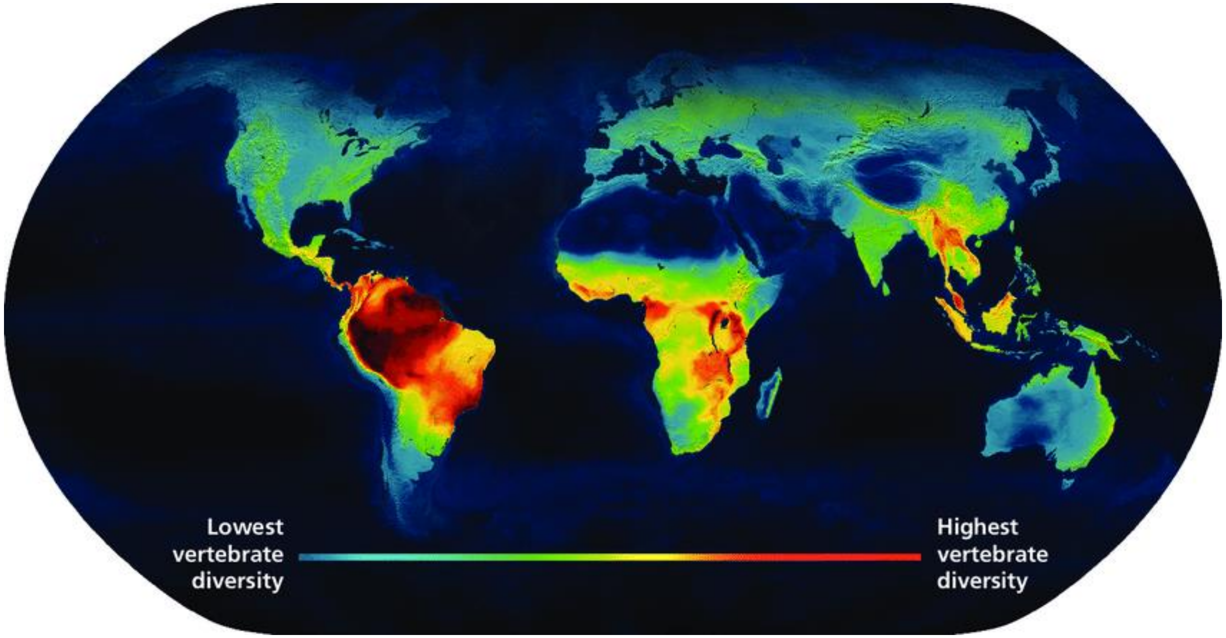
The Physical Environment

- Large-scale environmental drivers of primary production
- Aquatic ecosystems
- Terrestrial ecosystems

The environment

- Understand and predict ecological patterns and processes based on environmental drivers
- What are climate-change impacts on biodiversity and ecosystem processes

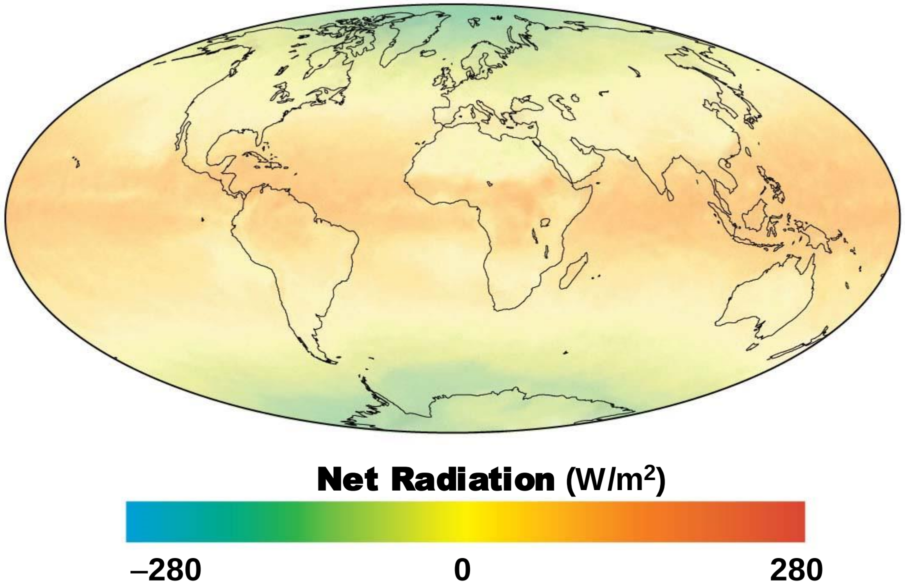


Examples:
How is biodiversity distributed from the tropics towards the poles (these are patterns)?,

What are underlying processes, and how may they respond to climate change?

What would be the impacts on ecosystem functions and services?

Large-scale environmental patterns and processes

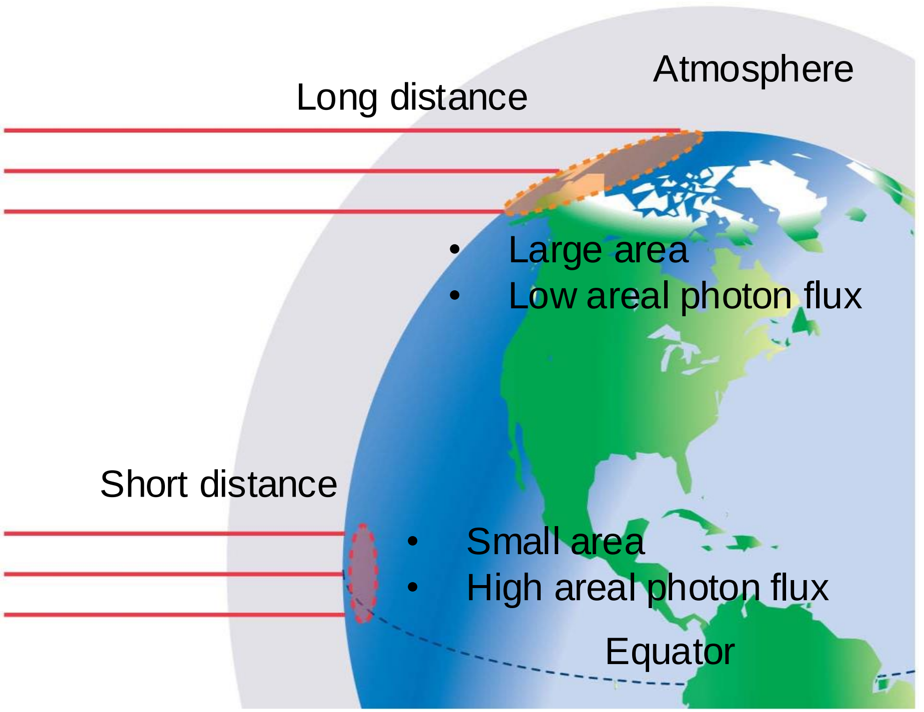


Average annual surface net radiation predictably varies across the globe.

