Introduction to Environmental Sciences

EES 102

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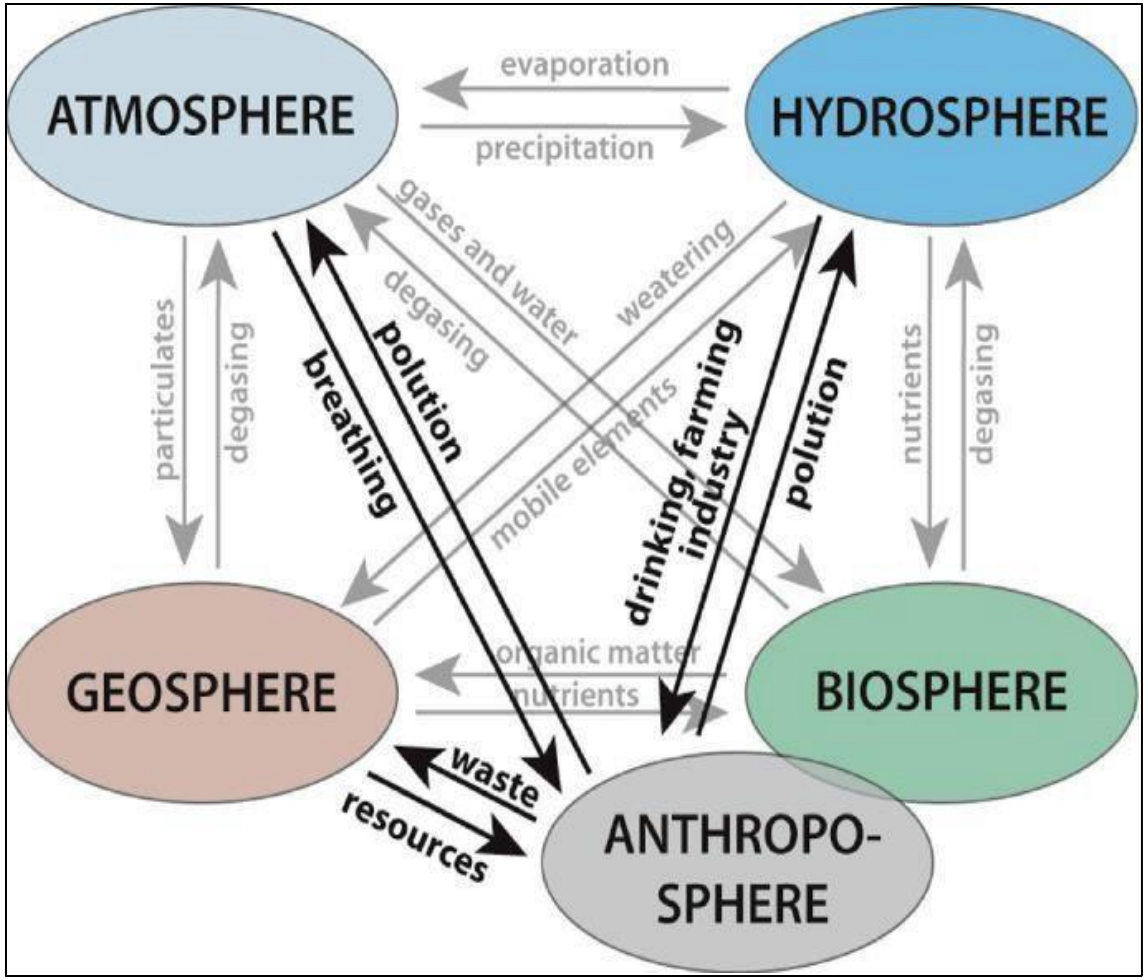
7-8/1/2025, L5

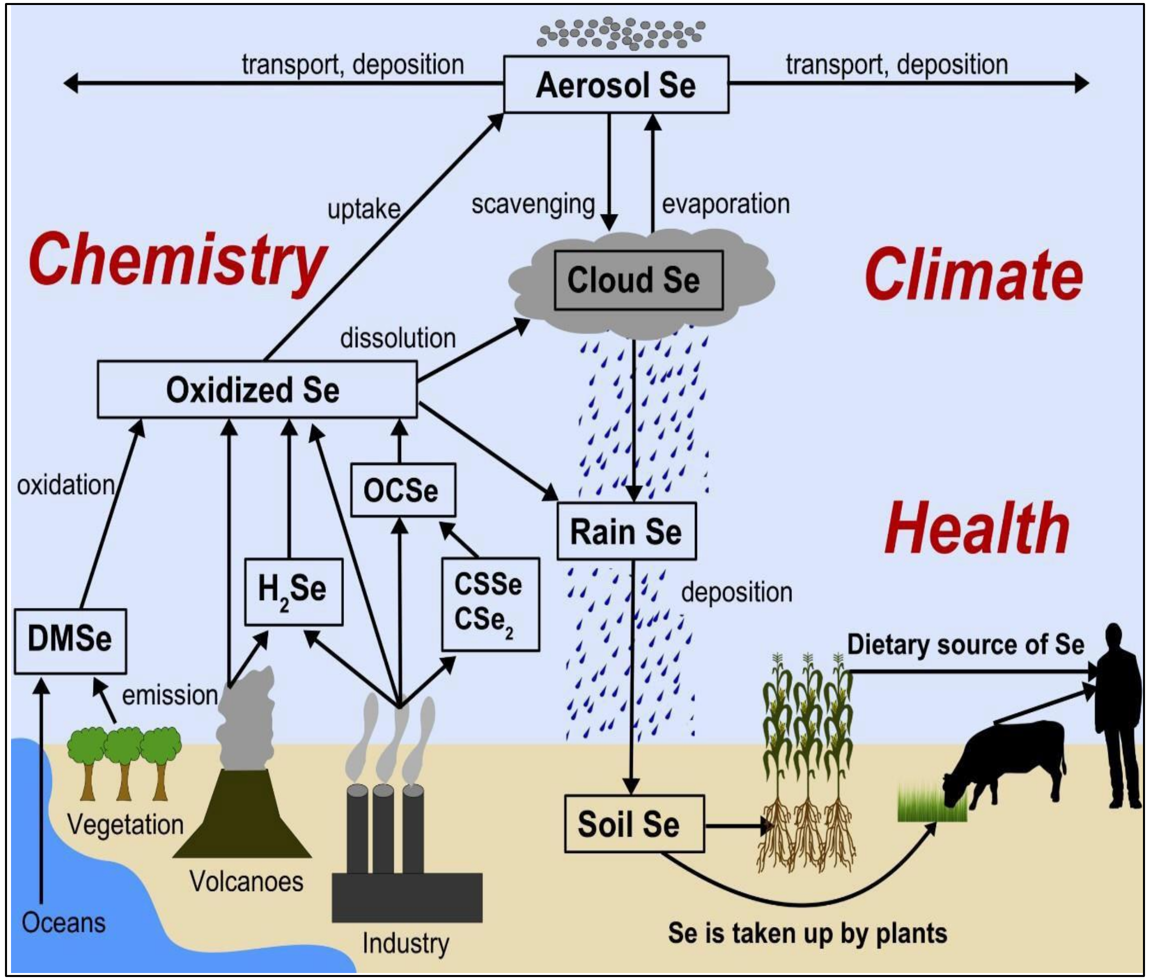
What we do at

the Earth and Environmental Sciences, IISERB

Environmental Geochemistry



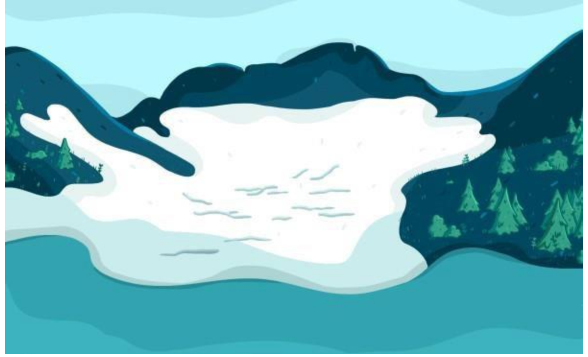
Source: Paul Alexandre, Environmental Geochemistry, 2021

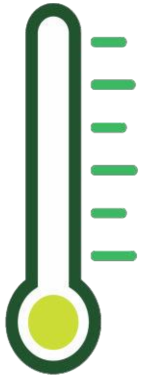


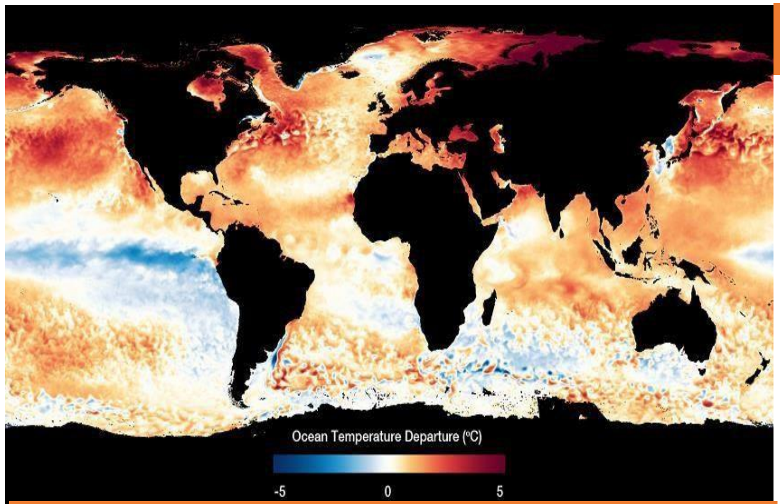
Source-https://ieg.ethz.ch/research/prev-research/selenium_model.html

Climate and Glacier Modelling Lab (CGMLI)

Rising temperatures threatening Himalayan glaciers!

