Biodiversity Changes and their Drivers

"Biodiversity and nature's contribution to people are our common heritage and humanity's most important life-supporting 'safety net'. But this safety net is stretched almost to the breaking point" – Prof. Sandra Diaz (Co-Chair, IPBES, 2019)

Learning Outcomes

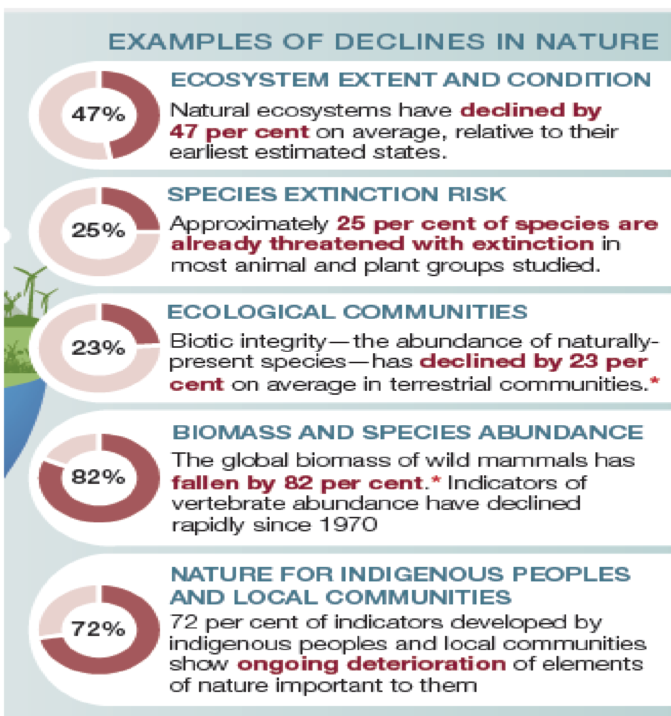
By the end of this unit, students will:

- Become aware of the changing global trends of biodiversity
- Appreciate the factors that are driving species into extinction
- Understand the varying patterns of human consumption of natural resource and their role in biodiversity loss

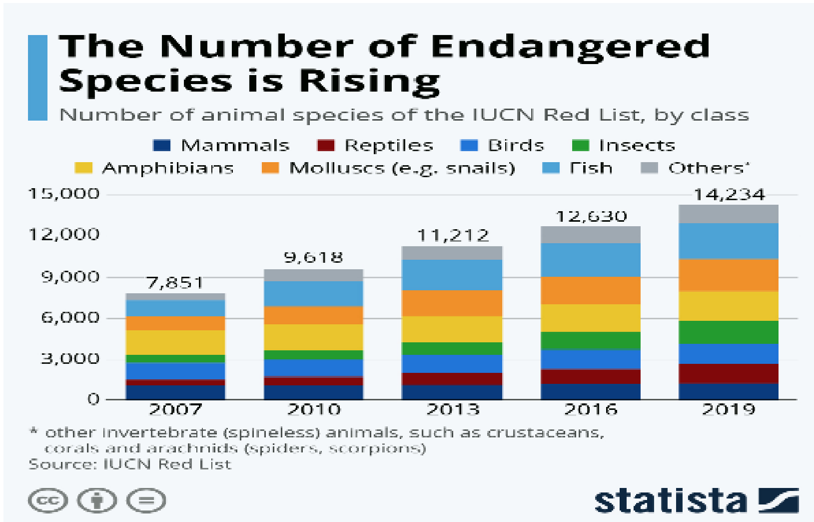
Trends in Global Biodiversity Change

- Biodiversity change is one of the most pressing environmental issues of our time; an important global change in its own right.
- Since 1970, biodiversity has declined at a rate unprecedented in human history.
- Pressures driving this decline are also intensifying.

IPBES (2019)



Global Biodiversity Change



Global trends in the capacity of nature to sustain contributions to good quality life (1970-2019; IPBES 2019)

Trends in Global Biodiversity Change

- About 35-40% of the world's forest and natural free ice habitats have been converted to cropland and pasture
- Half of the world's large river systems have been affected by dams
- About 40% of the oceans have been affected by several drivers

Dimensions of Biodiversity Change

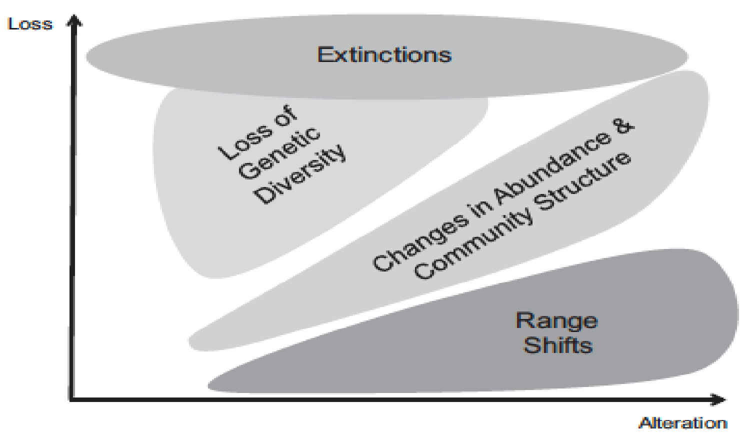


Figure 1

Conceptual diagram illustrating the intensity of loss and alterations associated with the different dimensions of biodiversity change: extinctions, loss of genetic diversity, changes in abundance and community structure, and range shifts.

Pereira et al. 2012

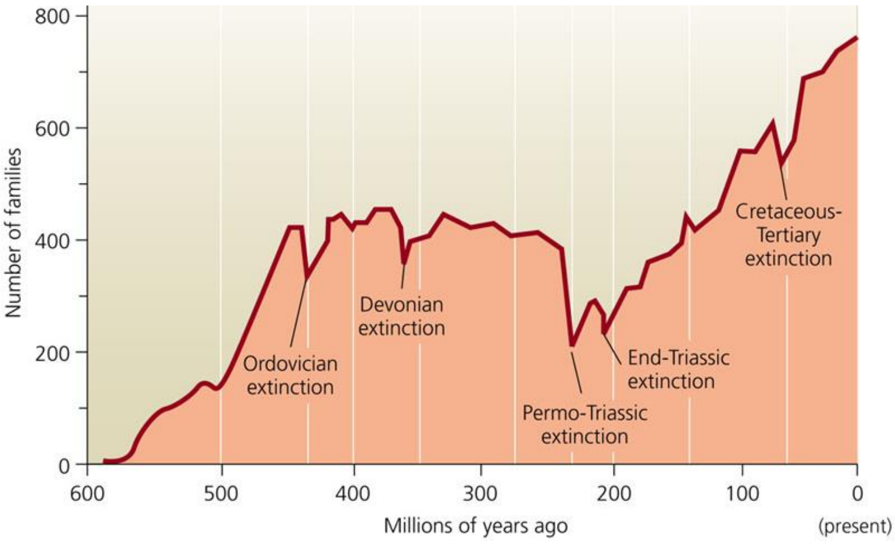
Extinction of Biodiversity

- Global biodiversity including the genetic resources is declining.
- The loss of biodiversity may take many forms but the most dramatic aspect is ***extinction***.
- A species is extinct when no member of the species remains alive anywhere in the world (global extinction).