As one moves away from the equator to higher latitudes, the average annual surface net radiation decreases

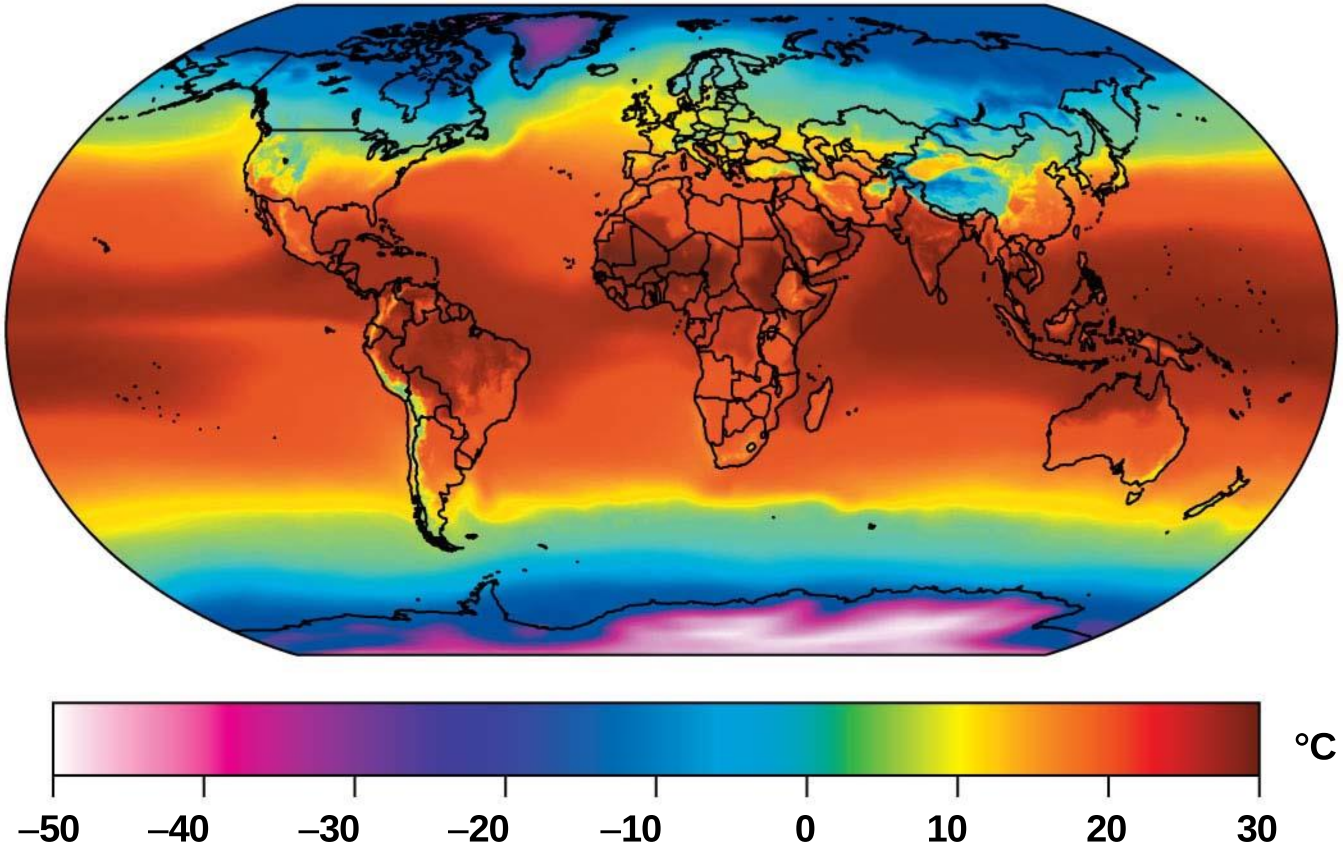
High latitudes:

- The solar radiation travels a longer distance through the atmosphere, hence more radiation is reflected.
- The incoming solar radiation is spread over a larger surface area.



The environment

Distinct spatial pattern of global temperatures — with strong latitudinal (and altitudinal) gradients



The environment

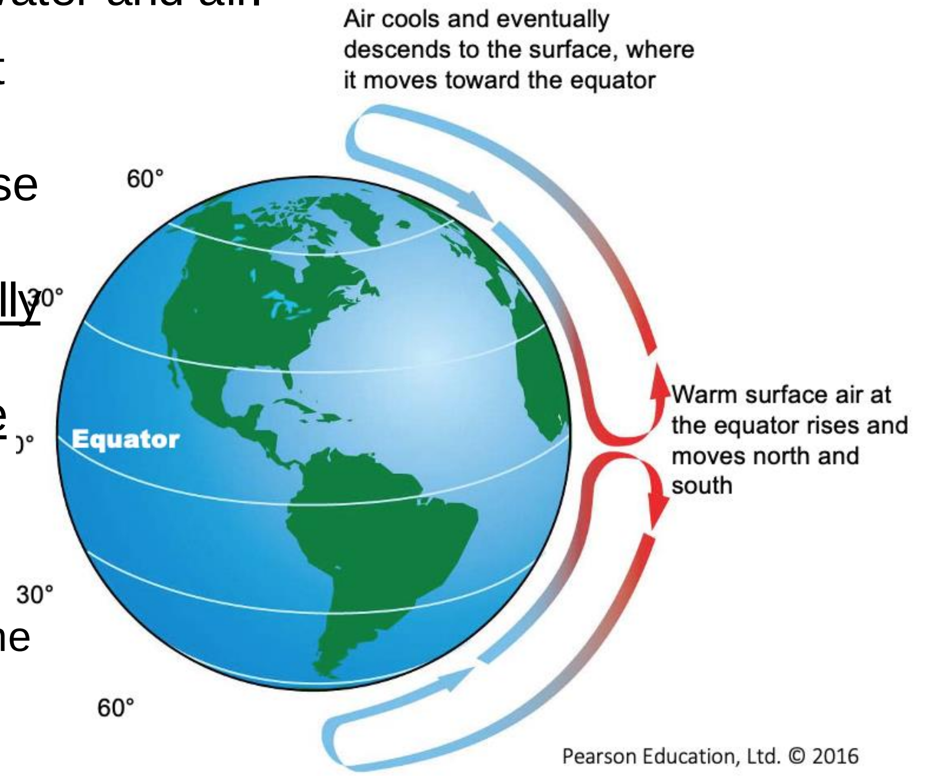
Geographic differences in surface net radiation result in global patterns of atmospheric circulation

Imbalance in net radiation (incoming/outgoing radiation) results in a global pattern of thermal energy redistribution from the equator to the poles.

The primary mechanism of this planetary heat transfer is the process of convection — through the circulation of water and air.

