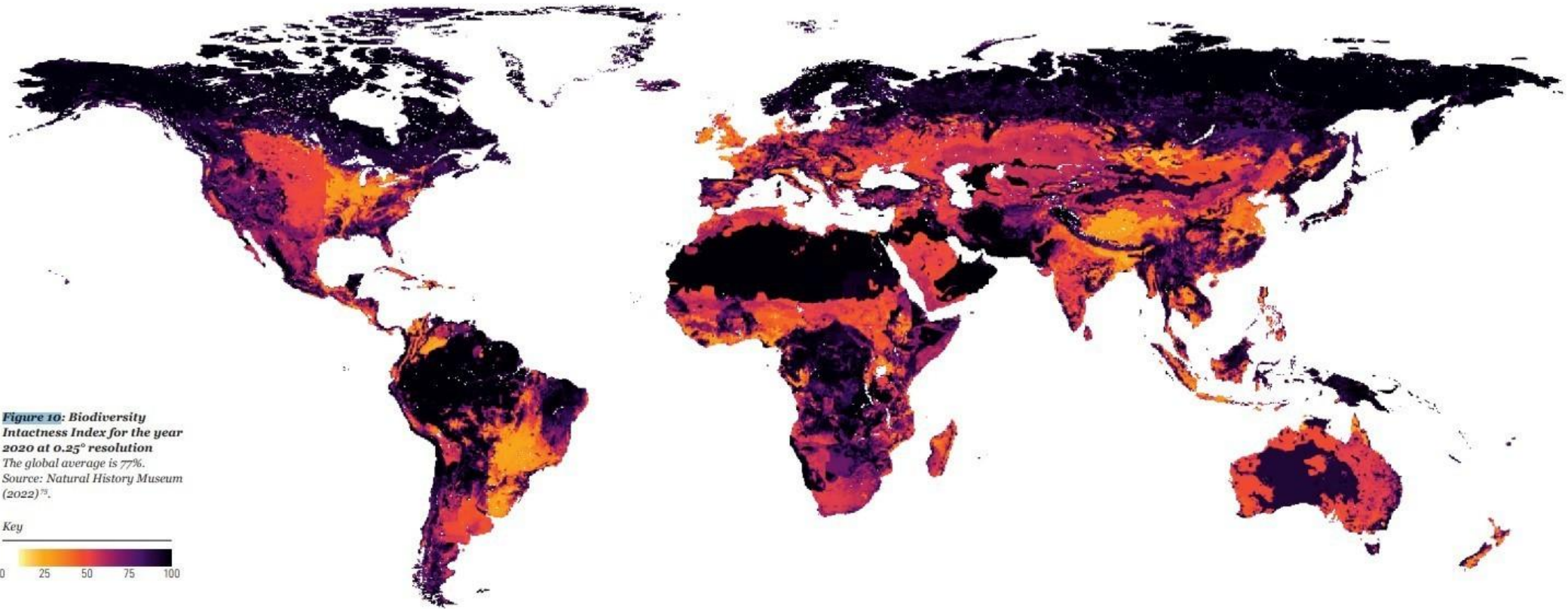
Key

- Global Living Planet Index
- Confidence limits



<https://www.weforum.org/agenda/2022/10/nature-loss-biodiversity-wwf/>

Biodiversity loss



The drivers of environmental impact

The **environmental impact** of economic activity can be looked at in terms of:

- ▶ **extractions from** the environment
- ▶ **insertions into** the environment

The drivers of environmental impact

In either case, the immediate determinants of the total level of impact are:


- ▶ the **size of the human population** and
- ▶ the **per capita impact**.

The per capita impact depends on:

- ▶ how much **each individual consumes**, and
- ▶ the **technology of production**.