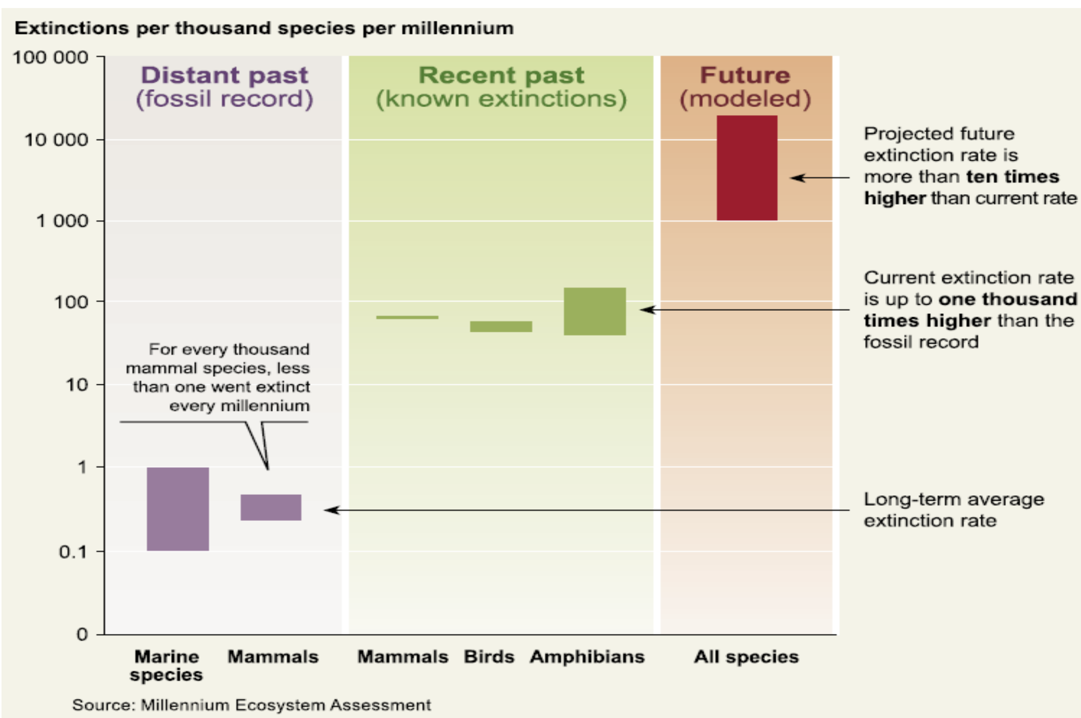
Extinction

- Extinction is a natural process, perhaps routine, from geological perspective.
- Background rate of extinction
  - On average, one species goes extinct naturally every 500-1000 years.
  - Approximately, 99% of all species that ever lived are now extinct.
- Occasionally, there has been episodes of mass extinction, an event in which a large percentage of all living species become extinct.

Mass extinctions

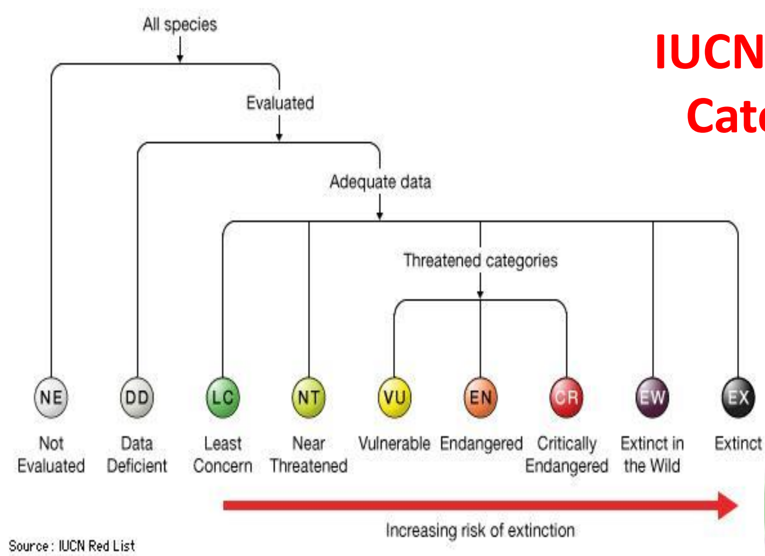


Earth has experienced five **mass extinction** events in which over half its species were wiped out suddenly.

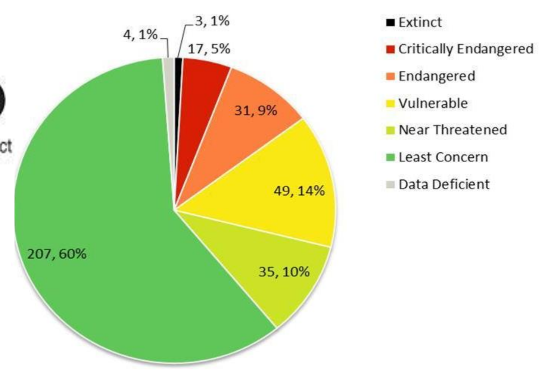


Today's mass extinction

- Currently, the earth is undergoing its sixth mass extinction—because of us.
  - Human have increased the rate and magnitude of extinction by 50-1000 times more than naturally expected.
  - 1,100 species are known to have gone extinct in the past 400 years.
- The **Red List**, from the IUCN, lists species that today are facing high risks of extinction.



IUCN Red List Categories



❖ 1,000,000 species threatened with extinction (IPBES, 2019)

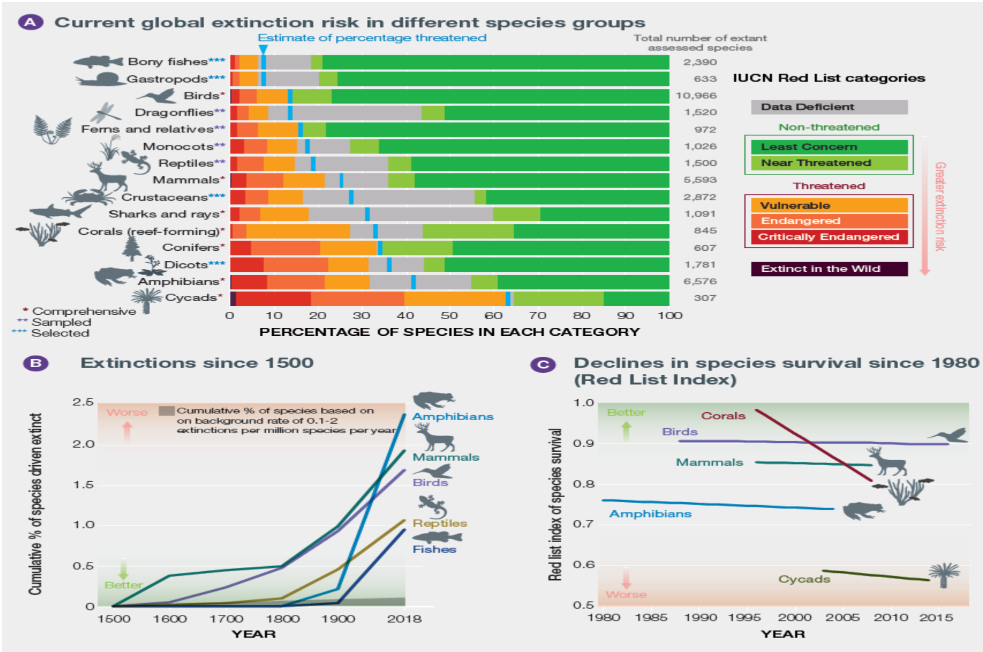
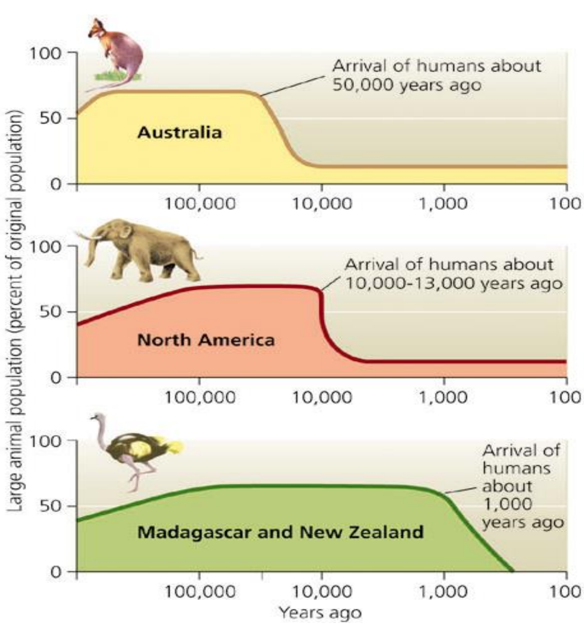


Figure SPM 3 A substantial proportion of assessed species are threatened with extinction and overall trends are deteriorating, with extinction rates increasing sharply in the past century.