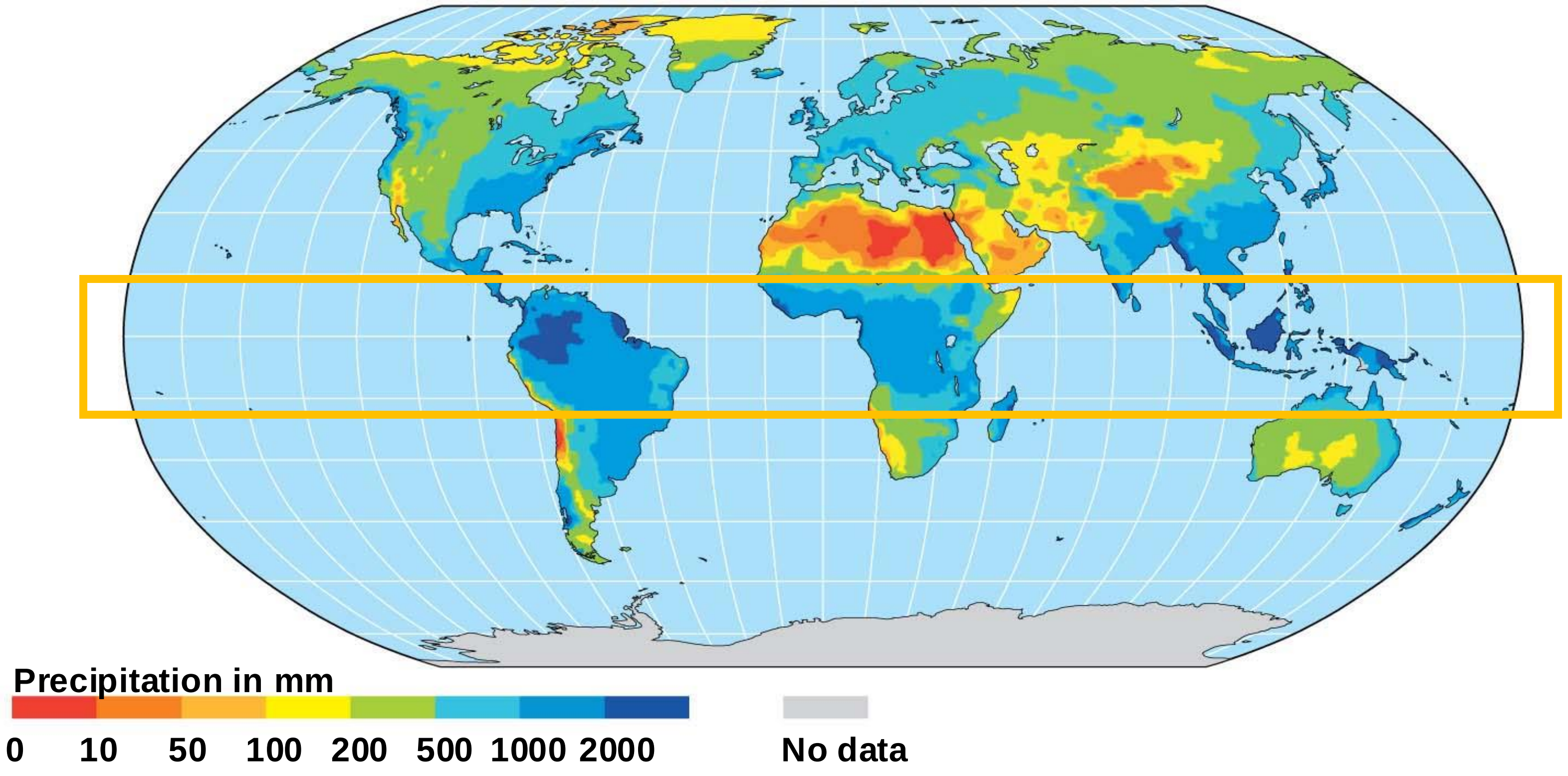
- Solar input highest at equator – greatest net radiation surplus
- Rising of warm air at the equator because it is less dense
- Moves N and S to the poles and gradually cools down
- Cooler air sinks – leads to high pressure at surface

This movement of air creates cells of circulation. The convergence of winds from the N and S at the equator is called the Intertropical Convergence Zone (ITCZ).