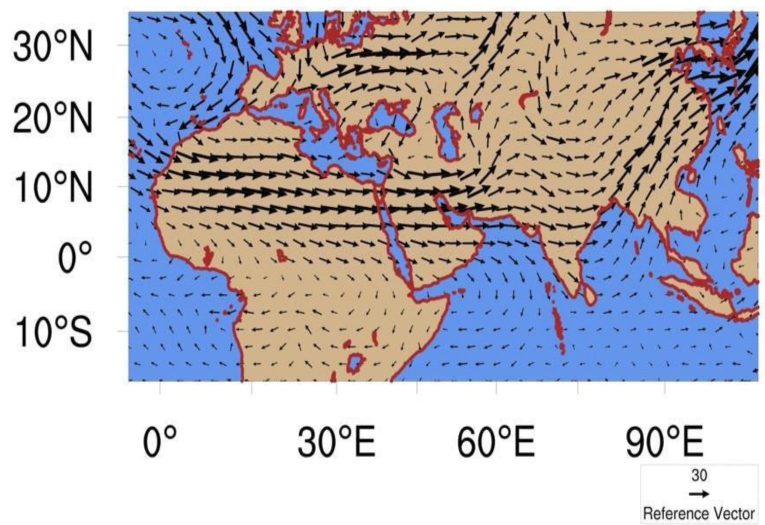


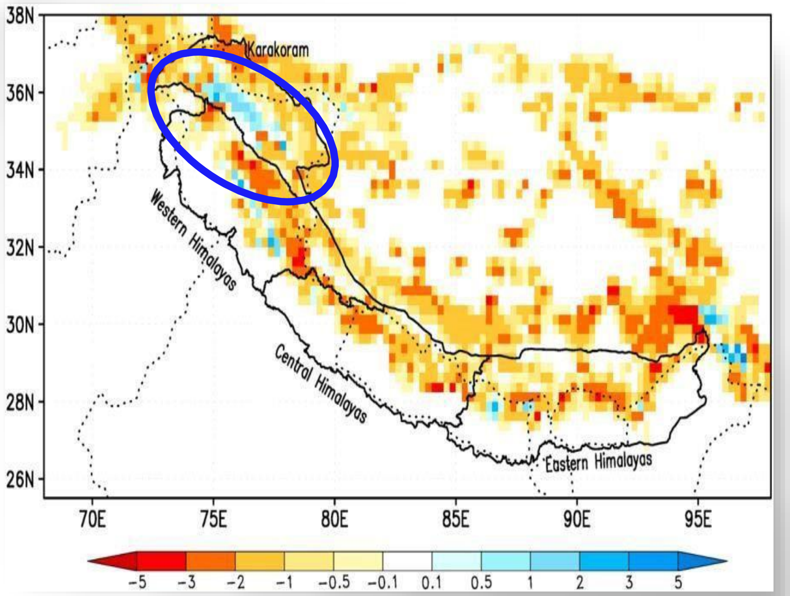




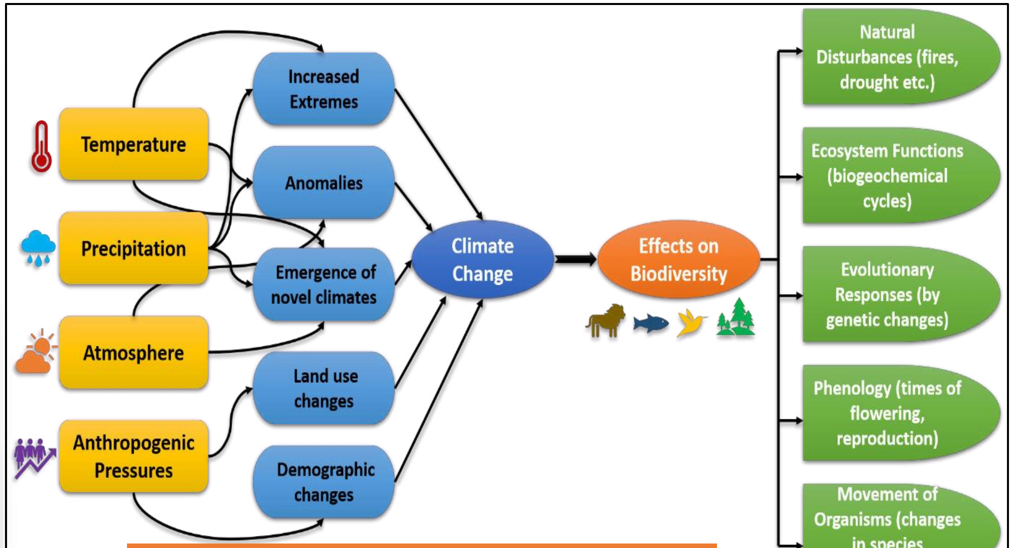
Warming Ocean

Wind at 400 hpa





Karakoram Anomaly (Javed et al., 2022)

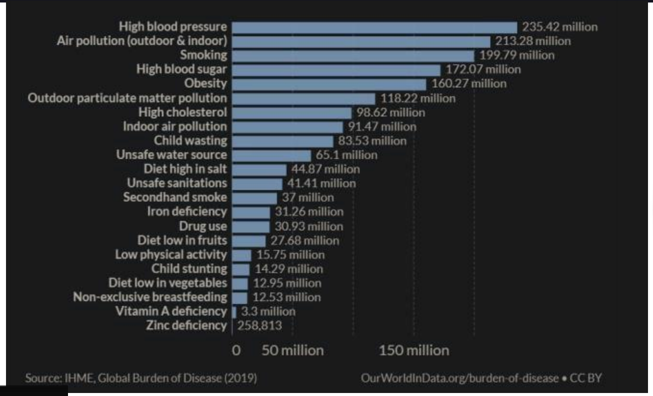


Climate affects biodiversity.

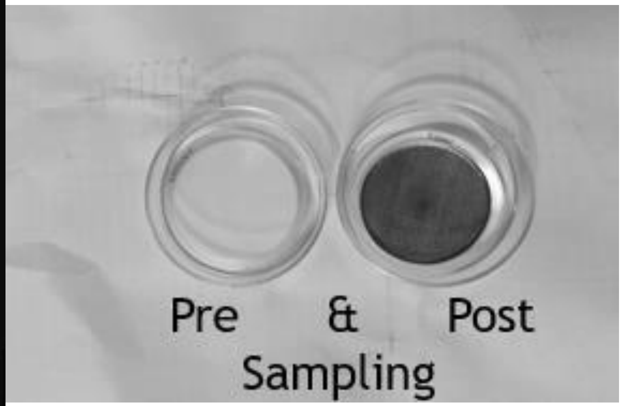
Glacier Modelling
Climate Modelling
Climate-Impact Studies
Techniques and methods for the development and improvement to study climate

ACE

Aerosol Characterization and receptor modEling Group



AEROSOLS
Suspension of liquid or solid particles in a gas



SOURCES

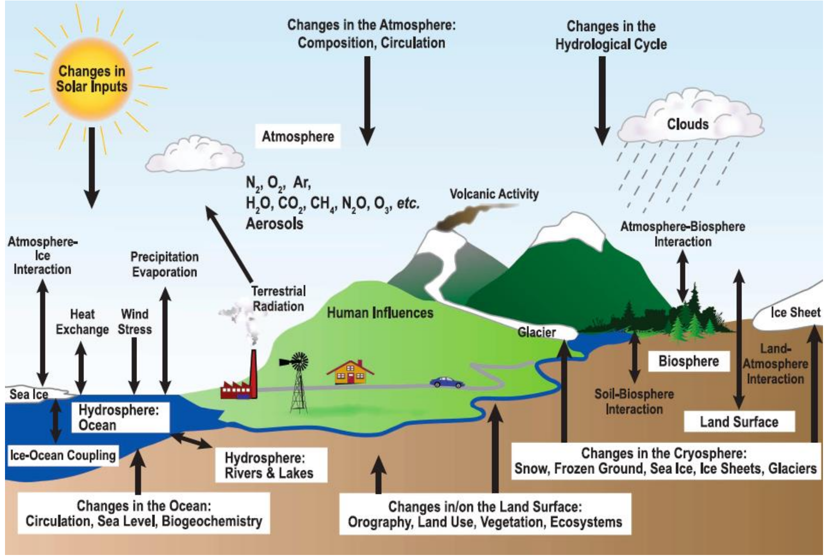
Biomass Burning
Industrial Emission
Vehicles
Secondary Organic Compounds
Dusts….

MODELS

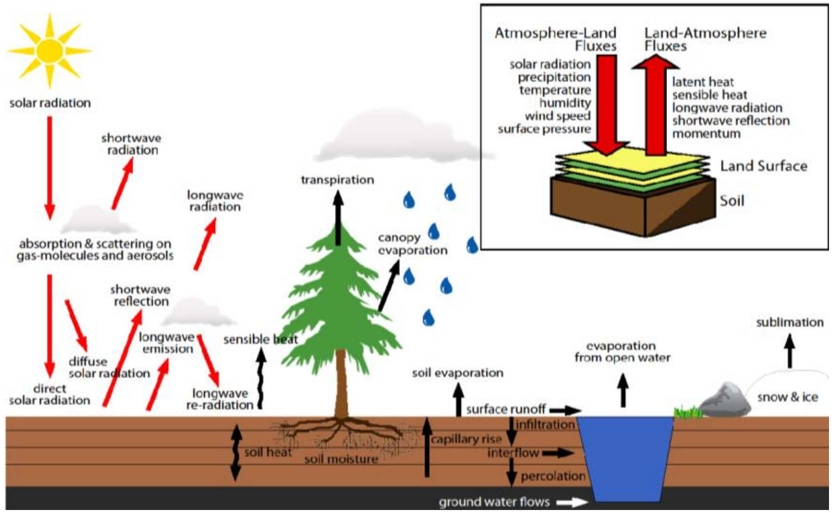
- WRF-Chem
- CTM
- PMF

Policy, Awareness

Climate and Monsoon variability Research Group



Our climate system



Energy balance at the land surface, divided into the radiation balance (red arrows), the water balance (black, straight arrows) and the heat fluxes (black, curved arrows). ([Zabel, F. (2012)])

<- All the processes involved in land-atmosphere-ocean interactions-> coupled systems

We use observations, satellite data, reanalysis data, and models to answer some questions related to climate and monsoon variability

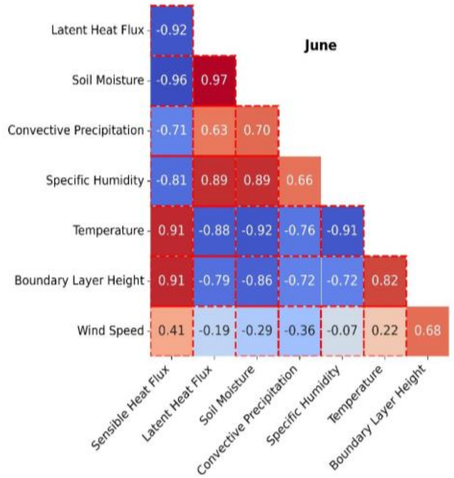
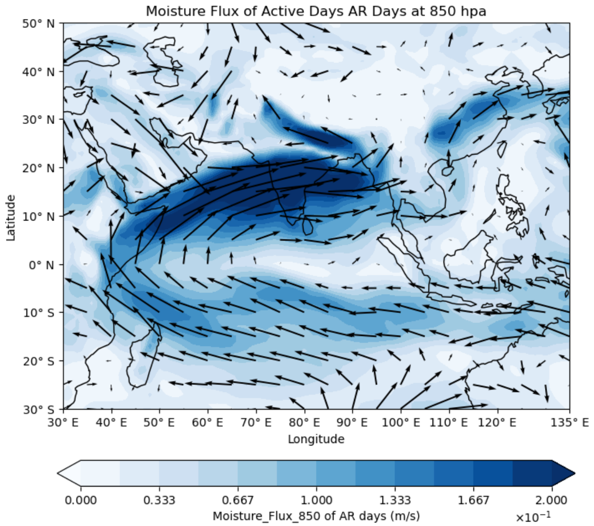
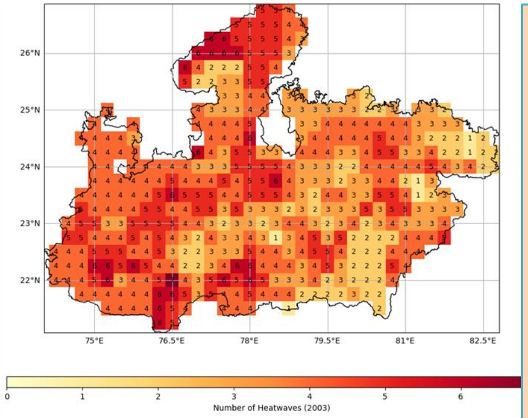


Figure shows Daily correlation analysis of different land and atmospheric variables over a particular study domain during June