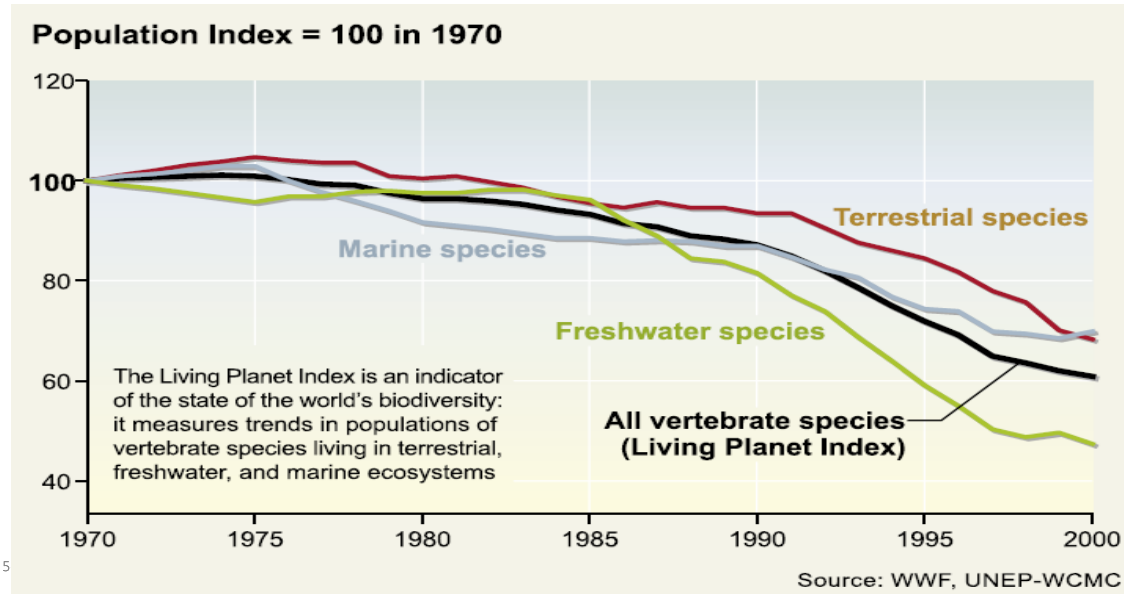
Today's mass extinction



Species of large mammals and birds plummeted with the arrival of humans, independently, on each of three continents—suggesting that human hunting was the cause.

Pearson Educational Inc., 2005

Today's Mass Extinction



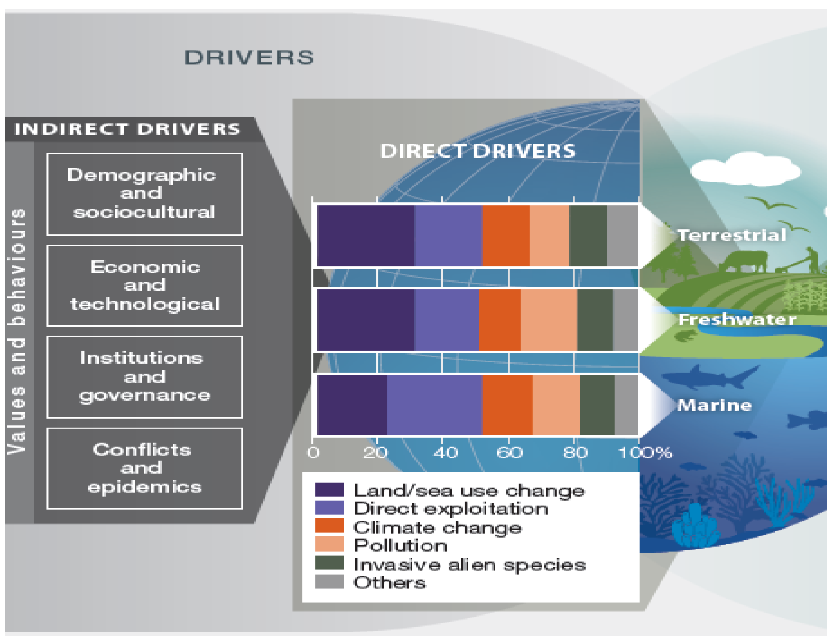
What are the Main Direct and Indirect Drivers of Biodiversity Change?

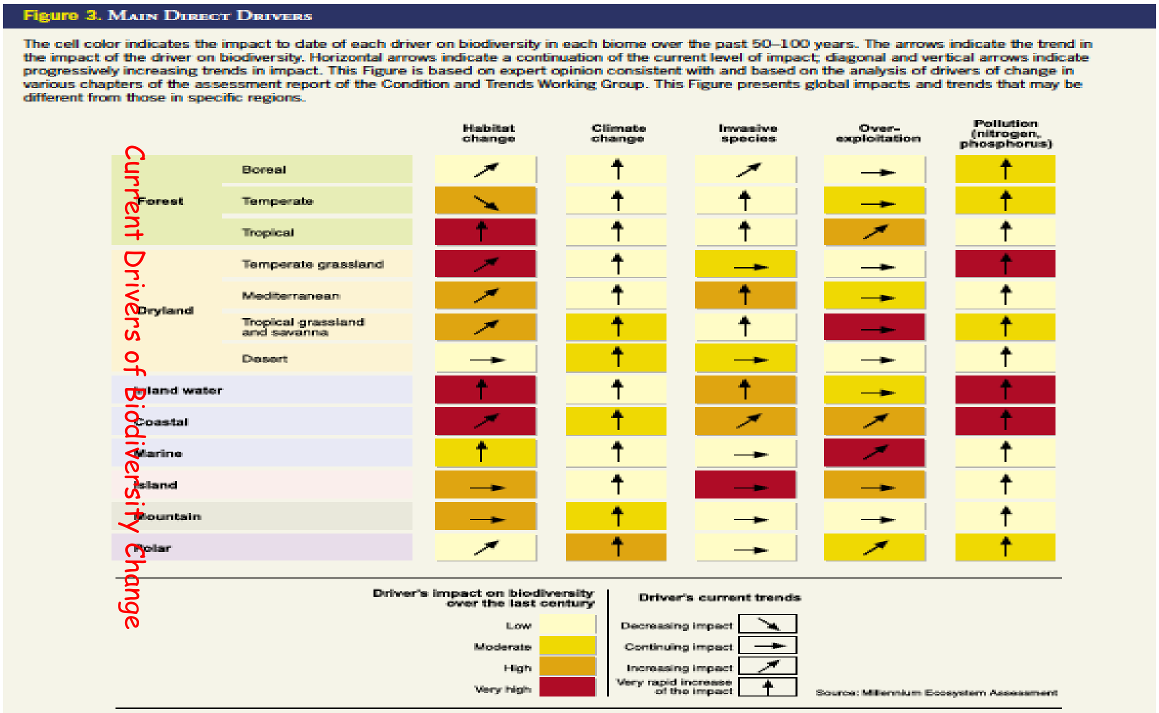
Threats to Biodiversity

*"The worst thing that can happen during the 1980s is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. **The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats.** This is the folly that our descendants are least likely to forgive us."*

— E. O. Wilson, 1985

Direct and Indirect Drivers of Biodiversity Change





Drivers of Biodiversity Change in 2100?