The environment

Latitudinal patterns of precipitation



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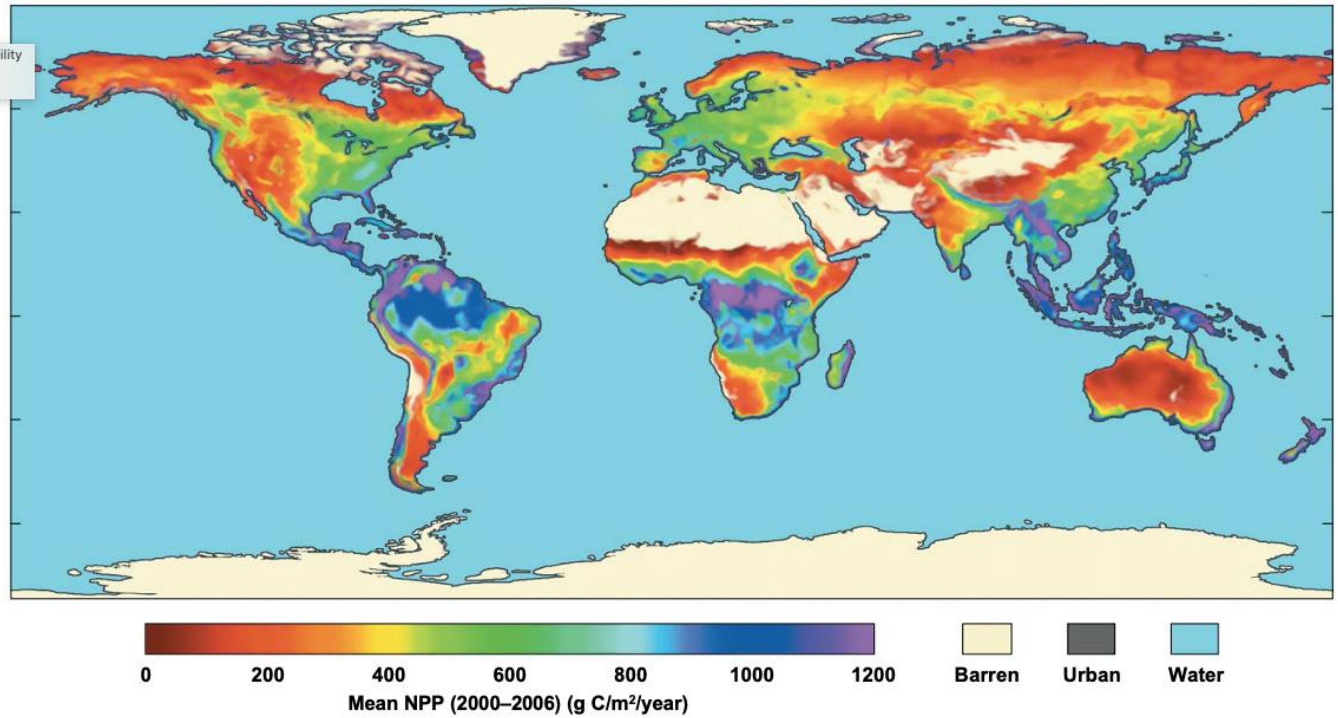
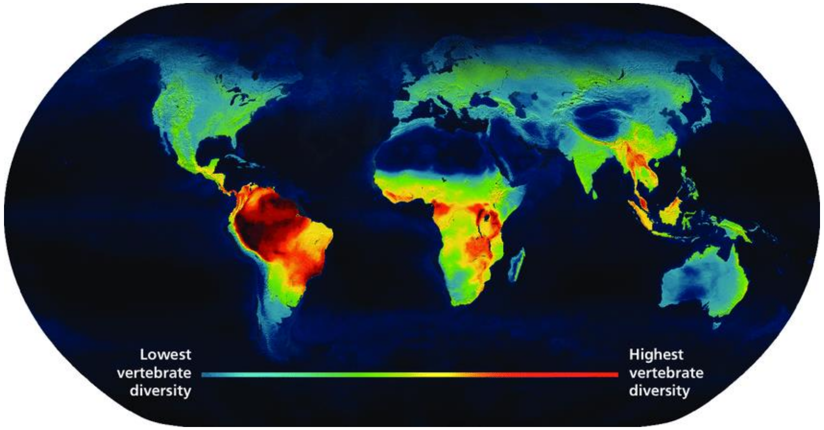
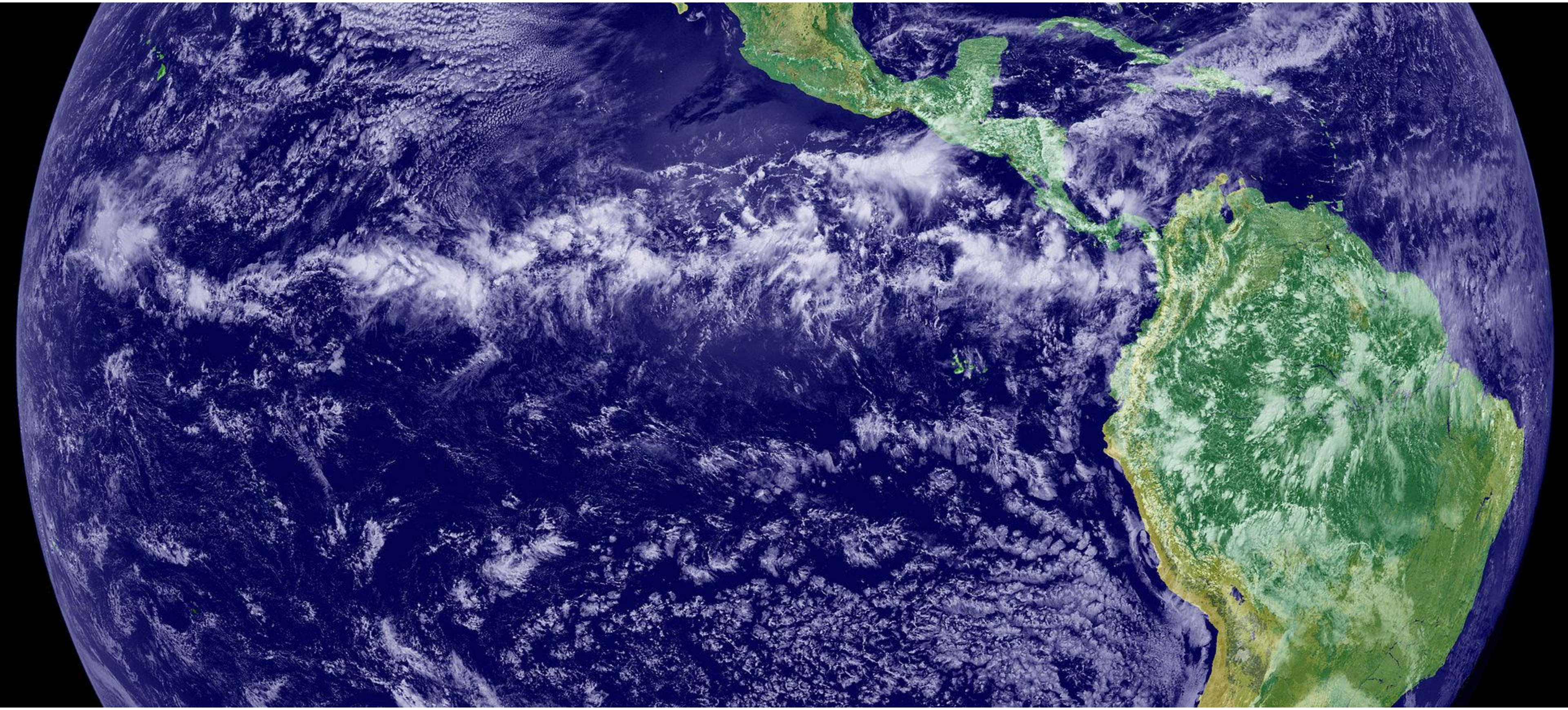
Temperature and precipitation are key drivers of the terrestrial net primary production