Moisture transport and atmospheric rivers



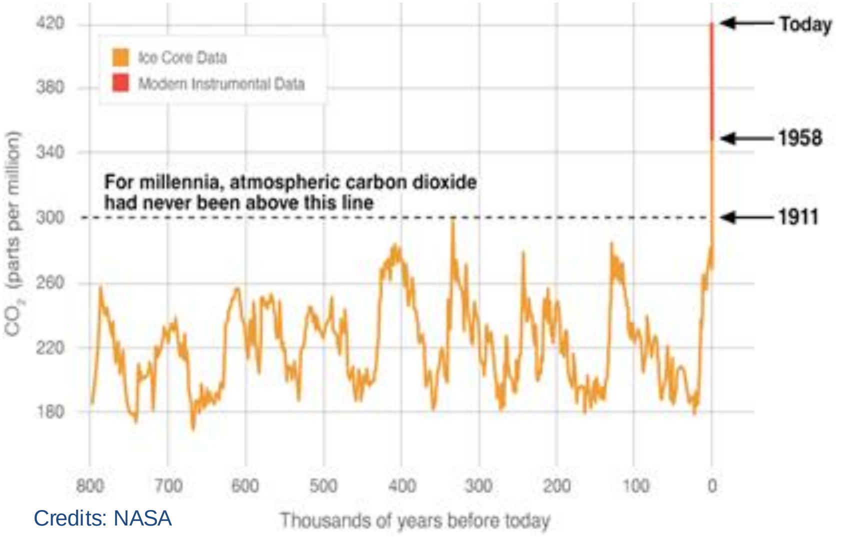
Heatwaves in MP

Key questions:

1. How are land-atmospheric processes driving our monsoon circulation?
2. How strongly land and atmosphere are coupled over India.
3. How does it impact extreme events?
4. What is the role of teleconnections on the monsoon

Greenhouse Gas Modelling and Applications (GMA) Group

GHG rise in the atmosphere

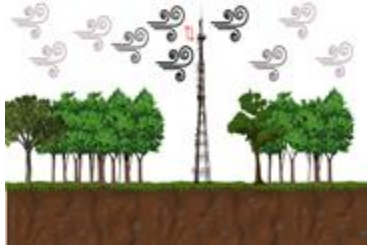


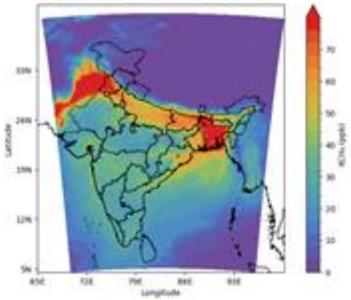
Credits: NASA

Methods of GHG estimations

Observations

Ground and remote

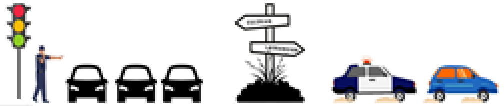


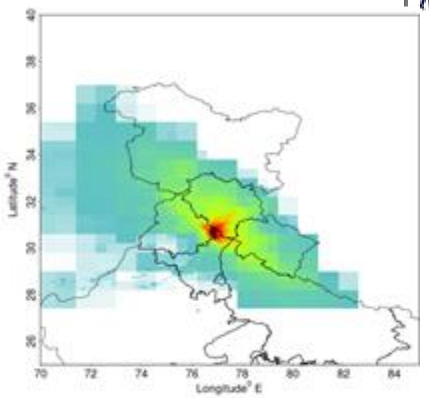


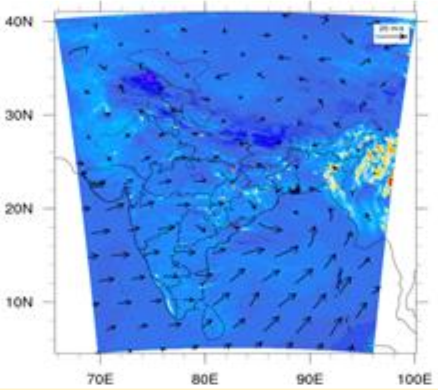
Inadequacy in ground network over India

Models

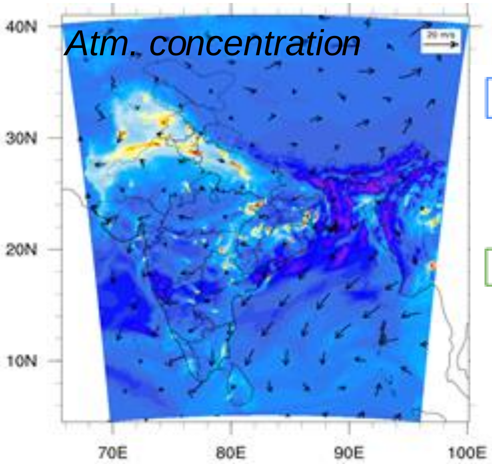
Eulerian & Lagrangian



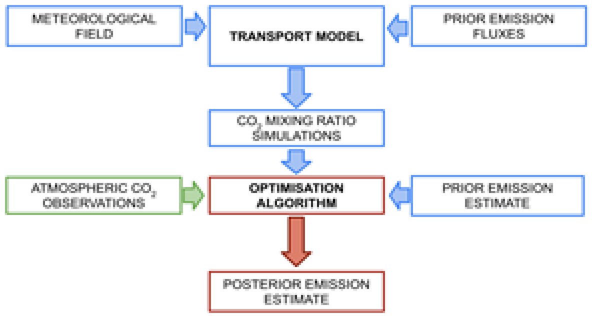




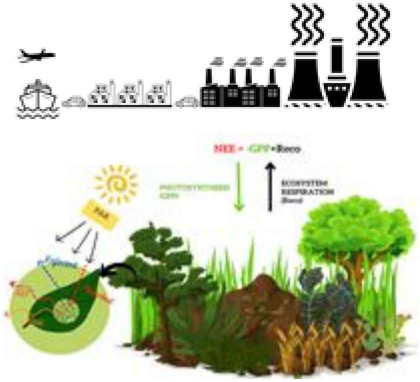
Optimisation of GHG Estimation



Methodology



Anthropogenic and natural sources & sinks



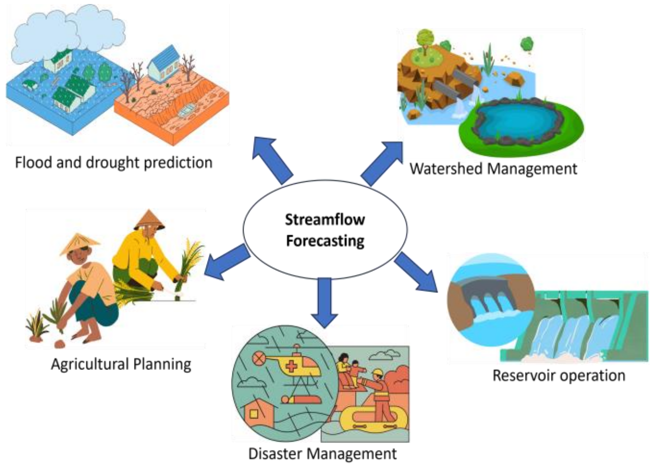
A multi-data-modelling approach

Key Questions Addressed

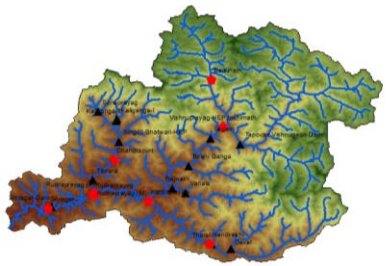
- To improve GHG estimation thereby understand the Carbon Cycle and Climate for mitigating the adverse effect of the Climate Change.
- The group develops techniques to extract information from atmospheric ground & remote (satellite) measurements combined with model simulations for optimising the available global inventories to better represent Indian emissions.

WATER RESOURCES AND HYDROLOGY LAB

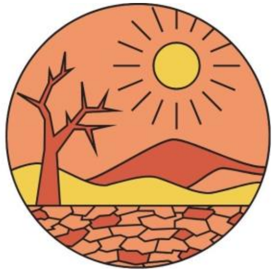
Streamflow forecasting



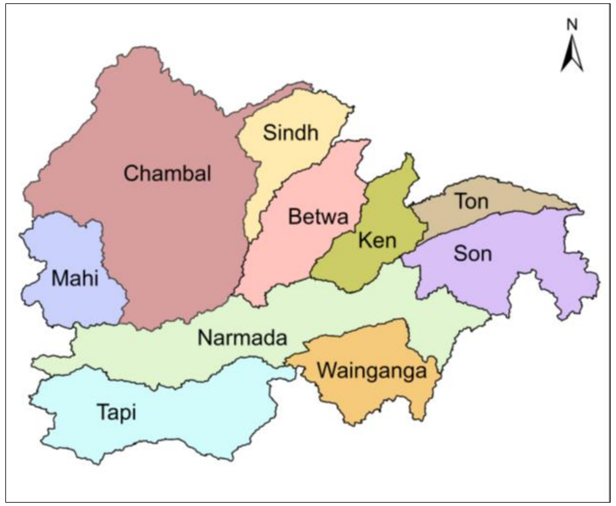
The Himalayan region's hydrology is challenging to study due to complex terrain, extreme climate, and limited data. We are addressing data scarcity and building a streamflow forecasting system for the Alaknanda River basin.



Impact of Climate Change on Water Resources

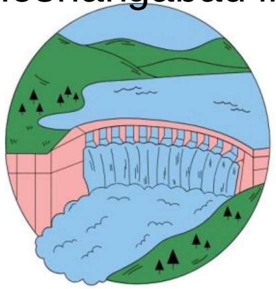


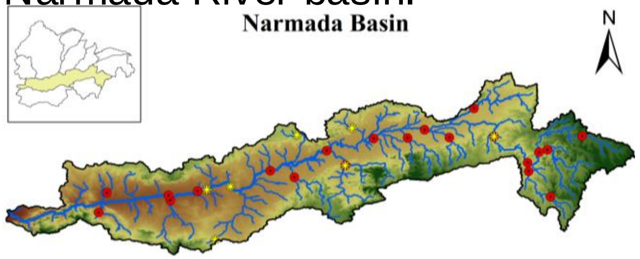
Extreme weather affects water availability, Water quality, and Stream flow patterns. We study its impact on ten Madhya Pradesh river basins using hydrological models for different climate change scenarios .



Reservoirs' Impact on Flood Control

Reservoirs regulate streamflow by storing excess water during high flow periods and releasing it during low flow. We are doing streamflow forecasting with reservoir operations to prevent flooding at Hoshangabad in the Narmada River basin.