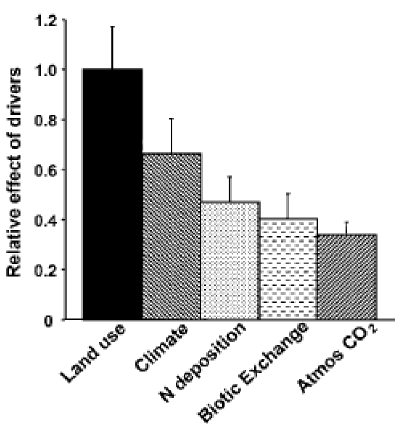


Fig. 1. Relative effect of major drivers of changes on biodiversity. Expected biodiversity change for each biome for the year 2100 was calculated as the product of the expected change in

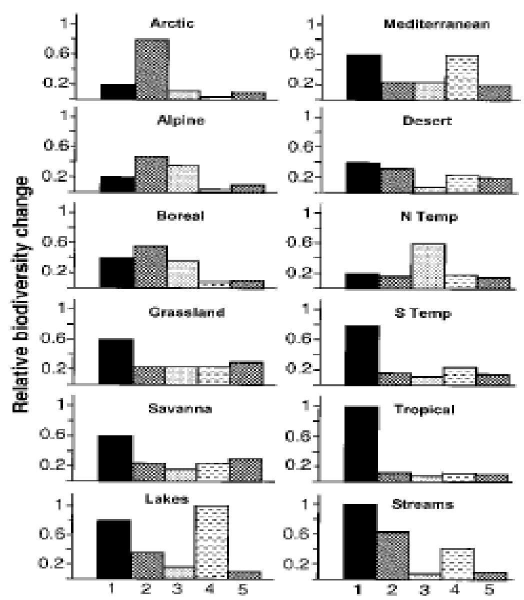
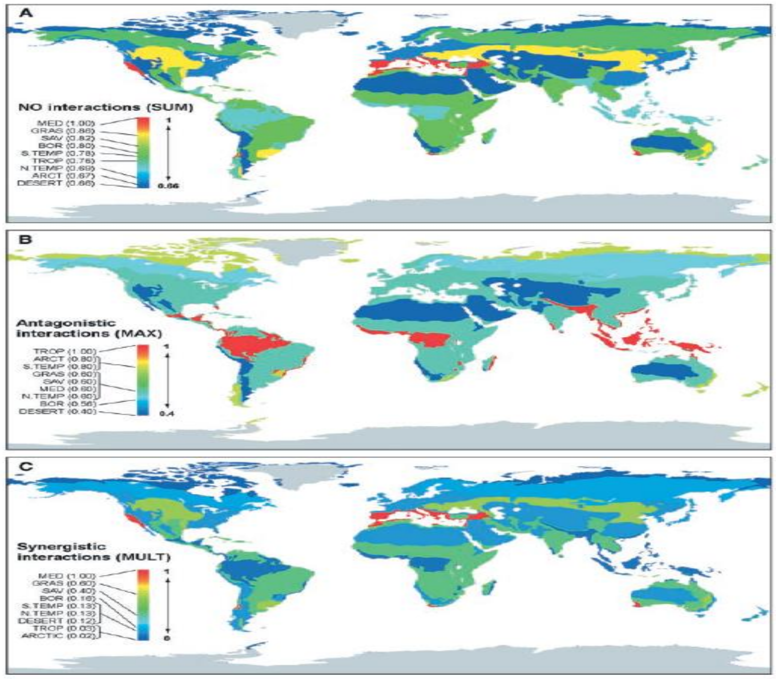


Fig. 2. Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of

Sala et al. 2000

Which ecosystems will be most affected in 2100?



Sala et al. 2000

Fig. 3. Maps of three scenarios of the expected change in biodiversity for the year 2100. **(A)** There are no interactions among drivers of biodiversity change; consequently, total change is calculated as the

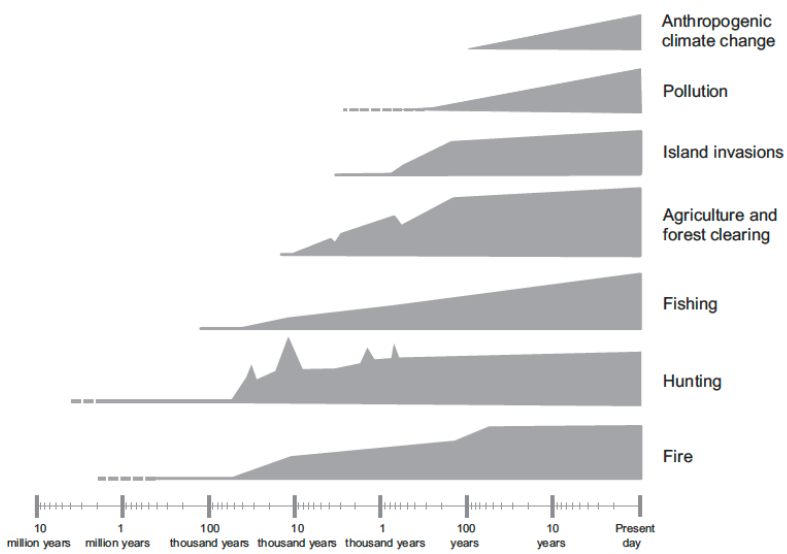


Figure 2

Qualitative representation of the temporal evolution of the main anthropogenic drivers of biodiversity change. References used for dating the pressure trend of each driver: fire (23, 24), hunting (28), fishing (160), agriculture and forest clearing (36, 40, 41), species invasions on islands (42), pollution (2), and anthropogenic climate change (138).

Pereira et al. 2012

Habitat Destruction

- Primary cause of biodiversity loss today.
- Results from expanding population growth and human activities.
  - Forest clearing
  - Agriculture
  - Urban development
  - Land use change, etc
- Limits resources for organisms or alters how they interact with other organisms.
- *Immediate* or *direct* impacts on ecosystems or biodiversity.

Habitat Destruction

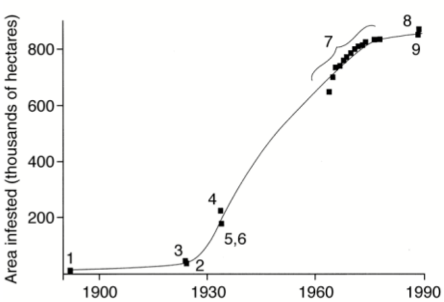
- Native species might have to relocate or they will die.
- Declining population of one species can affect an entire ecosystem—**keystone species**, for example.
- **Habitat fragmentation**: a closely related process to habitat destruction.
  - Separation of an ecosystem into smaller pieces of land.
  - Reduces the opportunities for individuals in one area to reproduce with those of another area (***reproductive barrier***).
  - Increases ***edge effect*** (different environment – abiotic conditions, that occur along the boundaries of an ecosystem.)
    - Renders species more vulnerable to predators and parasites
    - Not always a disadvantage; some species may find these conditions favourable.