The IPAT identity

- ▶ A simple but useful way to start thinking about what drives the size of the economy's impacts on the environment.
- ▶ It can be formalized as the IPAT identity:

$$I = P \times A \times T \qquad I \equiv P \times \frac{\text{GDP}}{P} \times \frac{\text{Resource Use}}{\text{GDP}}$$


I: impact, measured as mass or volume

P: population size

A: per capita affluence, in currency units

T: technology, amount of the resource used or waste generated per unit of production

An illustration of IPAT

	P	A	T	I
	(billions)	(PPP US \$)	(GHG tons per \$)	(billions of tons)
Current	7,8	22.555	0,00039	

An illustration of IPAT

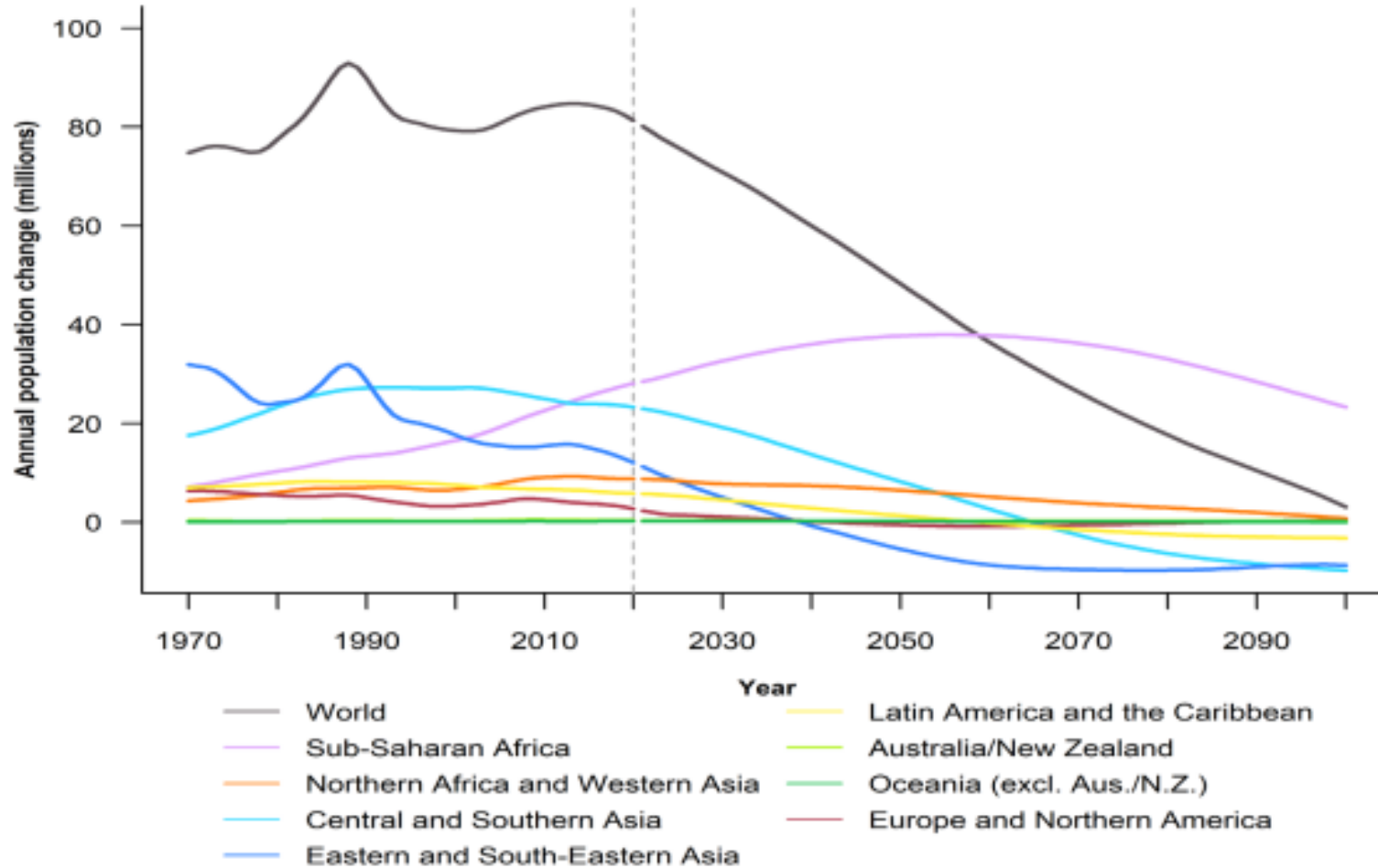
- ▶ Find the current values for P, A, and T and calculate the value of I
- ▶ Assume that P increases by 50%, calculate the value of I
- ▶ Assume that also A increases but by 100%, calculate the value of I
- ▶ What should be the value of T given the changes of P and A to keep I at its initial value?