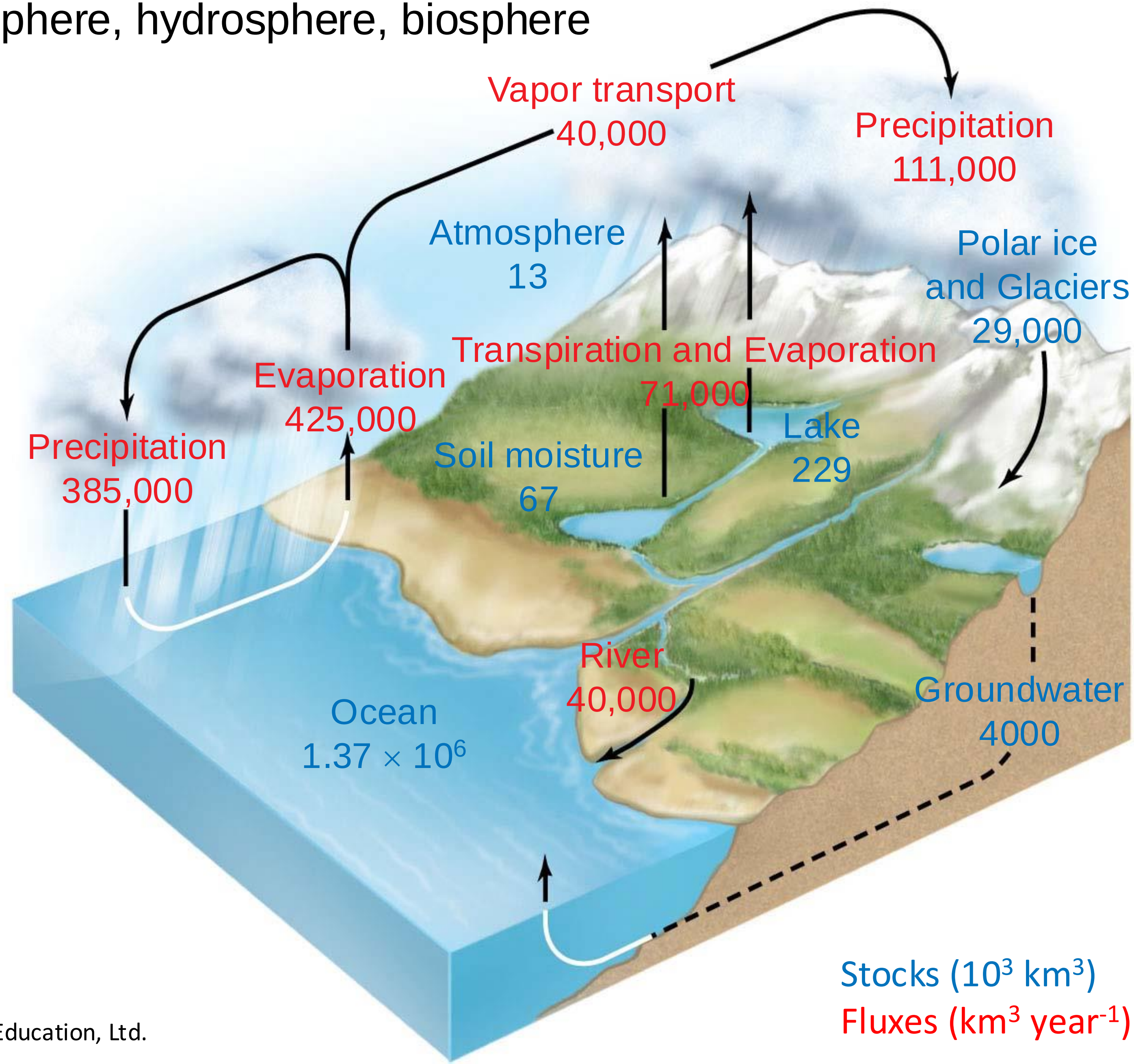
What are the potential relationships between primary production and vertebrate diversity?

Aquatic ecosystems



The water cycle

Integrator of atmosphere, hydrosphere, biosphere



Stocks (10^3 km^3)

Fluxes (km^3 $year^{-1}$)

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Water has important physical properties

Water has a <u>high specific heat capacity</u>

- It requires one calorie to raise one gram of water by 1°C
- Water can store large amounts of heat energy with relatively small increases in temperature

- Water serves as a buffer to temperature fluctuations
- Thermal homeostasis, beneficial to life in the water

Water has important physical properties

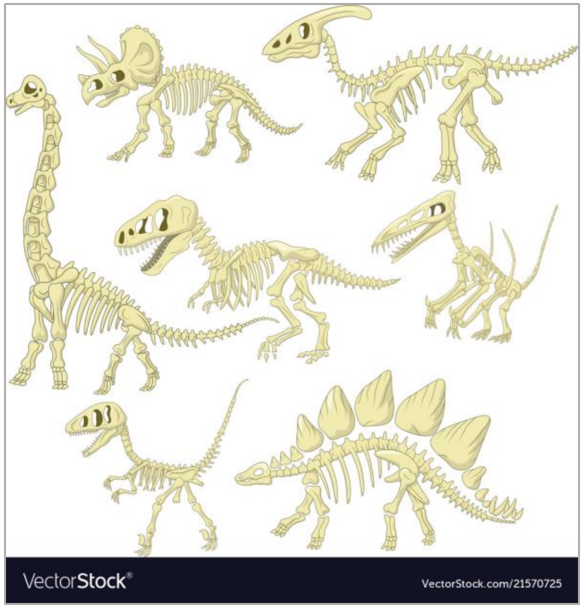
Density of water is about 860 times greater than air

<u>Buoyancy</u> – upward force exerted when a body in water weighs less than the water it displaces.

Reduces the effect of gravity and organisms need less structural support (e.g., skeleton)

Compare the skeleton of a bony fish to a terrestrial vertebrate of the same size.

Energetically advantageous: less resources spent into the production of structural components



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Water has important physical properties

Density of water about 860 times greater than air

Reduces the effect of gravity, hence organisms need less structural support.

Phytoplankton and zooplankton:

- Small organisms with little structural elements floating in the water
- Phytoplankton (suspended algae) is the ”forest” of the lakes and oceans
- Major components of the food web
- Evolutionary highly successful mode of life