Invasive Species

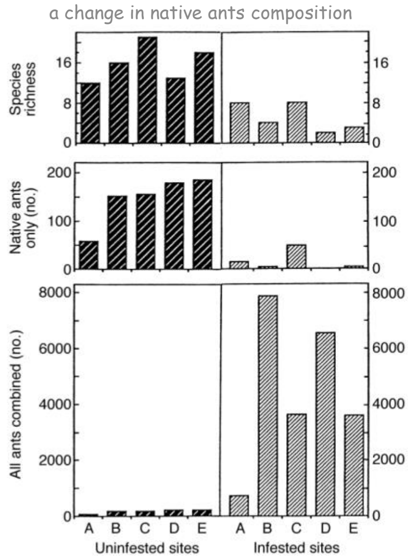
- Nonnative species intentionally or unintentionally introduced into a new habitat.
- Worldwide environmental problem.
  - Second major threat to native biota after habitat destruction.
  - Accounts for about 40% of extinction since 1750.
  - Control costs runs into billions of dollars.

Invasive Species

- Invader populations in new ranges have been accelerating with pronounced "lag" and "log" phases of spread.
- Usually outcompete the native species for resources.



Invasion of Brazilian ant in Texas causes a change in native ants composition



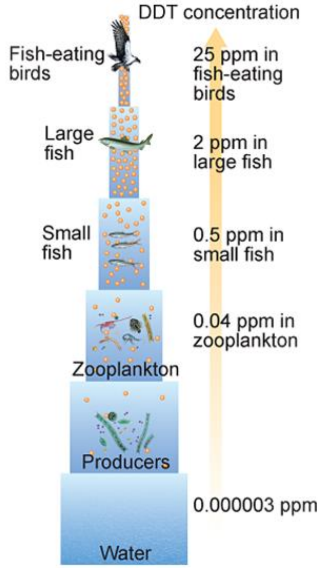
Mack *et al*. 2000

Pollution

- Air, water and land pollution
- Degrade the environment
- Threatens biodiversity and stability of ecosystems, globally.

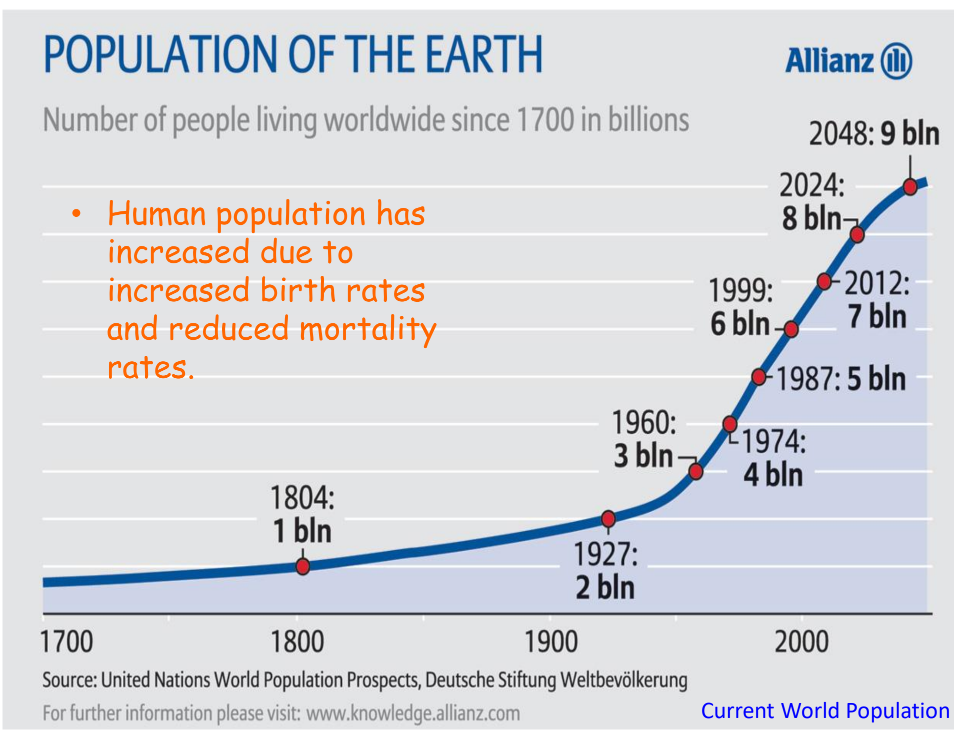
Pollution

- **Biological magnification**
  - Increasing concentration of toxic substances in organisms as trophic levels increase.
  - E.g., pesticides such as DDT.
- **Acid rain**
  - Sulphur and nitrogen compounds react with water and other substances in air to form sulphuric acid and nitric acid.
  - Precipitation of these acid removes calcium, potassium, and other nutrients from the soil, depriving plants of nutrients.
  - Damages plant tissue and slows growth.
  - May cause fish and other organisms to die, if concentrations are high.



Pollution

- **Eutrophication**
  - Occurs when fertilizers, animal wastes, sewage, or other substances rich in nitrogen and phosphorus flow into water ways causing extensive algal growth.
  - Algae use up the oxygen supply during their rapid growth, and after their deaths during the decaying process.
  - Eutrophication is a natural process, but human activies have accelerated the rate at which it occurs.



- Human population has increased due to increased birth rates and reduced mortality rates.

Current World Population

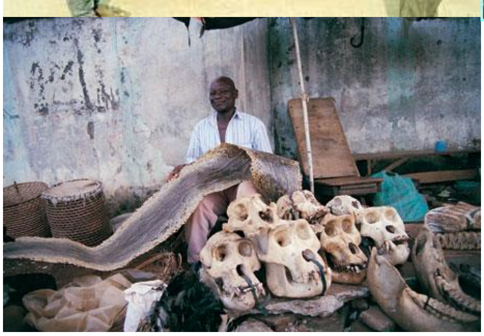
Human population growth

- Human population growth exacerbates every other environmental problem.
  - Use of resources inevitable
- The ***impact (I)*** of population growth is the result of ***population size (P),*** the level of ***affluence (A)*** measured as the *per capita consumption*, and the ***technologies*** *and socio-political-economic arrangements* ***(T)*** required to service the consumption.

I = PAT

- Human impacts may be felt at great distance
  - the concept of ***ecological footprint*** (the influence of a group of people on both the surrounding environment and locations across the globe, Rees 2001).
  - Citizens of developed countries have wider footprint than those of developing countries.
- The Way Forward: *"Live simply so that others may simply live"*

Overexploitation



- Increased demand for natural resources as standard of living improves.
- Inefficient and wasteful use of natural resources.

Natural Resource Consumption and Sustainable Development

BIOL 452 Biodiversity Conservation and Utilization Lecture

Natural Resources

Goods and services supplied by the environment.

Basis of life on earth; some satifying our wants.

Two types of natural resources

Renewable natural resources

- Replaced by natural processes faster than they are consumed.

- Replenish themselves in a relatively short time.

Two types of natural resources

Renewable natural resources

- Quantity not noticeably affected by human consumption.

- E.g., forests (plants and animals), soils, water, wind, solar, etc.

Two types of natural resources

Non-renewable natural resources

- Limited in quantity; finite.
- Used at a faster rate than nature can replenish them.
- May be replaced by natural processes *over extremely long periods of time* not useful to humans.

Two types of natural resources

Non-renewable natural resources

- May be *recyclable* but overall supply remains relatively constant.
- E.g.,fossil fuels, minerals, etc.

Consumption of Non-renewable Natural Resources

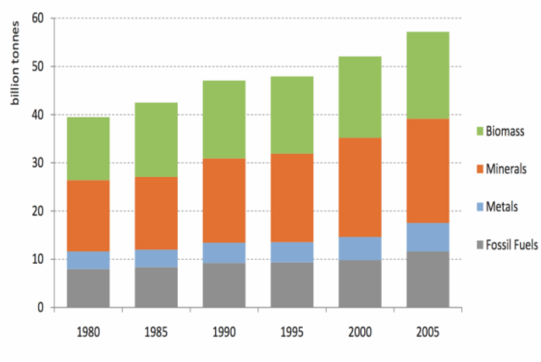
Humanity's consumption of non-renewable natural resources is increasing mainly due to:

- Increasing human populations
- *Per capita* demand rises.