An illustration of IPAT

	P	A	T	I
	(billions)	(PPP US \$)	(GHG tons per \$)	(billions of tons)
Current	7,8	22.555	0,00039	68,6
P x 1.5	11,7	22.555	0,00039	102,9
P x 1.5 and A x 2	11,7	45.110	0,00039	205,8
P x 1.5 and A x 2 with I at current	11,7	45.110	0,00013	68,6

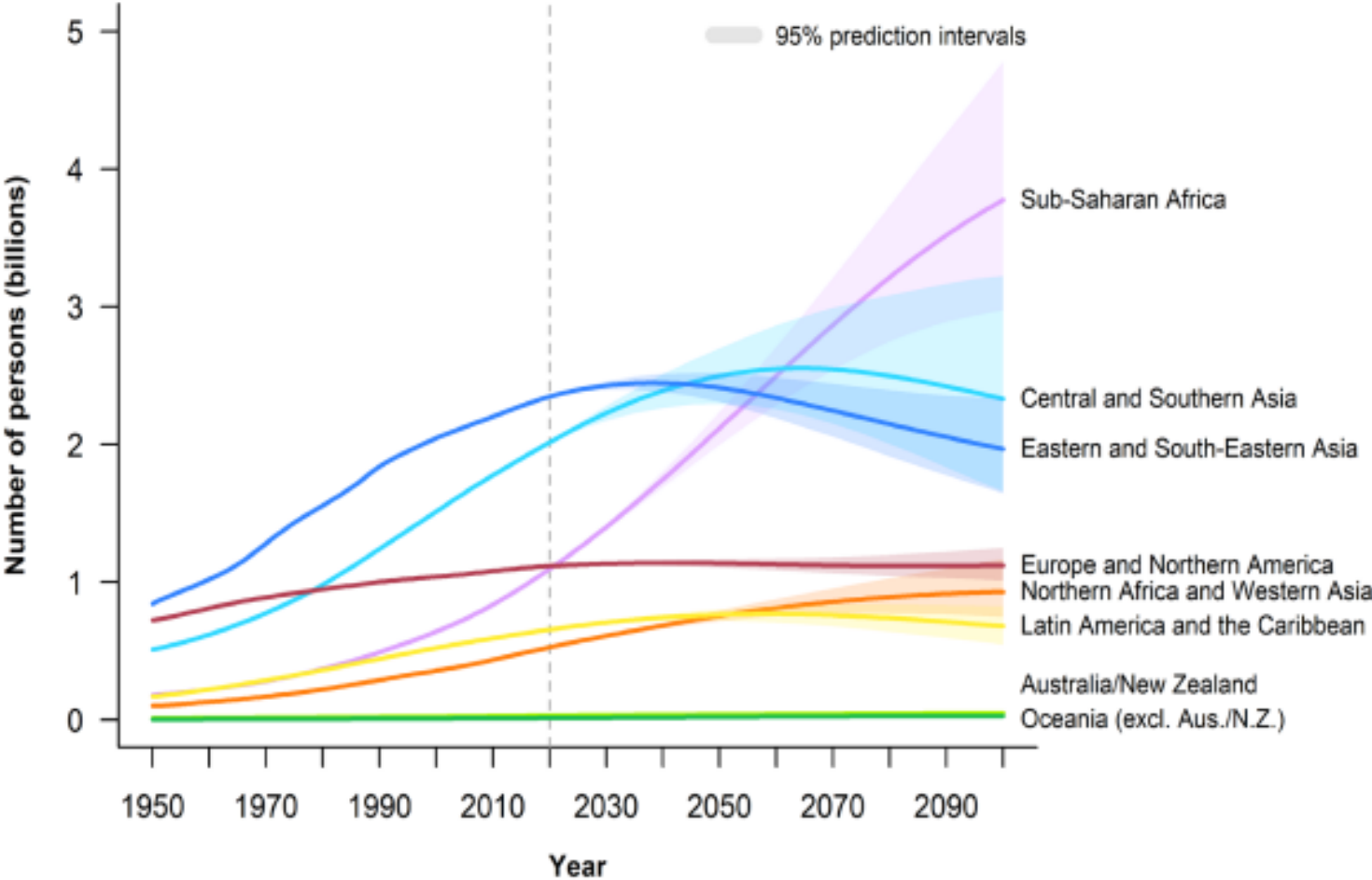
Population (annual change)