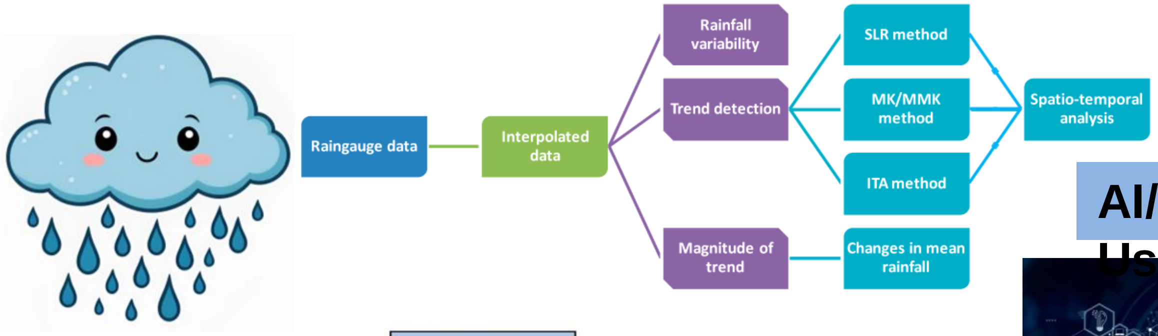


Vulnerability Assessments of Natural Hazards

Vulnerability assessment evaluates the susceptibility of systems, communities, or resources to potential harm from different hazards. It helps prioritize actions for adaptation. Our group conducted vulnerability assessments for various hazards, including floods and avalanches

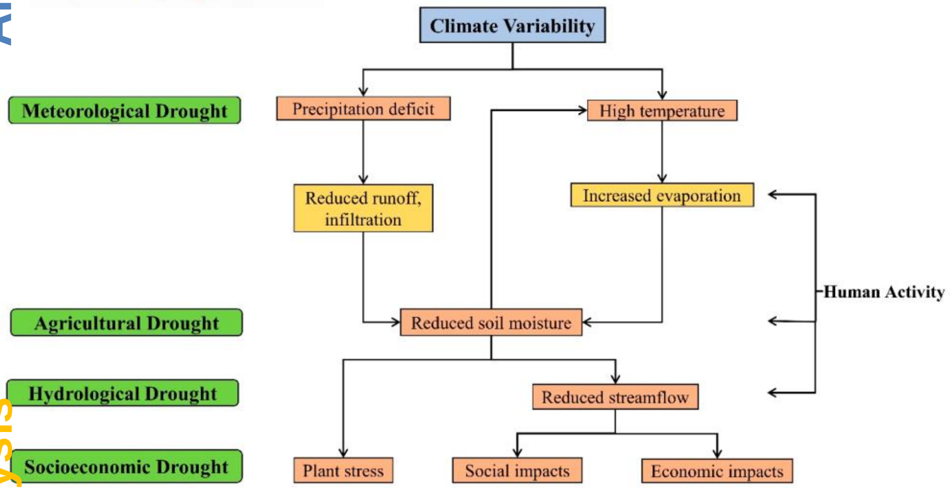
STOCHASTIC HYDROLOGY LAB (SHL LAB)

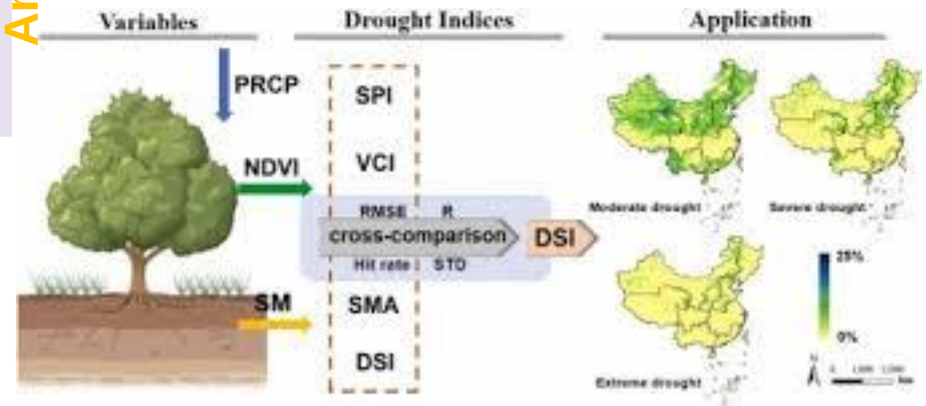
Rainfall Analysis



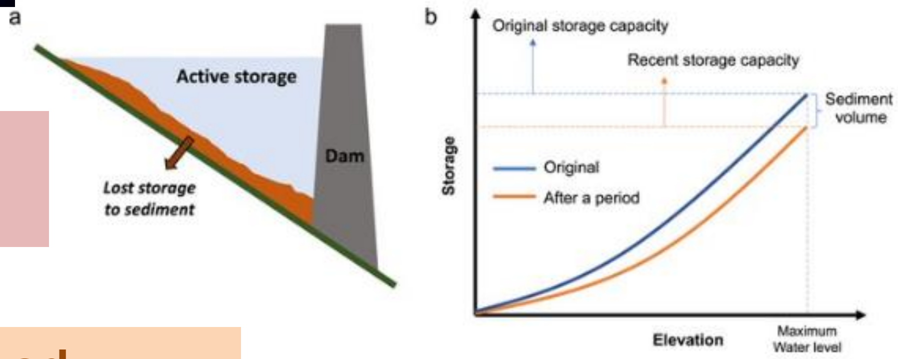
AI/ML Usage

Drought Analysis

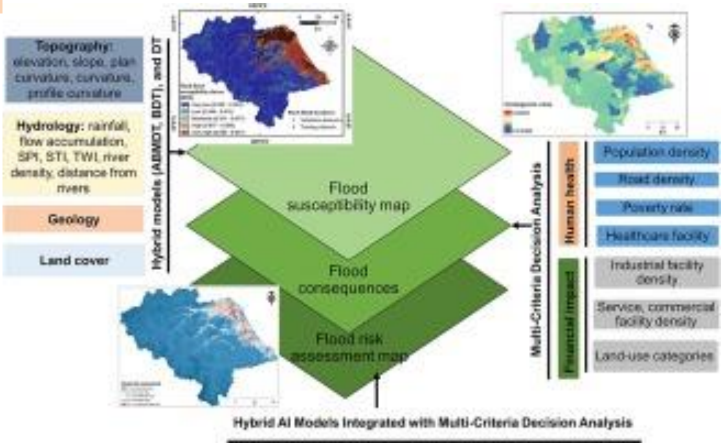




Sedimentation and Reservoir Analysis



Flood Analysis



What is environmental science?

Definitions

Environment:

- The circumstances or conditions that surround an organism or group of organisms, or
- The complex of social or cultural conditions that affect an individual or community.
- Humans inhabit the natural world as well as the 'built' or technological, social, and cultural world, all constitute an important part of our environment.

Environmental Science is the systematic study of our environment and the ways in which we both depend on it and influence it.

Much of environmental science focuses on understanding and resolving problems in our natural environment, such as pollution or lost biodiversity.

FIGURE 1.2 Many kinds of knowledge contribute to solutions in environmental science. A few examples are shown.

For an increasing number of environmental issues, the difficulty is not to identify remedies. The problem is to make them socially, economically, and politically acceptable.

Engineers know how to control pollution, but not how to persuade factories to install the necessary equipment.

Environmental science is interdisciplinary, integrating natural sciences, social sciences, and humanities.

Major themes in environmental science

- Sustainable development

How do we foster healthy, rewarding livelihoods under conditions of population growth, shifting food systems, precarious water resources and water quality, air pollution, and growing demands for energy?

- Climate change and climate action: the single most urgent issue of our time

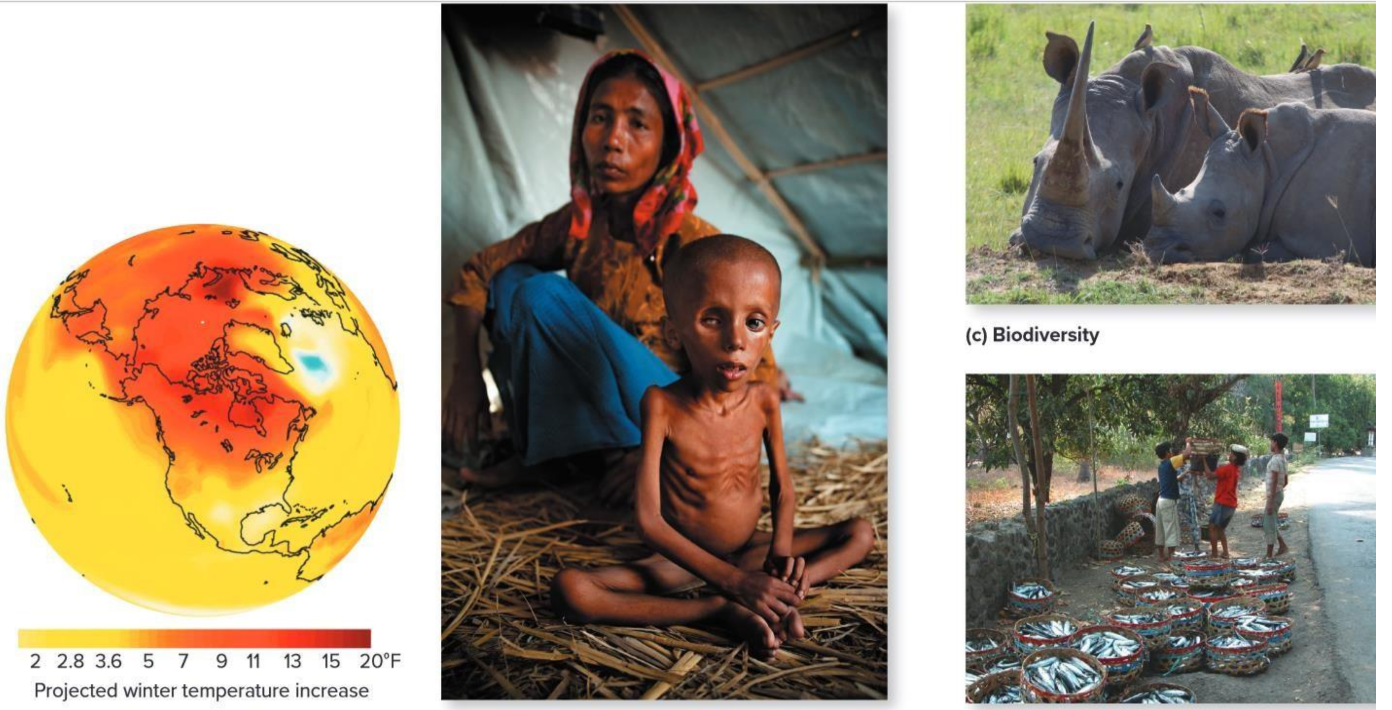
It will affect human health, economies, poverty, and conflict, as well as dramatically changing environmental systems, including water resources, weather, food production, and biodiversity, on which we depend.

Major themes in environmental science

- Population and resource consumption: current population is 8.2 billion, increasing by about 80 million every year. The impacts on our natural resources and ecological systems is a serious concern. All high-birth rate countries are low-income. Of the 40 countries with the highest birth rates, all are in Africa except Afghanistan. Rising resource consumption with affluence.

- Hunger: the United Nations estimates that some 800 million people are chronically undernourished, often because of drought, floods, displacement from land, or war. Soil scientists report that about two-thirds of all agricultural lands show signs of degradation.

- Biodiversity loss and conservation efforts: The UN Environment Programme reports that, over the past century, more than 800 species have disappeared and at least 10,000 species are now considered threatened. This rate comparable to the great extinction that marked the end of the age of dinosaurs.