Global extraction of natural resources, 1980 to 2005

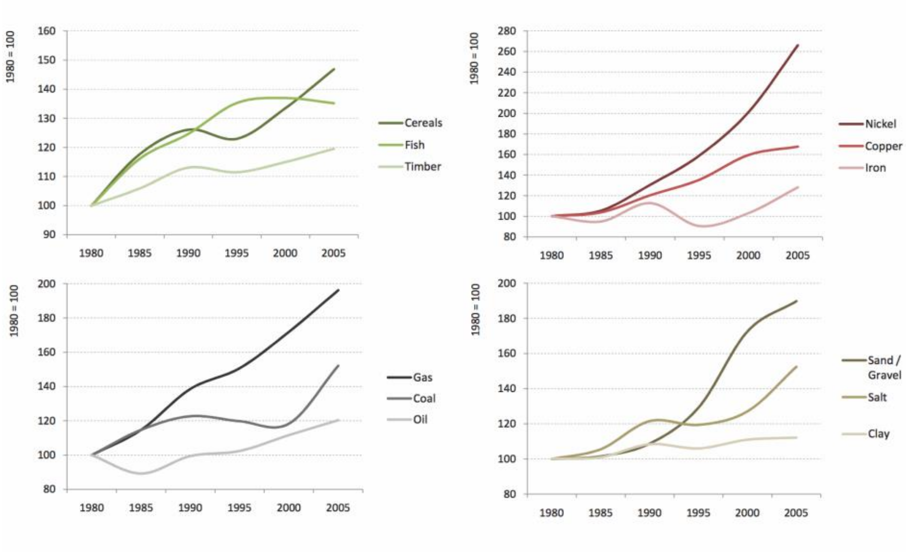
Humans extracted and used ~ 50% more natural resources between 1980 and 2005.

- About 60 billion tonnes a year.
- 100 billion tonnes by 2030.

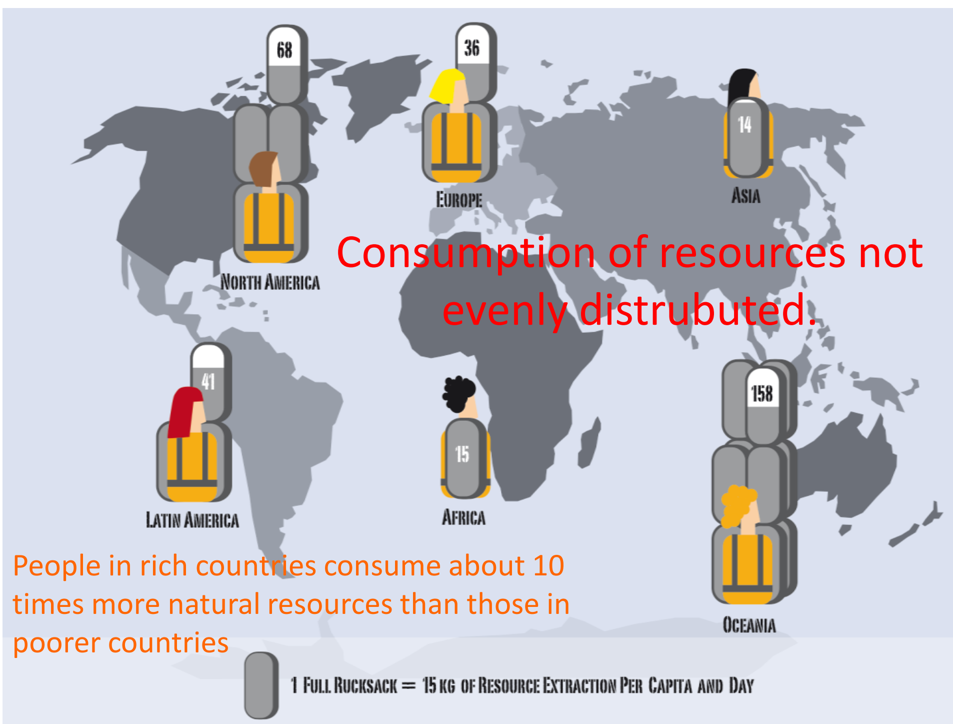


Credit: SERI

Trends in world-wide resource extraction of selected minerals, 1980 to 2005



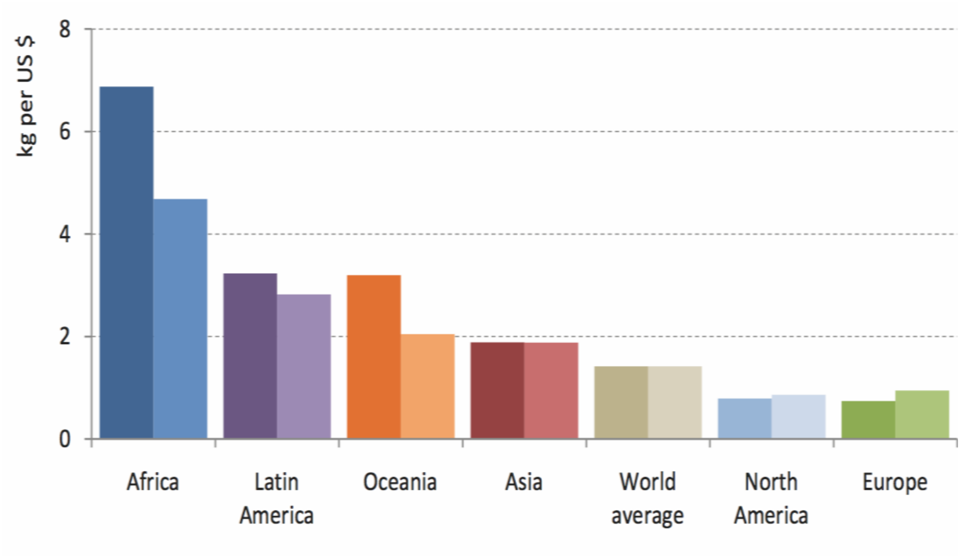
Credit: SERI



Consumption of resources not evenly distrubuted.

People in rich countries consume about 10 times more natural resources than those in poorer countries

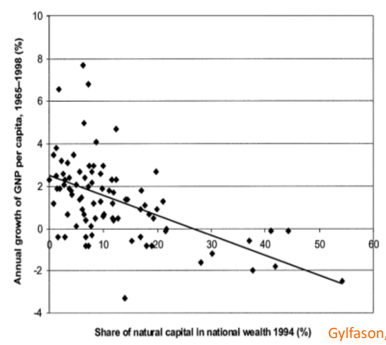
Resource extraction (darker column) and consumption (lighter column) in kg per US$ of GDP, 2000



Credit: SERI

What are the effects of increasing natural resource consumption?

- Slows down economic growth (the natural resource curse).
- Generates lots of waste.
- Damage to the environment.
- ***Increases threat*** to natural resources, raising the issue of ***sustainability***, and the need for ***conservation***.



Gylfason, 2001

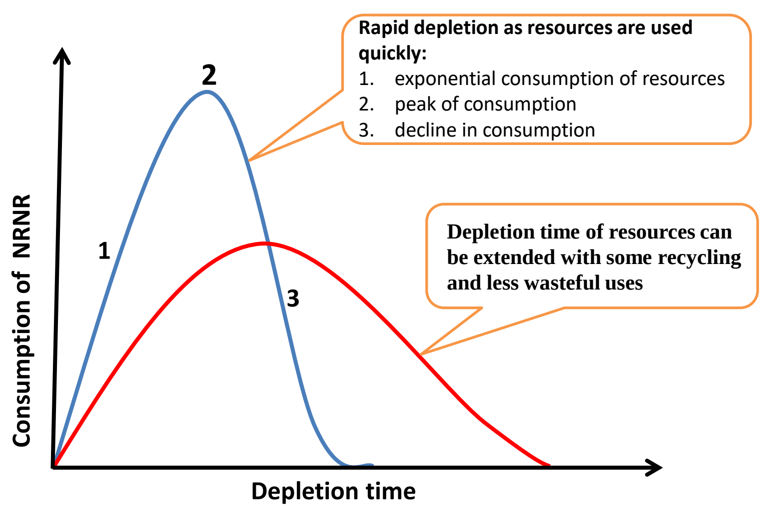
What is sustainable resource use?