Annual population change: estimates, 1970-2020, and projections, 2020-2100, world and regions



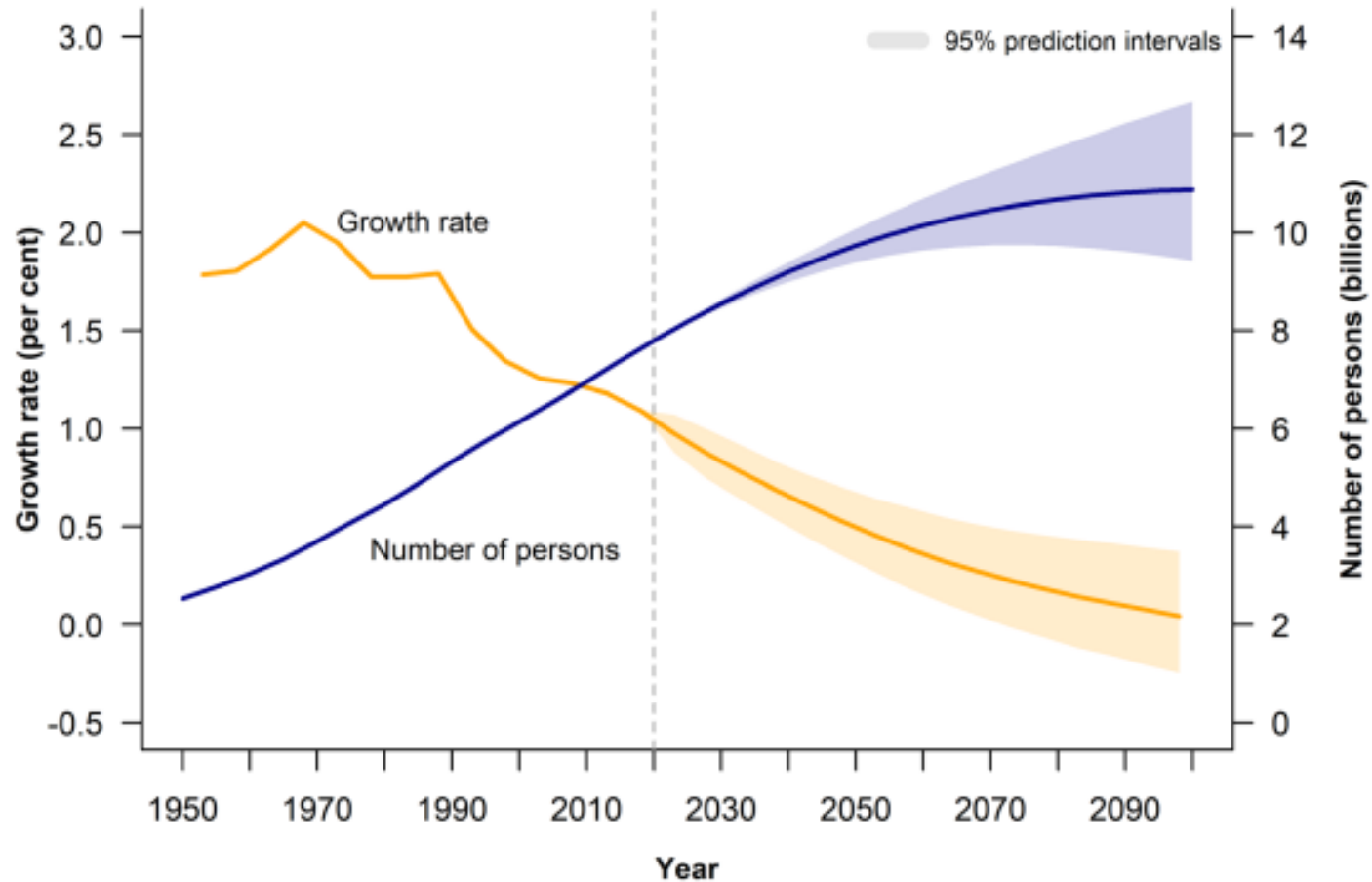
Population (size)