(a) Climate change

(b) Hunger

(c) Biodiversity

(d) Resource management

FIGURE 1.5 Major environmental themes: (a) Climate change is projected to raise temperatures, especially in northern winter months. (b) Chronic hunger remains a persistent problem, especially in regions of political conflict. (c) Poaching and habitat loss threaten many species, including rhinos, but (d) sustainable resource use can safeguard vital resources, such as local fisheries.

a: Source: NOAA Geophysical Fluid Dynamics Laboratory; b: Jonas Gratzer/LightRocket/Getty Images; c: Tom Finkle; d: William P. Cunningham

Major themes in environmental science

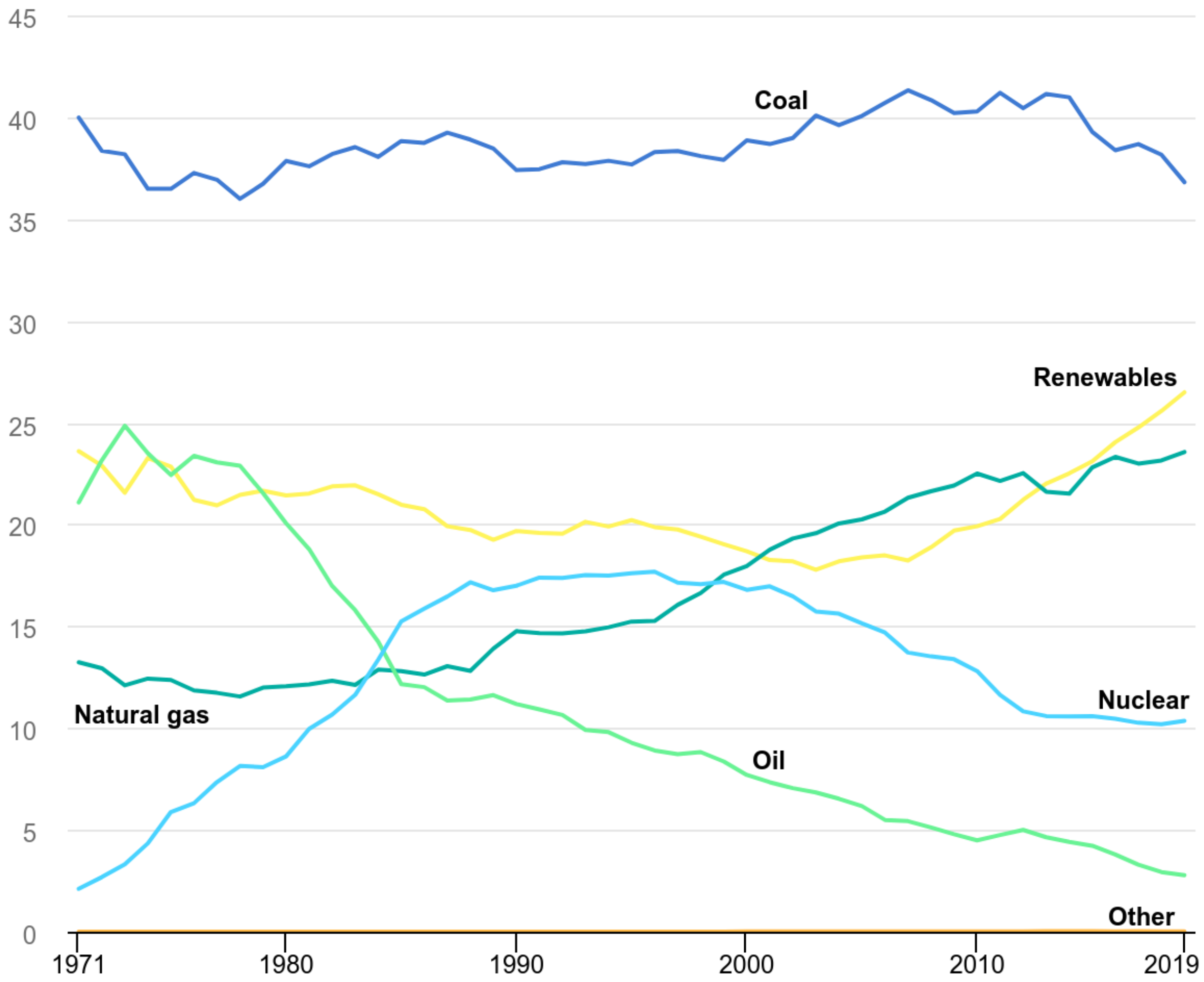
- **<u>Energy</u>**: How we obtain and use energy will determine our environmental future. Fossil fuels (oil, coal, and natural gas) presently provide around 80 percent of the energy used in industrialized countries. Cleaner energy resources, including solar power, wind, geothermal, and biomass, could give us cleaner, less destructive options. China leads the world in solar energy, wind turbines, and biogas generation. Solar panels prices dropped from $20 per watt in the 1980s to less than 50 cents today. For India, 46% of the total energy comes from renewable sources as of 2024.

- **<u>Pollution and environmental health</u>**: Over southern Asia, satellite images recently revealed that a 3-km-thick toxic haze of ash, acids, aerosols, dust, and photochemical products regularly covers the entire Indian subcontinent for much of the year. At least 3 million people die each year from diseases triggered by air pollution. Pollutants are great travels, thanks to fluid air. The good news -Metals, dust, even greenhouse gases can be captured before they leave the smokestack.

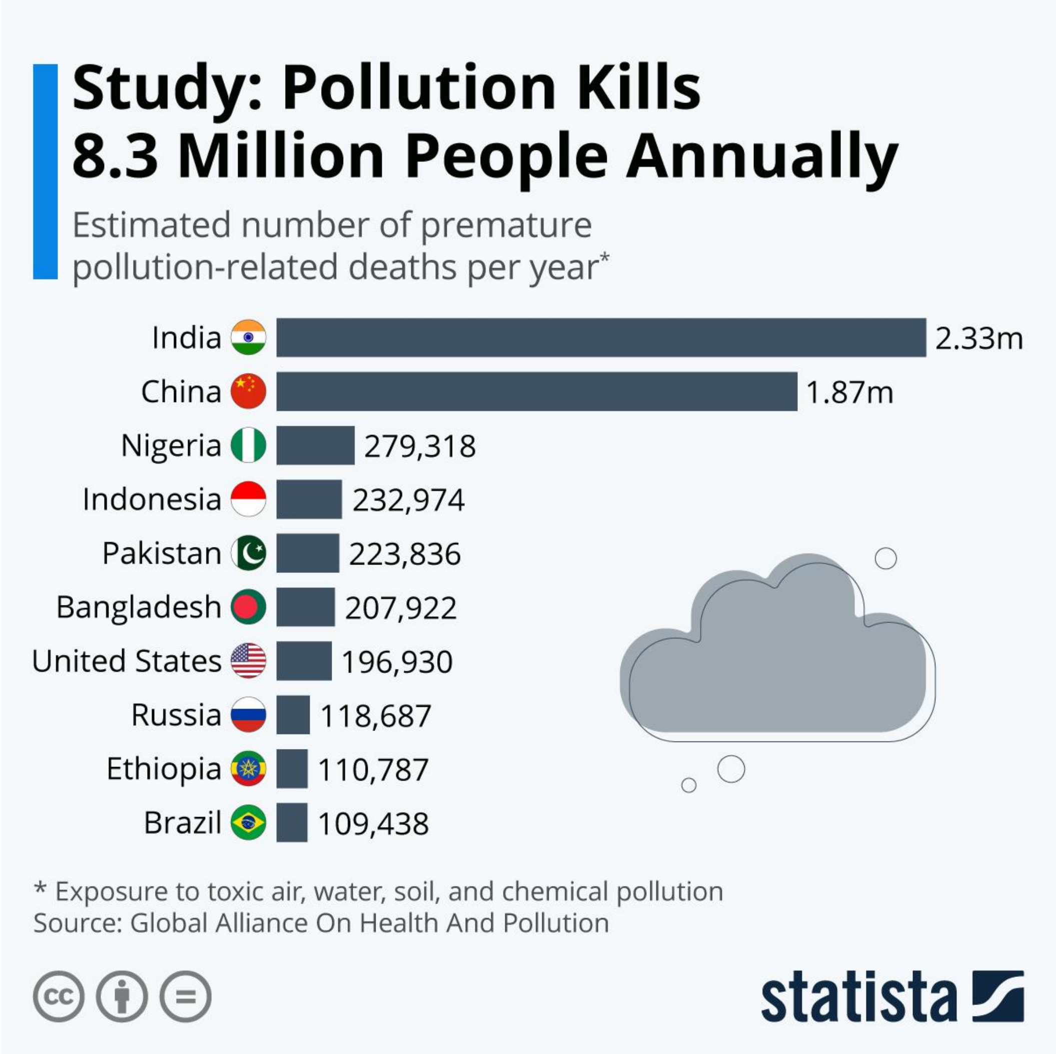
- **<u>Water resources</u>**: Over 600 million people (9 percent of us) lack safe drinking water, and 2.4 billion (32 percent) don't have safe sanitation. Polluted water causes illness in more than a billion people annually, and death of over 5 million children per year. Water shortages create "climate refugees".

- **<u>Information and education</u>**: Education, especially for girls, is now recognized to be the most powerful strategy for slowing population growth and reducing child mortality. Because so many environmental issues can be fixed by new ideas, technologies, and strategies, expanding access to knowledge is essential to progress.

World electricity generation mix by fuel, 1971-2019



https://www.iea.org/



(a) Renewable energy

(b) Water resources

(c) Health care

(d) Education

FIGURE 1.6 Renewable energy (a) is a central theme. Water quality (b) continues to cause illness around the world, but there has been substantial progress in (c) health care, and (d) education.

a: Source: Dennis Schroeder/NREL/U.S. Dept. of Energy; b: Roger A. Clark/Science Source; c: Dimas Ardian/Getty Images News/Getty Images; d: Anjo Kan/Shutterstock

- We depend on our environment for food, water, energy, oxygen, waste disposal, and other life-support systems.
- For resource use to be sustainable, we cannot consume them faster than nature can replenish them. Degradation of ecological systems ultimately threatens everyone's well-being.
- Although we may be able to overspend nature's budget temporarily, future generations will have to pay the debts we leave behind.
- Can the earth sustain our current lifestyles?
- Will there be adequate natural resources for future generations?

But,

- How do we know how much we are using?
- How do we quantify our impact on the environment?
- How do we know if our methods are sustainable?

What is Nature's productivity or Biological productivity?

Biological Productivity is typically measured as Net Primary Productivity (NPP), which refers to the rate at which plants in an ecosystem produce usable energy (biomass) through photosynthesis, minus the energy they consume through respiration.

Ecosystem	NPP ($gC/m^2/yr$)	Key Factors for Productivity
Tropical Forest	2,000–3,500	Ample rainfall, biodiversity, rich soil
Temperate Forest	600–1,500	Seasonal growth, moderate rainfall
Boreal Forest	200–800	Cold, shorter growing seasons
Desert	<200	Water scarcity, extreme conditions

In essence, forests are far more productive than deserts, often by a factor of 10 to 20 or more, depending on the specific forest and desert types being compared.

Ecological Footprint

- Ecological footprint is a measure used to quantify the demands placed on nature by individuals or by nations.
- It quantifies how much land and water area is needed to produce the resources people use (such as food, timber, and energy) and absorb the waste they generate (like carbon emissions).
- The ecological footprint is expressed in global hectares (gha), which standardizes the measurement of biologically productive land and sea areas.
- It is the global area that would be needed to support one person. [one hectare is an area 100 m × 100 m]
- The term "global hectares" also reminds us that we are always consuming resources from around the world.
- It considers five key components:

1. Cropland: Land used to grow food and other crops.
2. Grazing land: Land used for raising livestock.
3. Fishing grounds: Water areas required for fishing.
4. Forests: Land needed for timber and to absorb carbon dioxide emissions from fossil fuel use.
5. Built-up land: Land occupied by infrastructure like roads and buildings.