- Using resources at a rate at which they can be replaced or recycled while preserving the long-term environmental health of the biosphere.

- Can be practiced through
  - Recycling
  - Conserving
  - Preserving ecosystems
  - Using the environment responsibly

Two schools of thought regarding sustainability of resource consumption and availability

1. Malthusian view



1. Malthusian view

- Most resources would become exhausted.
- Finding new resources cannot sufficiently extend the depletion curve.
- Peak of consumption always followed by a decline; resources become more difficult to find and process.
- Technology will not overcome inevitable shortages.

1. Malthusian view

- Energy requirement to exploit previously inaccessible or less concentrated resources may not be met.
- Malthusians advise us to
  - Cut back on growth
  - Conserve resources
  - Recycle resources when possible

2. Cornucopians view

- Technology will put off the day when no further exploitation is possible.
- Improved technology will make it possible to
  - Find new resources
  - Exploit new reserves
  - Substitute one mineral or energy source for another.

2. Cornucopians view

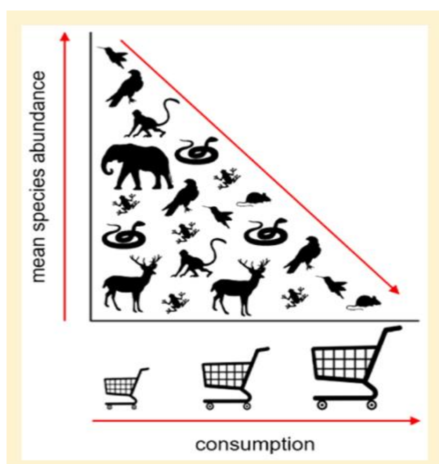
- Poorer grades of mineral ores may be utilized.
  - E.g., 0.3% copper ore can be used now as opposed to 3% in the past.
- Nuclear energy will help meet the energy requirement.
- Given time, a new plenty energy source would be found.

Nuclear energy plant

Human Consumption and Biodiversity Loss

Biodiversity Footprints of Rising Human Consumption

- Rising consumption of goods and services in modern industrialized societies adversely affects biodiversity and ecosystem services.
- That is **consumption-based biodiversity losses** or **biodiversity footprint**.



Wilting et al. (2017). Quantifying biodiversity loss due to human consumption: a global-scale footprint analysis. American Chemical Society Publications. 9pp.

Table 2. Total (Million MSA-loss·ha·yr) and Per-Capita Biodiversity Footprints (MSA-loss·ha·yr) of 10 Countries/Regions in 2007[a]

country	total footprint	footprint per capita	domestic share (%)	import share (%)	land use (%)	GHG (%)
Africa	668	0.7	94	6	90	10
China	539	0.4	89	11	48	52
Europe	811	1.4	70	30	55	45
India	281	0.2	91	9	65	35
Japan	138	1.1	46	54	48	52
North America	977	2.2	83	17	58	42
Oceania	162	4.6	89	11	78	22
Rest of Asia	783	0.6	82	18	66	34
Russia	348	2.4	92	8	77	23
South America	539	1.2	94	6	80	20
World	5246	0,8	100	0	66	34

[a]Contributions of domestic and foreign pressures, and GHG emissions and land-related pressures.

- Biodiversity footprint per citizen show large variations across countries, with higher values when *per-capita* income increases.
  - Higher in Australia, Canada, Finland and USA
  - Lower in China, India, and Indonesia
  - In Europe, 2-3 times higher than available areas on the continent.

Wilting et al. (2017).

Trade in Biodiversity Footprint

- Telecoupling of environmental and socioeconomic systems over large distances
  - Reliance on resources cultivated, extracted or processed in other parts of the world.
  - More than 50% of footprint occurring in faraway places. E.g., 30% of global species threat in Global South attributed to production of agricultural materials, textiles and other raw materials destined for consumption in the Global North

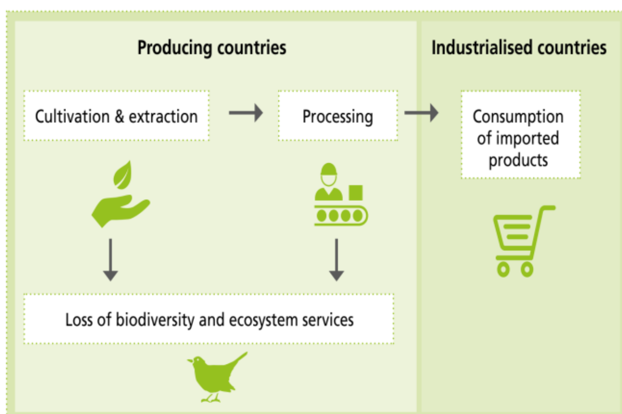


Figure 1: How consumption leads to loss of biodiversity and ecosystem services worldwide

Kliem et al. (2019). Sustainable consumption for biodiversity and ecosystem services: the cases of cotton, soy and lithium. Federal Agency for Nature Conservation, Germany. 84 pp.

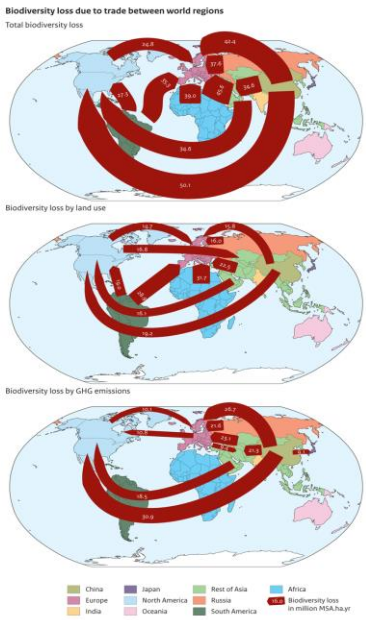


Figure 2. (a−c) Trade in biodiversity loss among 10 world regions and countries, and for the primary pressure categories (total, land use, and GHG emissions). Each part shows the ten trade flows causing the highest losses. The arrows start in the regions where the pressures take place and end in the consuming regions. Losses are measured in million MSA-loss·ha·yr.

- Europe, North America and Japan imported far more biodiversity losses than they exported.
- Large countries such as Brazil, Russia, India, Australia, China and Indonesia imported less (< 15%) because they are self-sufficient in producing food products.

Table 2. Total 2007[a] iodiversity Footprints (MSA-loss·ha·yr) of 10 Countries/Regions in

country	domestic share (%)	import share (%)	land use (%)	GHG (%)
Africa	94	6	90	10
China	89	11	48	52
Europe	70	30	55	45
India	91	9	65	35
Japan	46	54	48	52
North America	83	17	58	42
Oceania	89	11	78	22
Rest of Asia	82	18	66	34
Russia	92	8	77	23
South America	94	6	80	20
World	100	0	66	34

[a]Contributions o ions and land-related pressures.

Most of the biodiversity losses were caused by land-use related pressures.

Wilting et al. (2017).