Population estimates, 1950-2020, and projections with prediction intervals, 2020-2100, by region



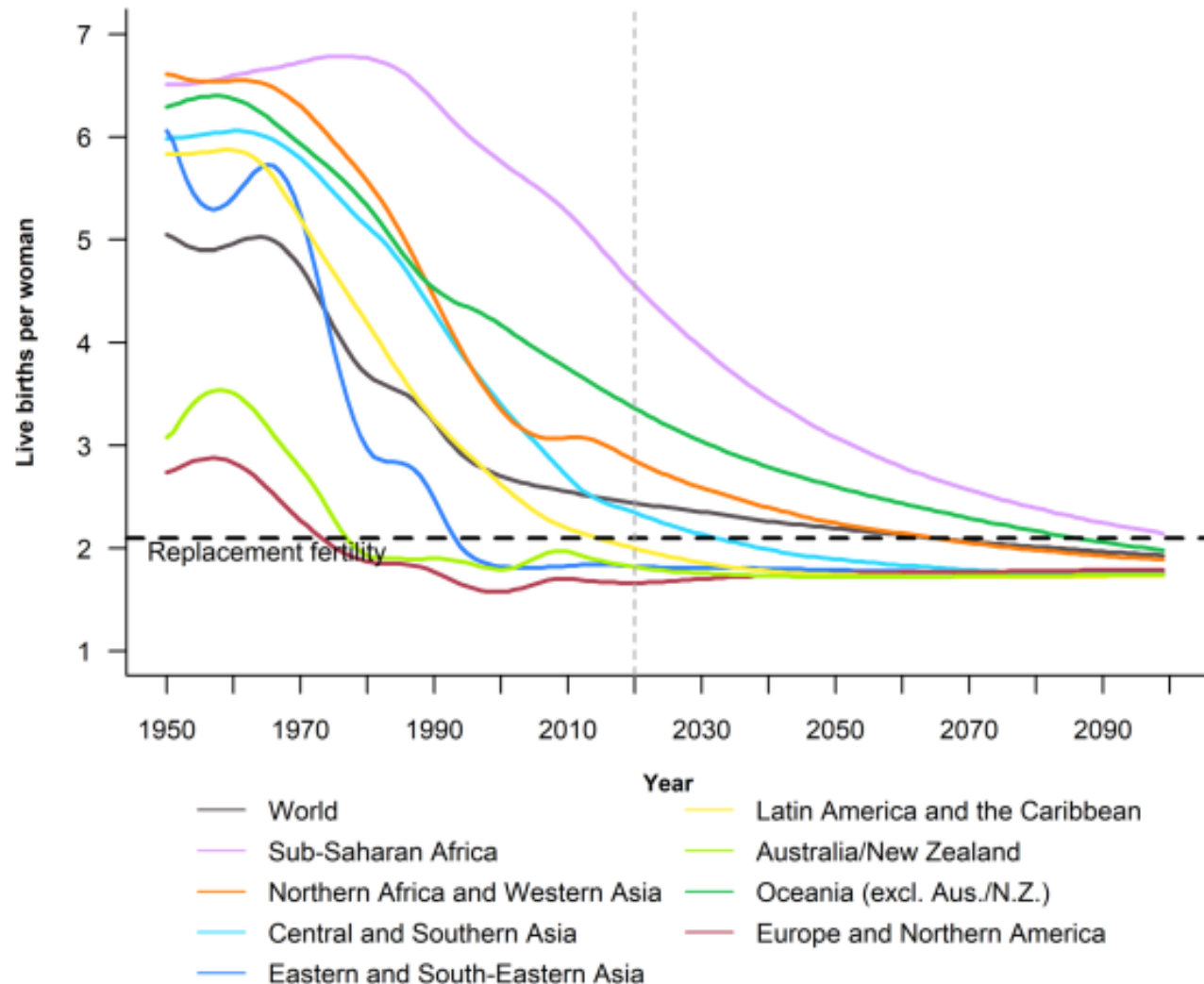
Population (global rate and size)