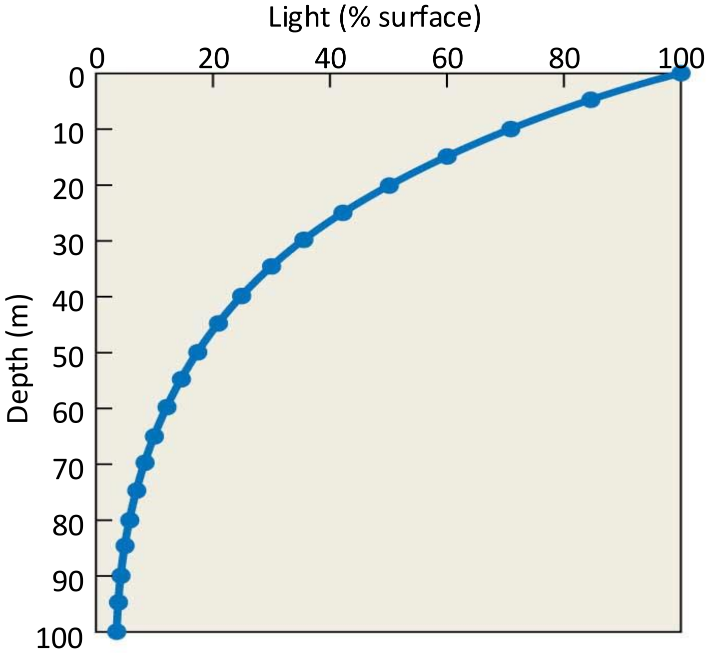
Water has important physical properties

Phytoplankton: The ‘forest’ of the ocean

Phytoplankton relies on light for photosytnthesis

Light varies with depth in aquatic environments

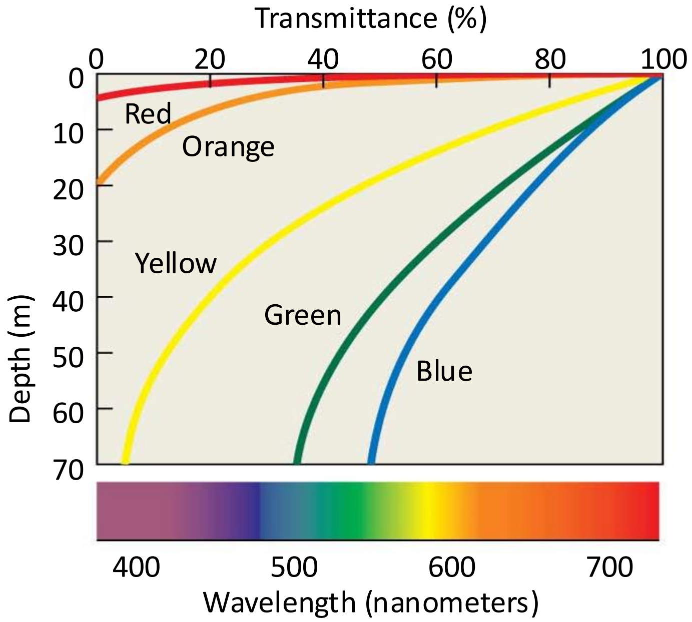
- When light hits the surface of the water, part of it is reflected, the rest is transmitted into the water
- The lower the angle at which it strikes the surface, the more light is reflected; changes with time of the day and season.
- Water itself, dissolved solutes and suspended particles and organisms (e.g., phytoplankton) either absorb or scatter light; this is the attenuation of light.
- Exponential decrease of light intensity with water depth, following the Lambert-Beer's law.



(a)

Light varies with depth in aquatic environments

- Longwave radiation is attenuated more strongly than shortwave radiation
- Shortwave radiation penetrates deeper into water bodies



- Blue appearance of the deeper water landscape
- Consequences for the composition of phytoplankton communities, photosynthesis and primary production

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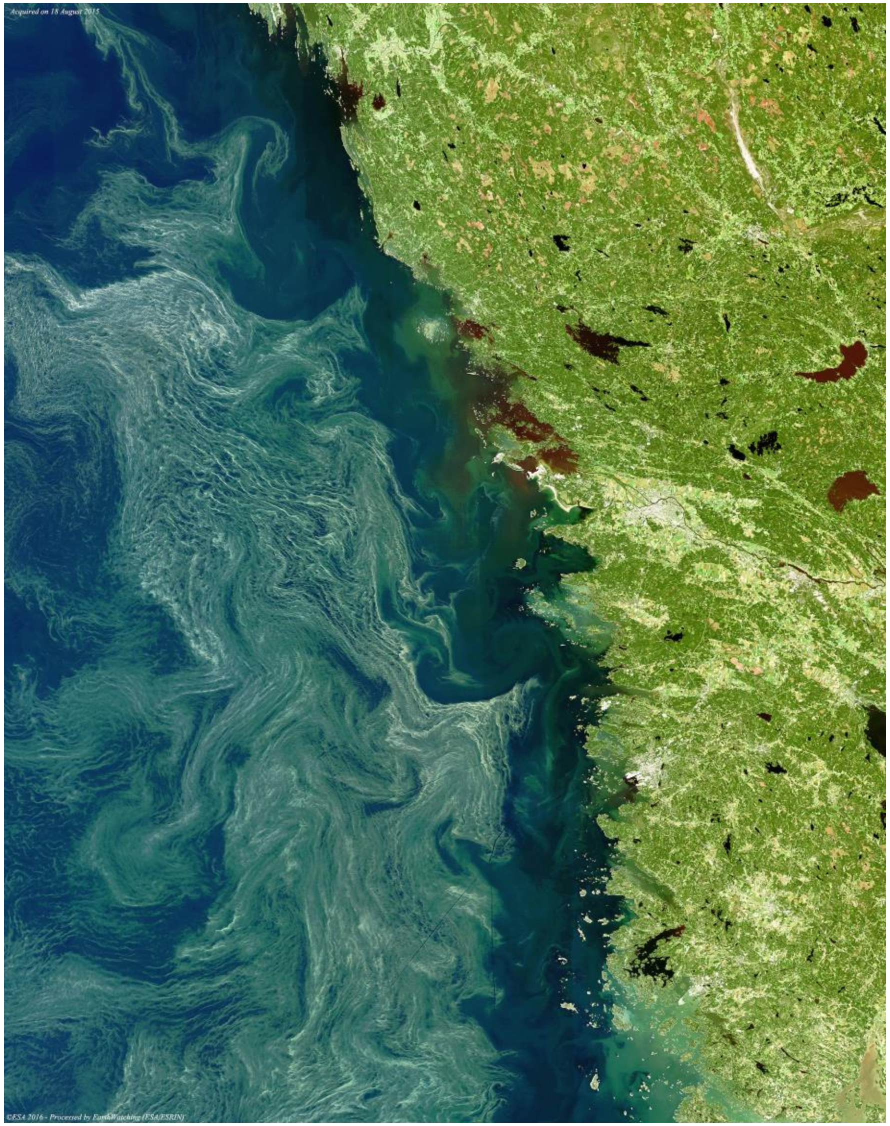
Applied ecology

High inputs of nutrients from terrestrial sources via river flow can induce eutrophication of coastal waters

- High N, P
- High phytoplankton biomass, including toxic cyanobacteria
- Decay of biomass
- Oxygen consumption larger than replenishment leads to deoxygenation
- Fish killing and biodiversity loss



Applied ecology

Gulf of Mexico Hypoxia: Past, Present, and Future

Nancy N. Rabalais and R. Eugene Turner

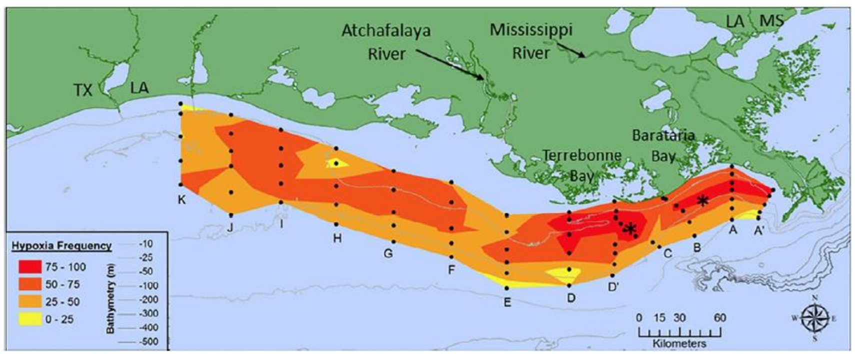


FIG. 1. The frequency of bottom-water hypoxia from shelf-wide hypoxia mapping (1985–2014) (updated from Rabalais et al. (2007b); frequency is determined from stations for which there are data for at least half of all cruises. Asterisks (*) indicate locations of near-bottom oxygen meters; transects C and F identified. Data source: N. N. Rabalais and R. E. Turner.