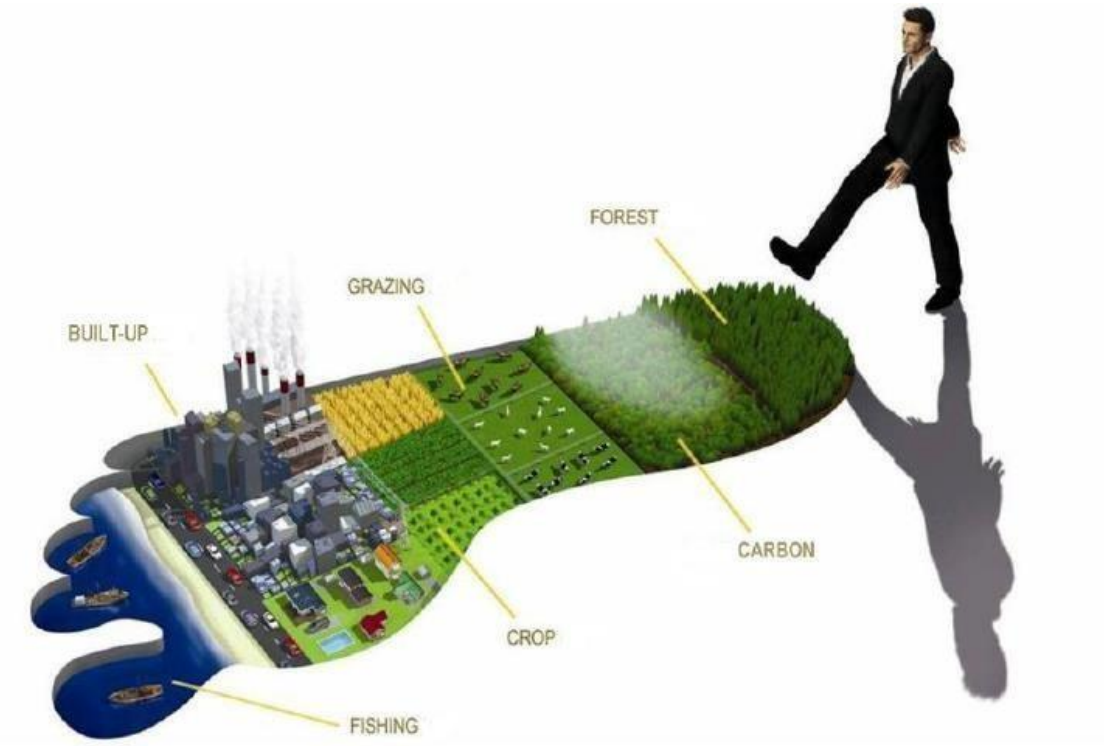
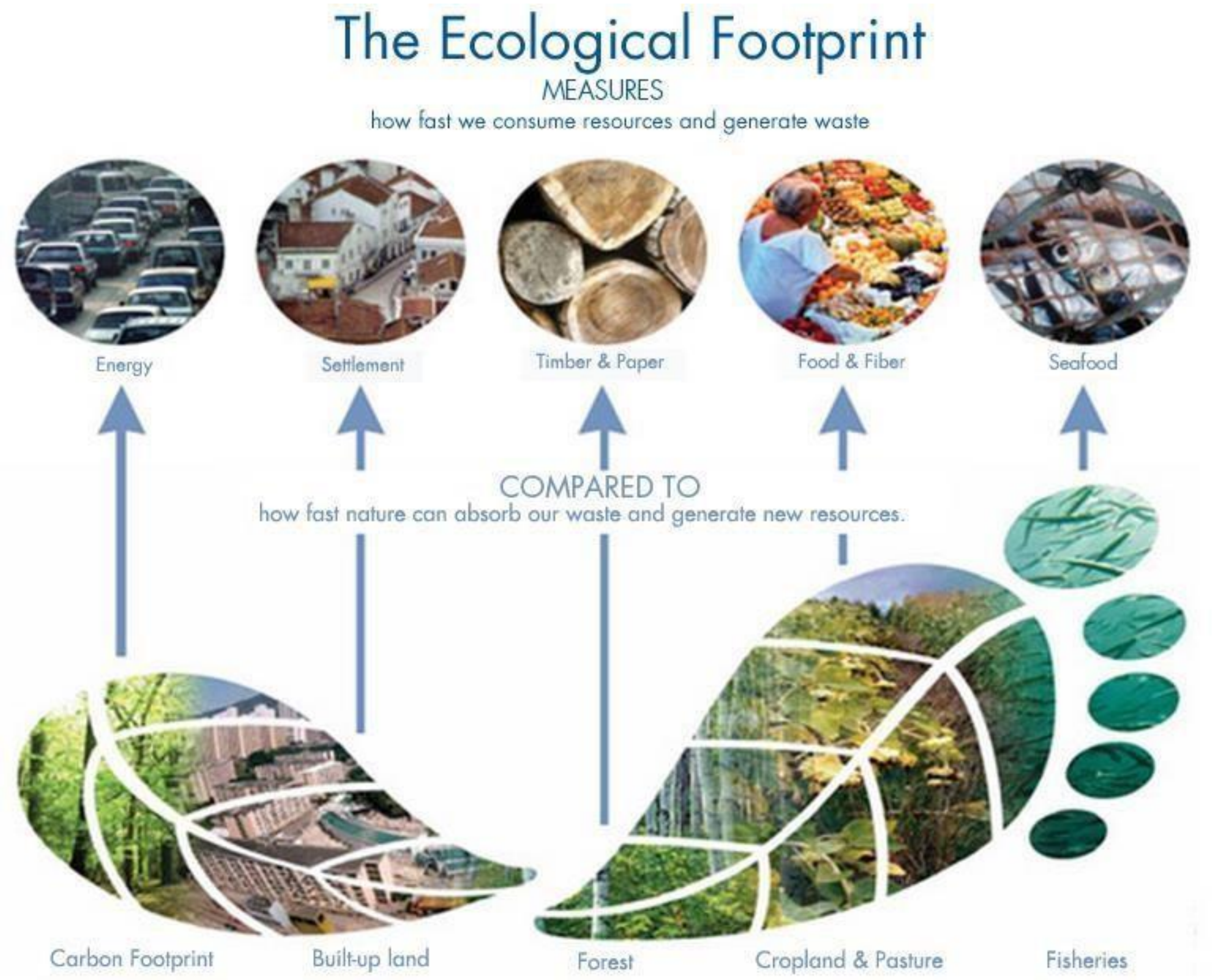


Figure 1 *The Ecological Footprint measures the human demand for energy, infrastructure, food, fiber, timber, paper and seafood. It is compared to biocapacity of five distinct area types: built-up land, grazing land, cropland, forest land and fishing grounds.*

Source: https://whygreeneconomy.org/information/ecological-footprint-of-the-richest-methodology/



Source: https://www.footprintnetwork.org/our-work/ecological-footprint/

Ecological Footprint

- An ecological footprint gives a usefully simplified description of a system. It is built on a number of simplifying assumptions:

I. Various measures of resource consumption and waste flows can be converted into the biologically productive area required to maintain them;

II. different kinds of resource use and dissimilar types of productive land can be standardized into roughly equivalent areas;

III. because these areas stand for mutually exclusive uses, they can be added up to a total—a total representing humanity's demand—that can be compared to the total world area of productive land.

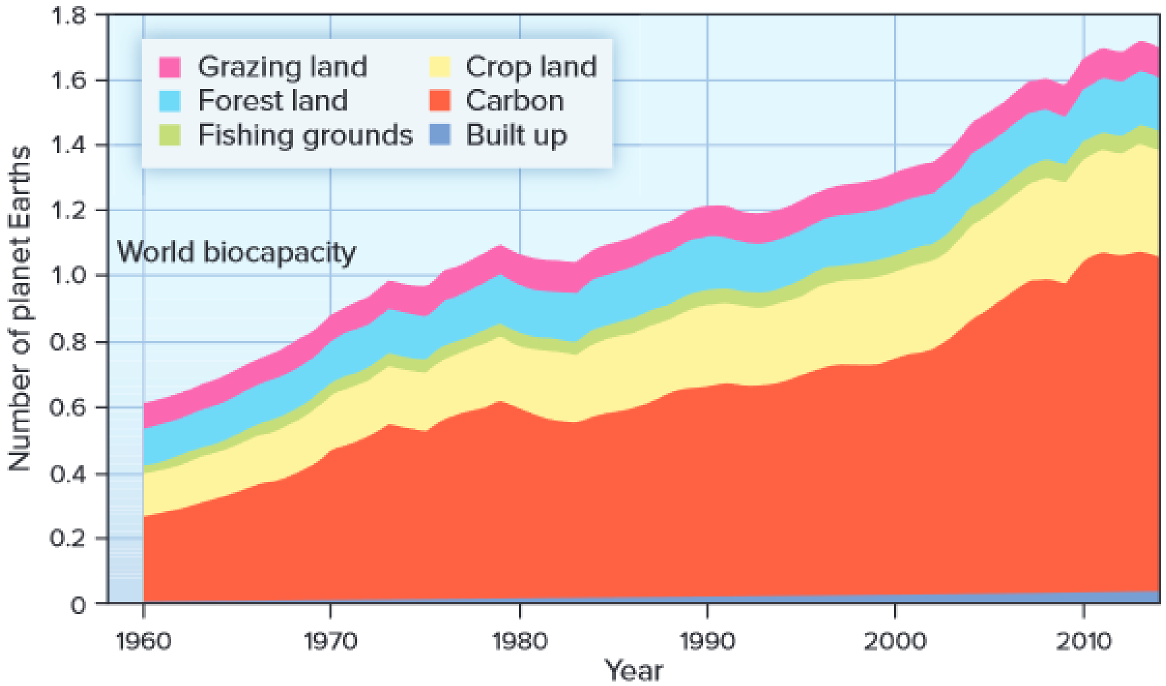


FIGURE 1.7 Humanity's ecological footprint has nearly tripled since 1961, when we began to collect global environmental data.
Source: WWF, Global Footprint Network, 2018.

Biocapacity

- Biocapacity, or biological capacity, refers to the capacity of ecosystems to generate renewable resources and absorb waste, particularly carbon emissions, in a sustainable manner.
- It measures the amount of biologically productive land and sea area available to meet human needs. Biocapacity is expressed in global hectares (gha) to standardize the assessment.
- The Earth's biocapacity is approximately **12.2 billion** global hectares (gha).

- Biocapacity is often expressed as:

$$\boxed{\text{Biocapacity} = \text{Actual Area} \times \text{Productivity (per unit area)}}$$

Actual Area: The physical extent of biologically productive land or water.
Productivity: The rate at which the land generates resources or absorbs waste.

Biocapacity

- The total ecological footprint of humanity is approximately **20–22 billion** global hectares (gha), meaning humanity is using resources at a rate equivalent to about **1.7 Earths**.
- According to Redefining Progress, the average world citizen has an ecological footprint equivalent to 2.7 gha, while the biologically productive land available is only 1.8 (~1.6 as per current reports) gha per person.
- We are using nonrenewable resources (such as fossil fuels) to support a lifestyle beyond the productive capacity of our environment.