Global population size and annual growth rate: estimates, 1950-2020, and projections with prediction intervals, 2020-2100

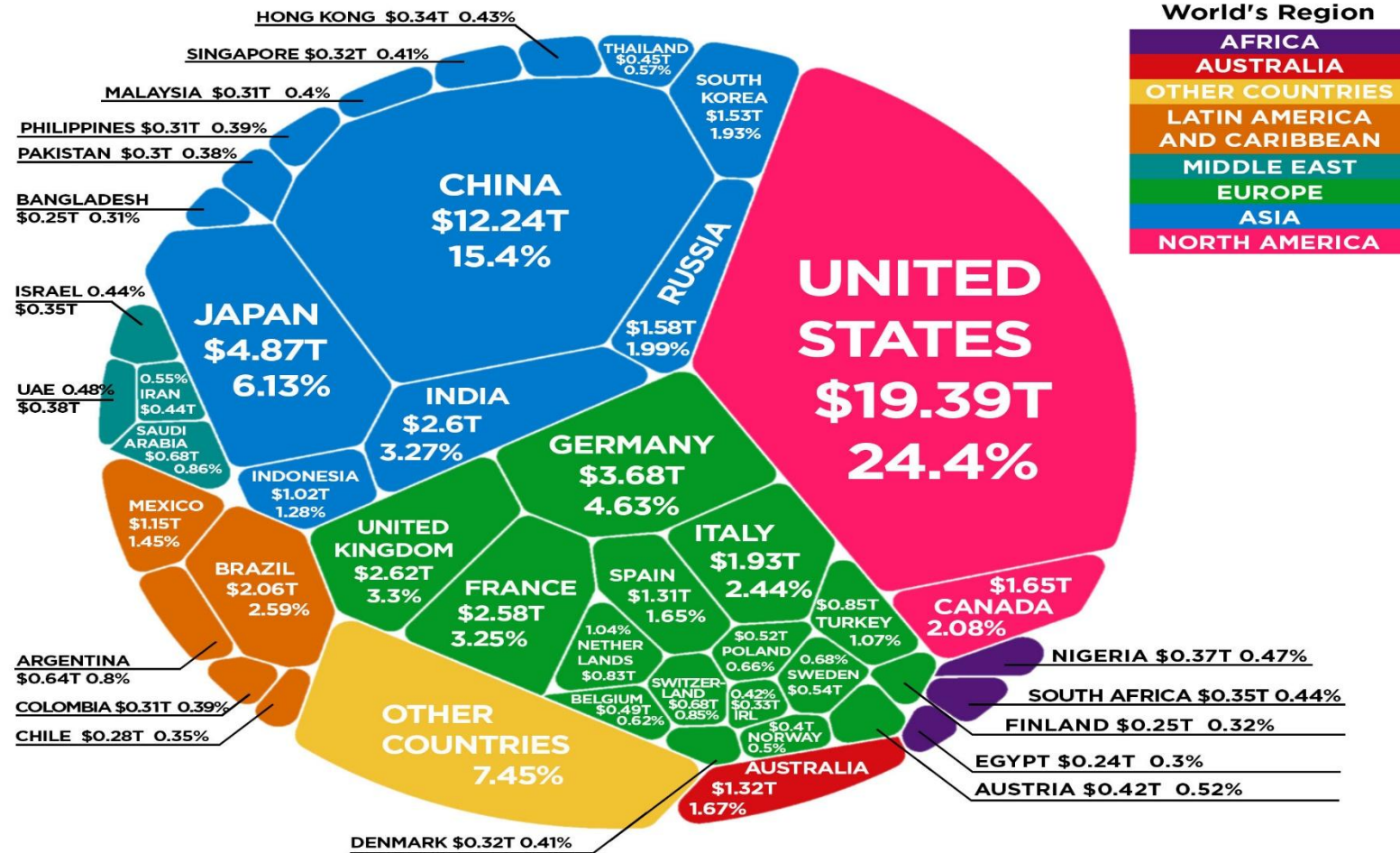


Population (fertility rate)

Total fertility rate: estimates, 1950-2020, and projections, 2020-2100, world and regions



Affluence - GDP (\$ trillion)