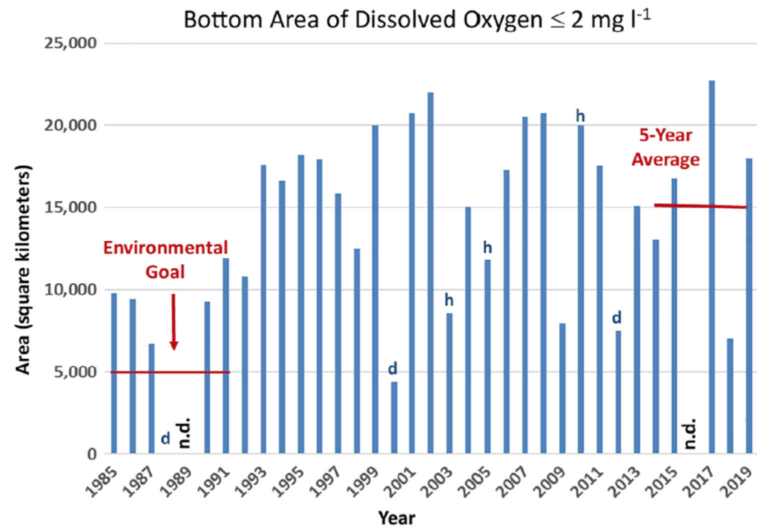
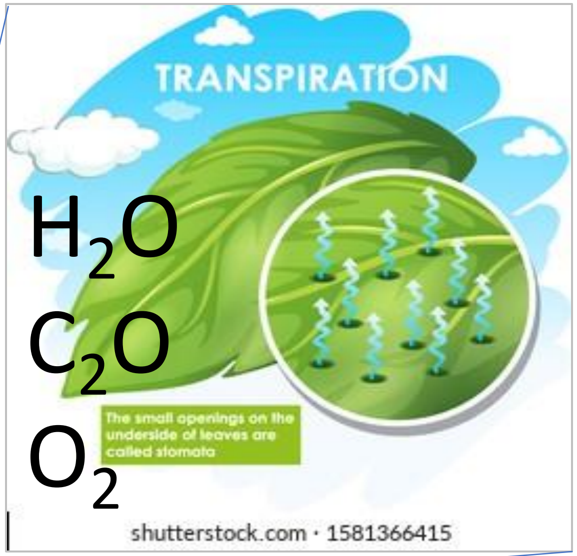


FIG. 2. Histogram of mid-summer bottom-area of dissolved oxygen ≤2 mg l^{-1} on the continental shelf west of the Mississippi River delta since 1985. Events that affect the size of the bottom area are d = drought, h = hurricane or tropical storm activity before or during the cruise to measure the area, w = winds from the west for an extended period before or during the cruise, and n.d. = no data. The only years not included are 1989 (lack of sufficient funding) and 2016 (lack of a suitable vessel).

- Excess nutrients delivered by the Mississippi River cause hypoxia in the Gulf of Mexico
- Up to half the surface area of Switzerland hypoxic
- Conflict of interest: Agriculture versus fisheries

Light and Terrestrial Ecosystems
Soils — The Dark Side

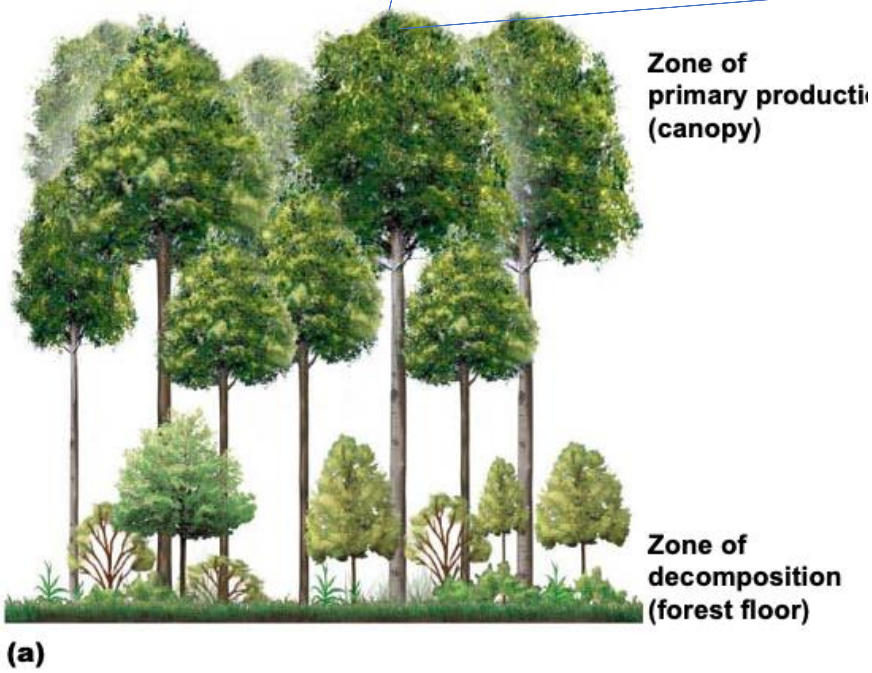
Light and Terrestrial Ecosystems
Soils — The Dark Side