Environmental Pressures Underlying Biodiversity Footprint

Table 1. Attribution of Environmental Pressures and Biodiversity Impacts to Economic Sectors and Consumers[a]

environmental pressure	biodiversity impacts due to	biodiversity loss factors	attributed to
land use	habitat replacement by cropland (ha·yr)	MSA-loss per ha of cropland	crop sectors (1−8)
	habitat replacement by pasture (ha·yr)	MSA-loss per ha of pasture	livestock sectors (9−12)
	habitat replacement by forestry (ha·yr)	MSA-loss per ha of forestry	forestry (13)
	habitat replacement by urban area (ha·yr)	MSA-loss per ha of urban area	consumers
	fragmentation by cropland (ha·yr)	MSA-loss per ha of cropland	crop sectors (1−8)
	fragmentation by infrastructure (km·yr)	MSA-loss·ha per km road length	all sectors (except agriculture) and consumers
	disturbance by infrastructure (km·yr)	MSA-loss·ha per km road length	all sectors (except agriculture) and consumers
	encroachment (MSA-loss·ha·yr)		consumers
GHG emissions	climate change (kg CO_2-equivalents)	MSA-loss·ha·yr per kg CO_2-equivalents	all sectors and consumers

[a]For sector numbers, see Table S2.

Wilting et al. (2017). Quantifying biodiversity loss due to human consumption: a global-scale footprint analysis. American Chemical Society Publications. 9pp.

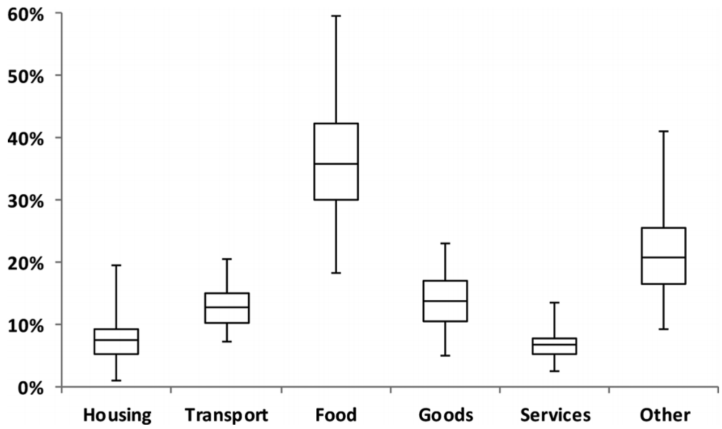


Figure 1. Contribution of different categories of consumption to total biodiversity loss due to GHG emissions and land use. Boxes show the first and third quartiles (25−75%), and whiskers show the ranges for 45 countries/regions. The consumer demand for each of the 48 industries was aggregated to six main consumption categories, i.e., housing, transport, food, goods, services and other consumption; "other" includes category "Not allocated" (see SI, Text Section S5 and Table S3).

Food consumption is the most important driver of biodiversity loss in many countries and regions.

Wilting et al. (2017).

Key Impacts of Human Consumption on Biodiversity

- **Loss of habitats**
  - Often the results of change in land use as production sites expand to meet increasing demand
  - Most important global driver of biodiversity loss

- **Pollution of water and soil**
  - Linked to industrial agricultural processes
  - Primarily caused by agrochemicals and chemical agents used in processing

- **Loss of freshwater resources**
  - Irrigation and resource extraction processes often required enormous amount of water.

Kliem et al. (2019)

Case Study: Cotton Consumption in Germany

- Cotton is one of the main resources of Germany's clothing industry
  - Cotton accounts for 30% of total textile fibre consumption worldwide.
  - Germany consumed approx. 4% (i.e., 760,000 tonnes of textiles, 218,000 tonnes of fibre, yarn and fabric) of the 25 m tonnes of cotton produced worldwide in 2016.
  - Imported 64% of its cotton from India, China, Pakistan and Turkey.

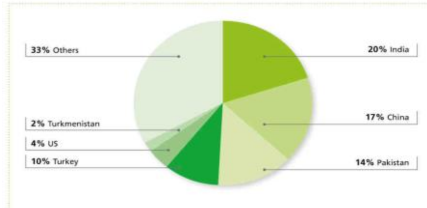


Figure 7: Origins of cotton imports to Germany in 2016; *Source: Eurostat Comext*

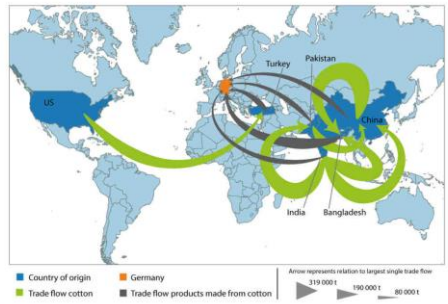
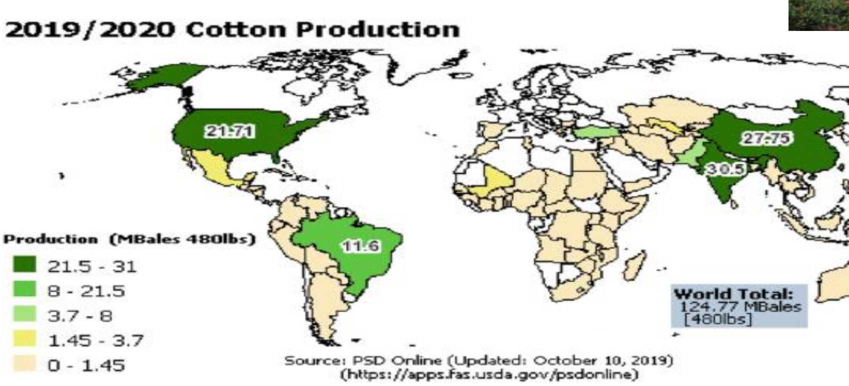


Figure 8: Trade flows of cotton and cotton products imported into Germany from outside the EU in 2016 (in tonnes); *Source: Eurostat Comext*

Case Study: Cotton Consumption in Germany

- Cotton is a water-intensive, pest-prone crop, grown primarily in semi-arid, water-scarce regions.



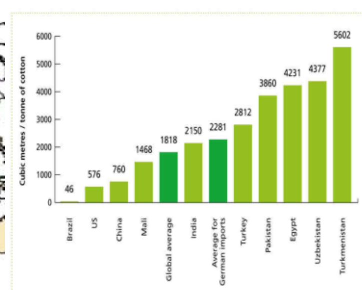


Figure 9: Average irrigation water usage per tonne of cotton production by country
Source: Chapagain et al. (2006), see endnote 44

Case Study: Cotton Consumption in Germany

- Impacts on biodiversity
  - Large-scale cotton irrigation can lead to changes of an entire aquatic ecosystems.
    - 2,300 million cubic metres of water required annually to satisfy the cotton deman of German consumers.
    - Enough water to fill 920,000 Olympic-size swimming pools
  - Cotton cultivation relies heavily on the use of pesticides and other agrochemicals.
  - Processing such as dyeing and textile finishing brings about additional environmental pressures in producer countries.

Main drivers	Impact on biodiversity	Impact on ecosystem services
Land conversion	→ Loss of highly biodiverse forests and grasslands → Destruction and changes in habitats threaten species	→ Depletion of permanent soil cover and associated functions → Depletion of carbon storage → Loss of buffering soil functions
Agricultural intensification	→ Reduced biodiversity due to intensive use of agrochemicals, especially pesticides → Decreased agrobiodiversity due to monoculture production → Loss of genetic diversity due to increasing use of genetically modified varieties	→ Contamination of river systems, groundwater and aquifers → Long-term persistence of pollutants in soils, reducing soil function → Reduction of pollinators and associated functions
Irrigation	→ Loss of aquatic habitats due to lake and river drainage	→ Severe changes in the hydrology of entire landscapes leading to water scarcity → Increased salinisation degrades soil fertility

Table 7: **Main impacts of cotton cultivation for biodiversity and ecosystem services**

Kliem et al. (2019)