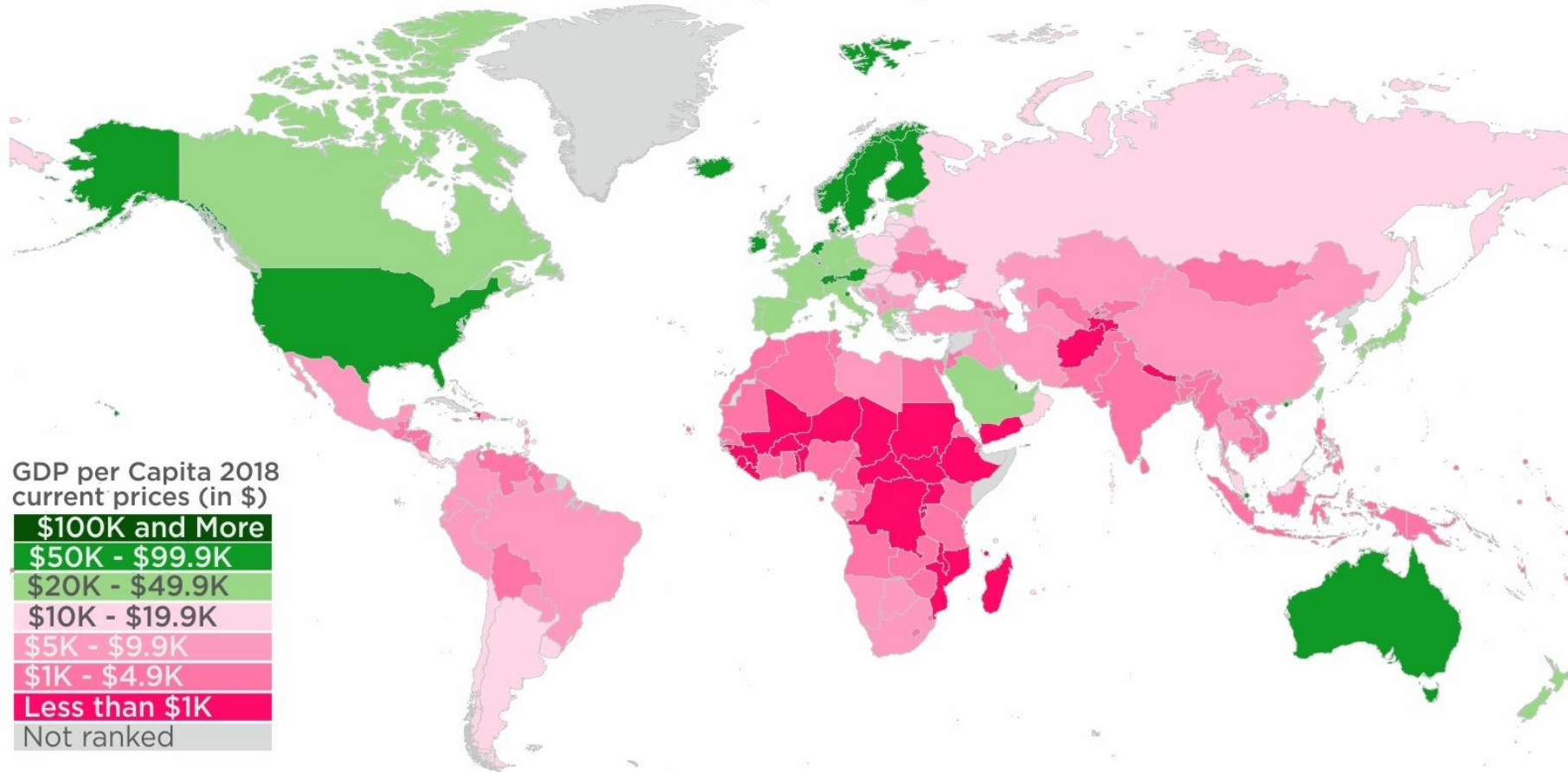


Article and Sources:

<https://howmuch.net/articles/the-world-economy-2017>
<http://databank.worldbank.org/data/download/GDP.pdf>

Affluence - GDP per capita

Gross Domestic Product (GDP) per Capita Around the World 2018



Article & Sources:

<https://howmuch.net/articles/gdp-per-capita-2018>
International Monetary Fund - World Economic Outlook (October 2018)

howmuch net

<https://howmuch.net/articles/gdp-per-capita-2018>

Technology

Energy use is of particular interest for 3 reasons

1. Moving and transforming matter – **work** - requires energy. The level of energy use varies directly with work done, and so is a good proxy for overall environmental impact
2. In modern economies, about 90% of energy use is based on **fossil fuel combustion**. Fossil fuels are non-renewable resources that cannot be recycled.