Biocapacity vs. Ecological Footprint

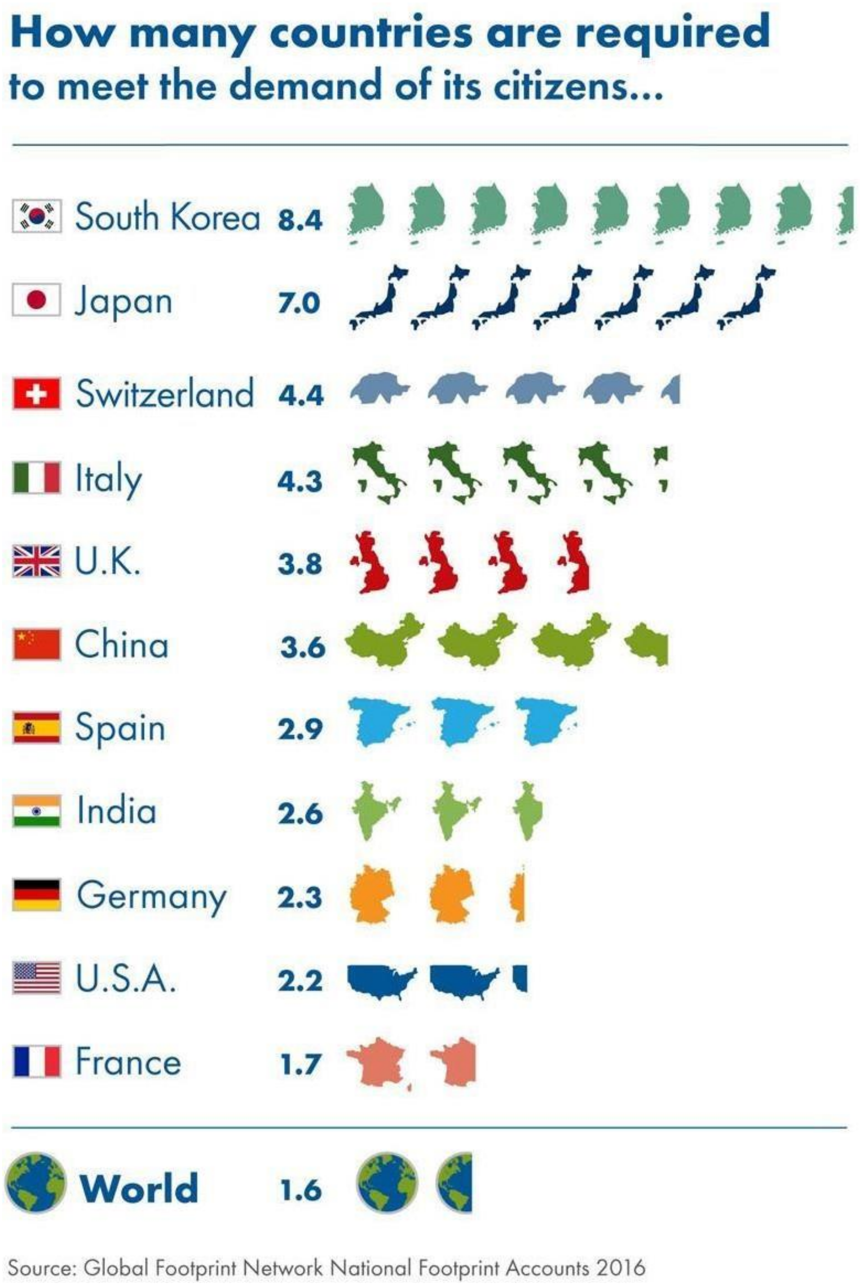
- When **biocapacity > ecological footprint**, a region operates sustainably, meaning it has surplus resources.

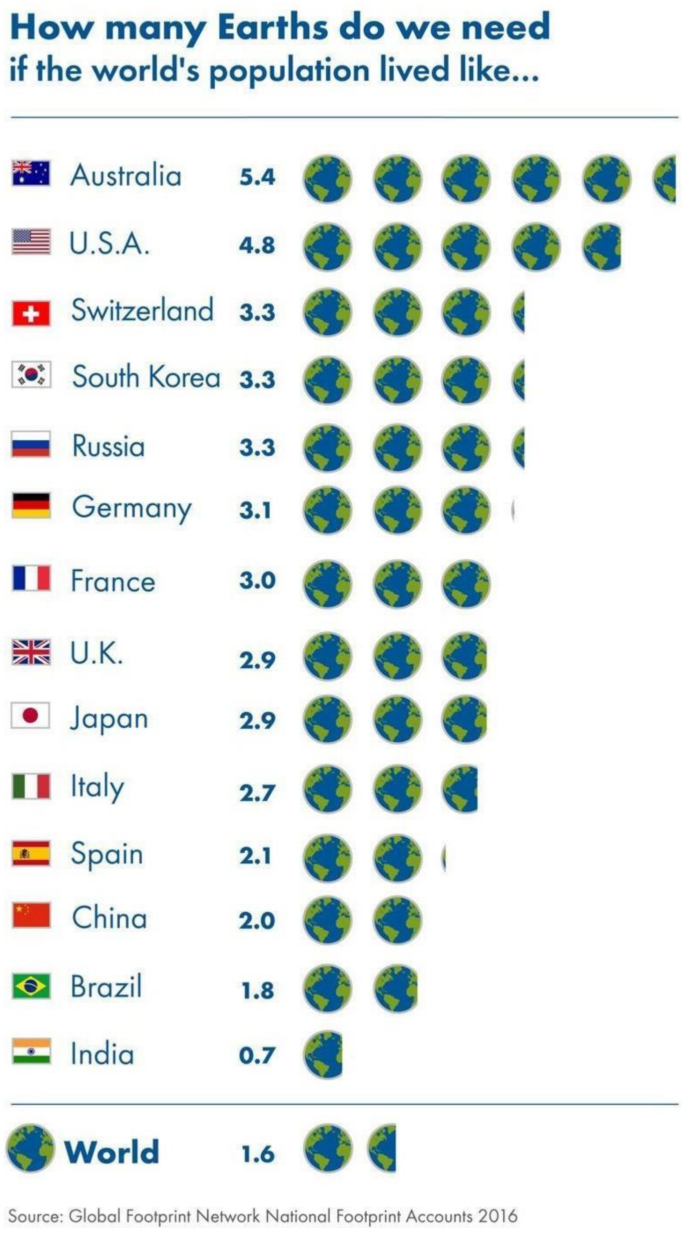
- When **ecological footprint > biocapacity**, the region is in **ecological deficit**, requiring imported resources or overusing its ecosystems, leading to **ecological overshoot**.

- The Ecological Footprint for the United States is **8.1 gha** per person (in 2018) and global biocapacity is **1.6 gha** per person (in 2018). Therefore, we would need **(8.1/ 1.6) = 5.1** Earths if everyone lived like Americans.

- The Ecological Footprint for Japan is **4.6 gha** per person (in 2018) and Japan's biocapacity is **0.6 gha** per person (in 2018). Therefore, it would take **(4.6/ 0.6) = 7.8** Japans to meet its residents' demand on nature.

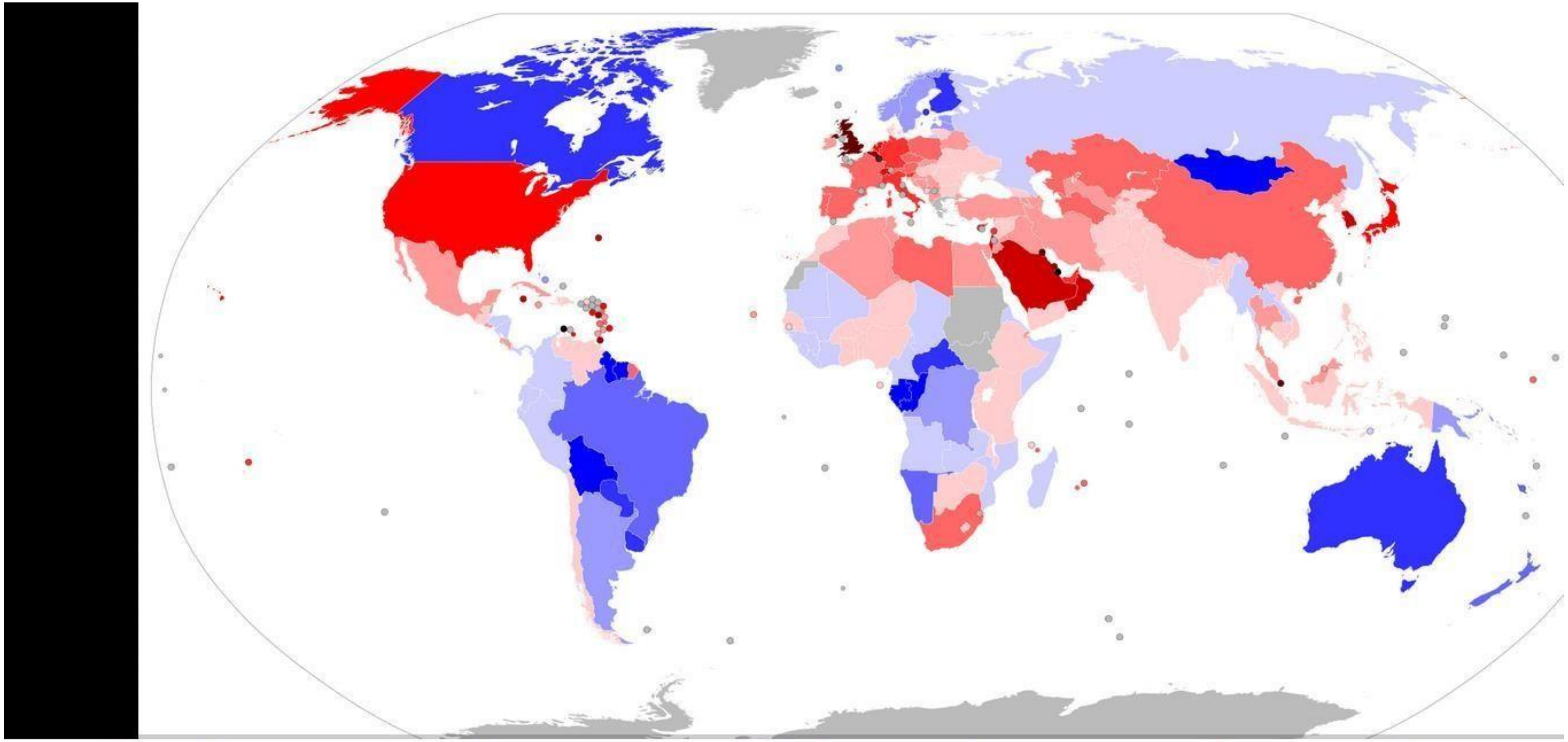
https://www.youtube.com/watch?v=nMn59yNwoZ8





Source:
https://www.overshootday.org/how-many-earths-or-countries-do-we-need/ https://commons.wikimedia.org/wiki/File:How_many_countries_2018_English.jpg