3. About 80% of anthropogenic **CO₂ emissions** arise from fossil fuel combustion. CO₂ is by far the most important of the greenhouse gases driving climate change, which is the most important environmental problem facing the world today.

The demographic transition

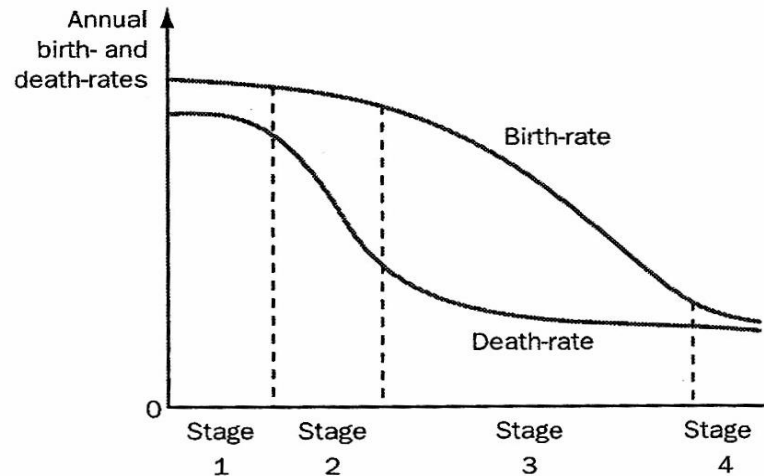


Figure 2.6 The theory of demographic transition

The theory of demographic transition is an attempt to explain the observed negative correlation between income level and population growth rate.

Stage 1. Low-income economy with high birth and death rates

Stage 2. With rising real incomes, nutrition and public health measures improve, leading to a falling death rate and rapid population growth.

Stage 3. Due to

increasing costs of child-rearing

reduced benefits of large family size

increasing opportunity costs of home employment

improved economic and social status of women

the birth rate falls and the rate of population growth declines

Stage 4. High-income economy with equal and low birth and death rates, and constant population size