Biocapacity minus Ecological Footprint

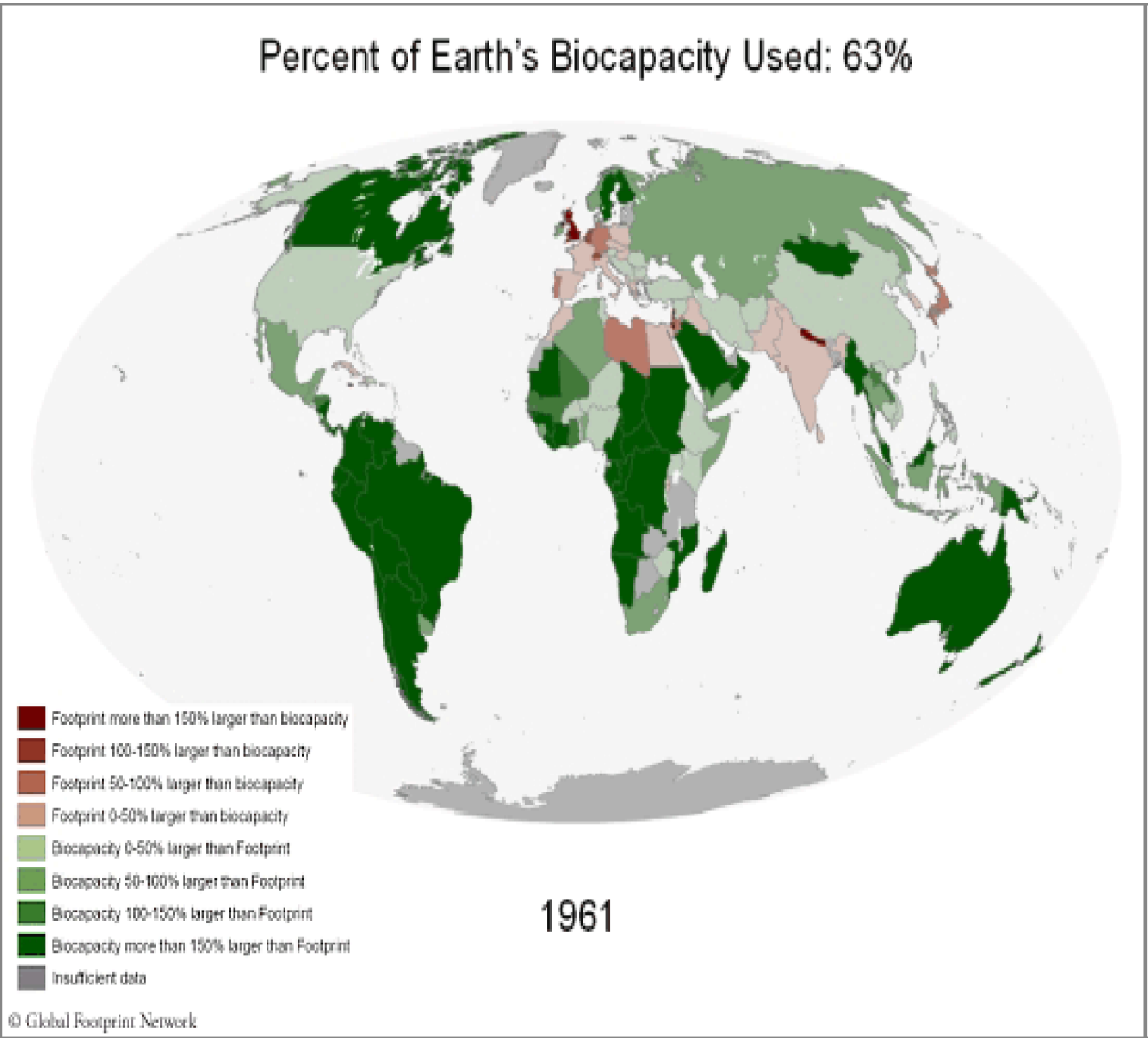


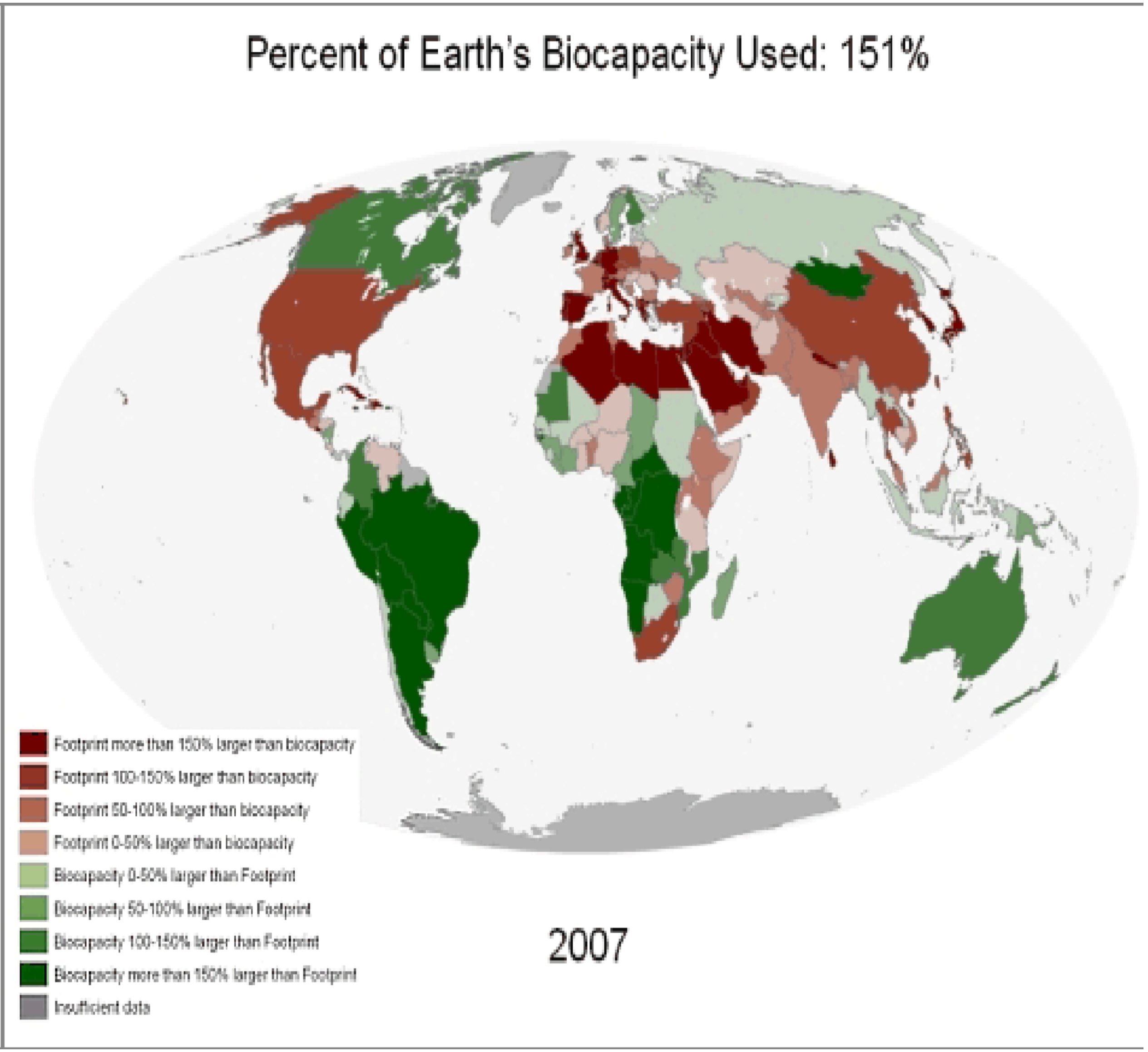
National ecological surplus or deficit, measured as a country's biocapacity per person (in global hectares) minus its ecological footprint per person (also in global hectares). Data from 2013.[1] x ≤ -9 -9 < x ≤ -8 -8 < x ≤ -7 -7 < x ≤ -6 -6 < x ≤ -5 -5 < x ≤ -4 -4 < x ≤ -3 -3 < x ≤ -2 -2 < x ≤ -1 -1 < x < 0 0 ≤ x < 2 2 ≤ x < 4 4 ≤ x < 6 6 ≤ x < 8 8 ≤ x Data unavailable

Blues- sustainable

Reds- unsustainable

Source: https://en.wikipedia.org/wiki/List_of_countries_by_ecological_footprint#/media/File:World_map_of_countries_by_ecological_deficit_(2013).svg





Source: http://livebettermagazine.com/article/biocapacity-the-human-ecological-footprint/

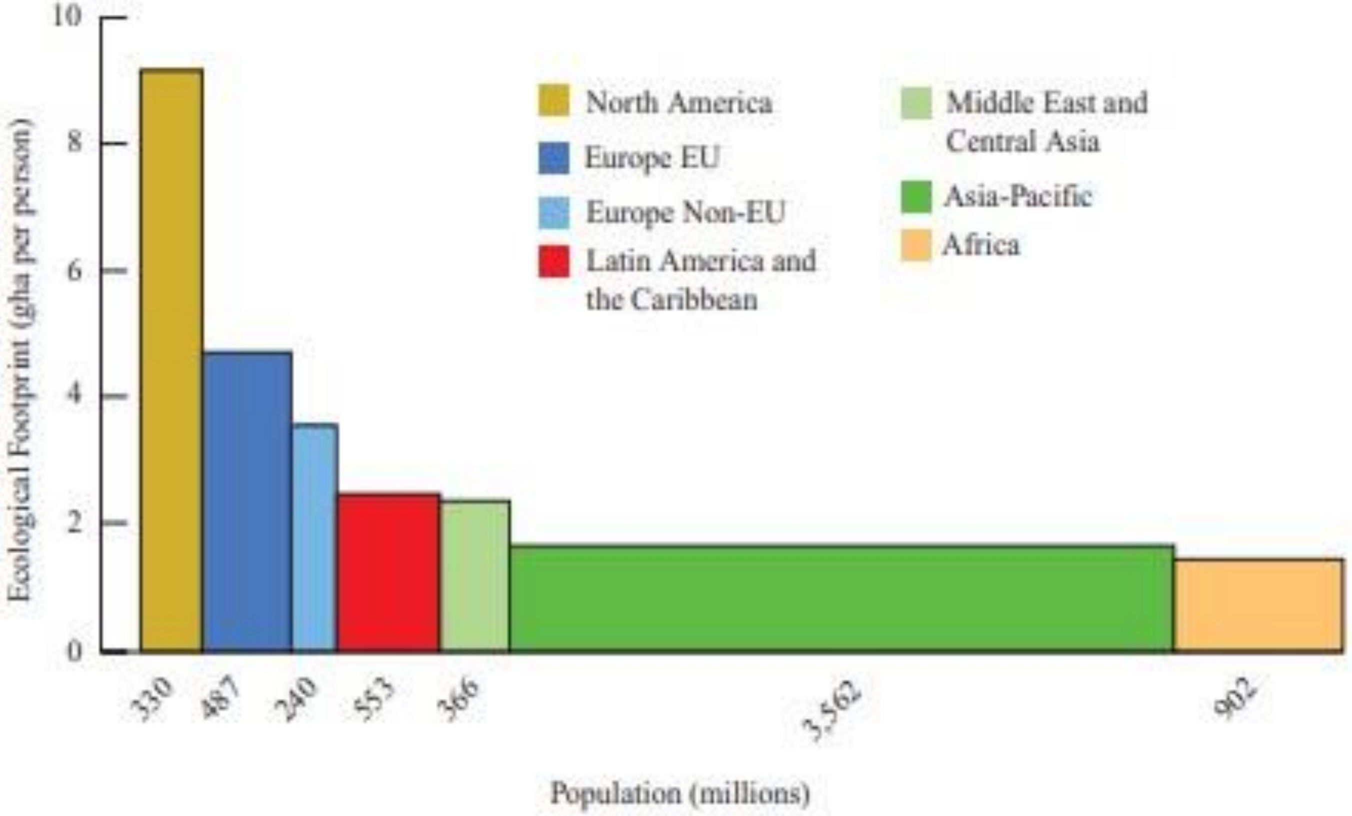


FIGURE 1 Ecological footprint by region, 2005. Bar weight shows footprint per person. Width of bars shows population size. Area of bars shows the region's total ecological footprint.

Source: WWF, 2008.

Redefining Progress Ecological Footprint calculator

- https://www.footprintcalculator.org/home/en

Thank you!