Light:
Production

Light
Water
Nutrients
Organic matter

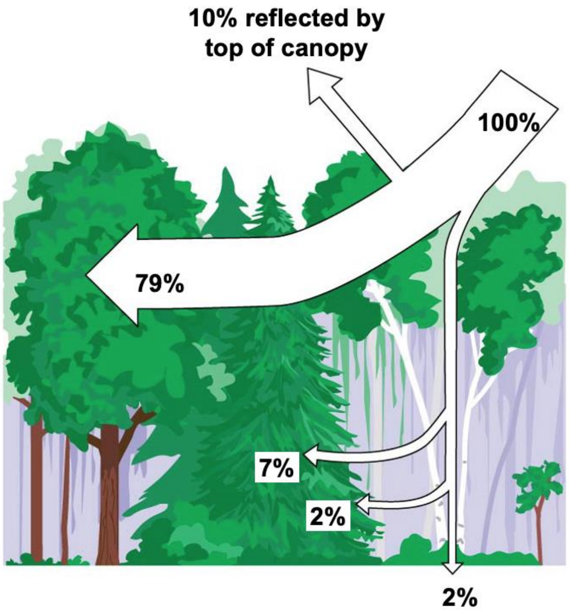
Dark:
Decomposition&
remineralisation

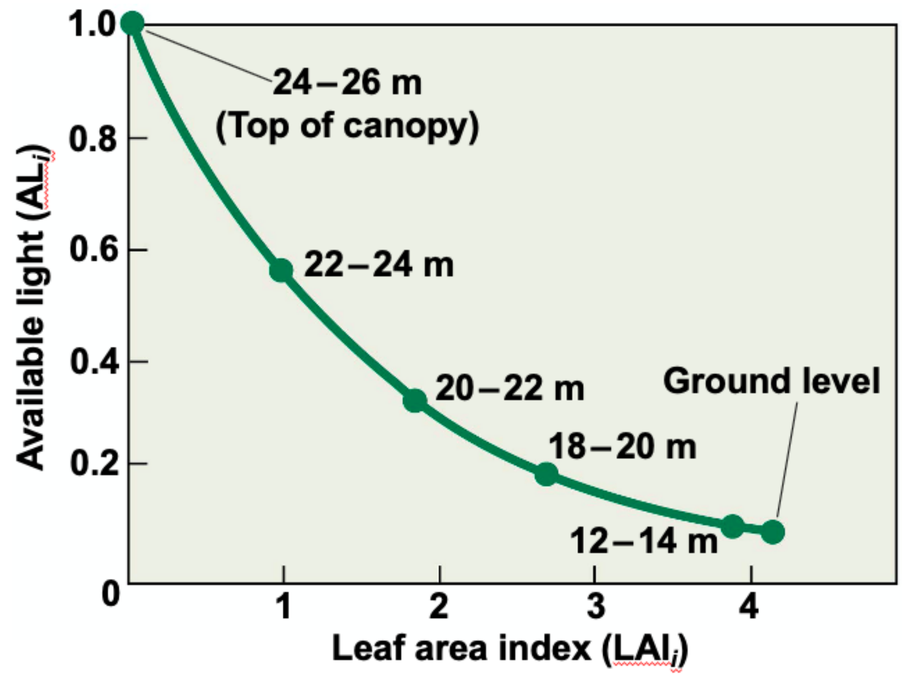


Plant cover influences the vertical distribution of light

What happens to light when it hits the vegetation?

Reflection and absorption — similar to aquatic ecosystems





Exponential decay of available light intensity (Al_i) with the leaf area index following Beer's Law (see aquatic ecosystems)

What is the leaf area index?

EPFL

Plant cover influences the vertical distribution of light

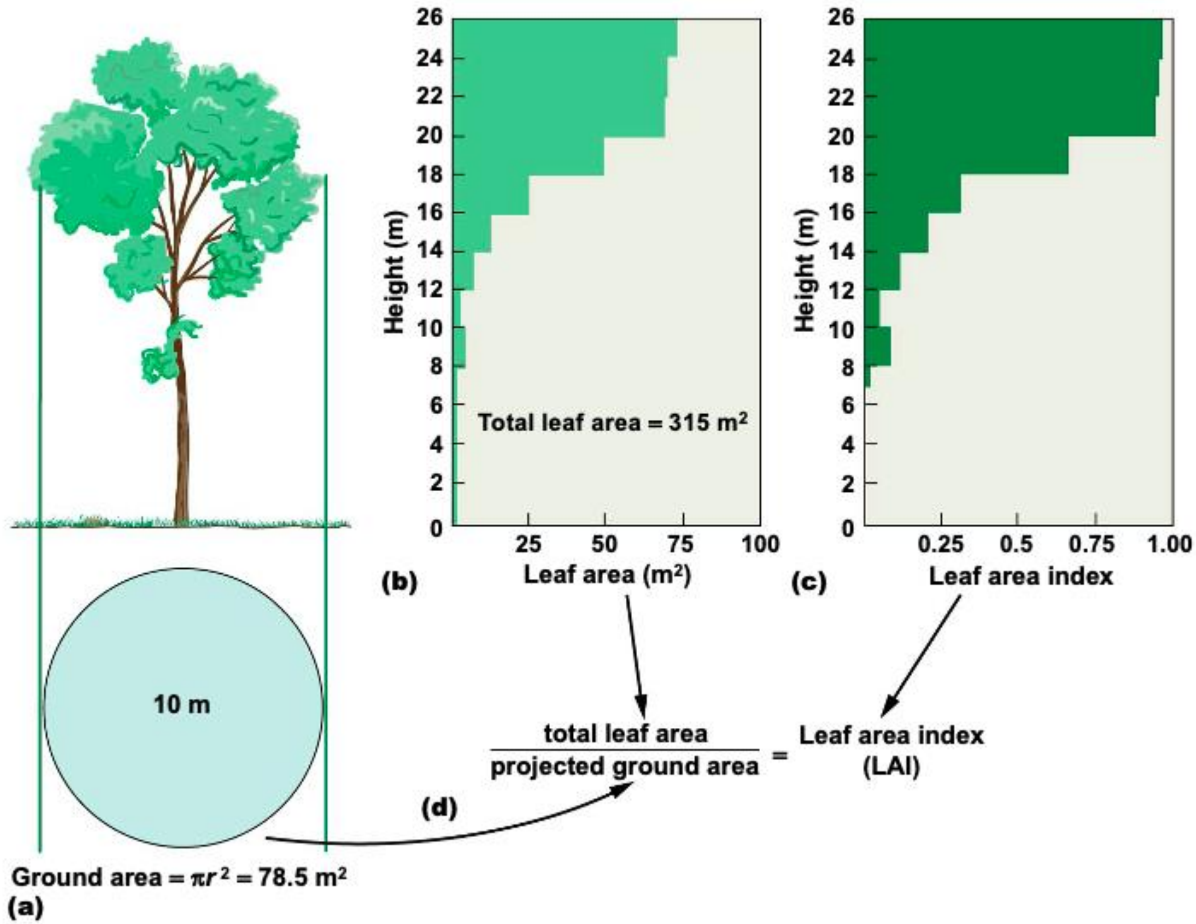
Leaves vary in size and shape and their density (foliage density) changes with height. Hence light intensity changes with height.

Foliage density expressed as leaf area

- leaves are flat
- leaf area measured on one or both sides

Leaf Area Index (LAI)

area of leaves per unit ground area = (m^2 leaf area / m^2 ground area)

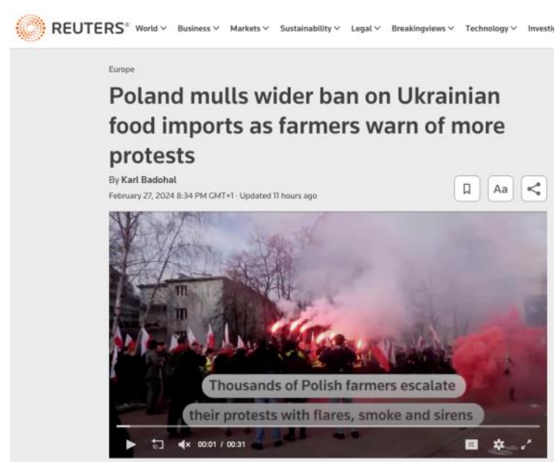


Soils matter for biodiversity, ecosystem functions and services

Soils matter for biodiversity, ecosystem functions and services

Ukraine: the breadbasket of Europe

- Soils rich in organic carbon (OC) (“Chernozem”) offer exceptional agronomic conditions.
- One-third of the worldwide stock of the fertile black soils, which cover more than half of Ukraine’s arable land
- Various climatic zones, favourable temperature and moisture regimes offer attractive conditions for the production of a large range of crops including cereals and oilseeds.


REUTERS World Business Markets Sustainability Legal Breakingviews Technology

Europe

Poland mulls wider ban on Ukrainian food imports as farmers warn of more protests

By Karl Badohal

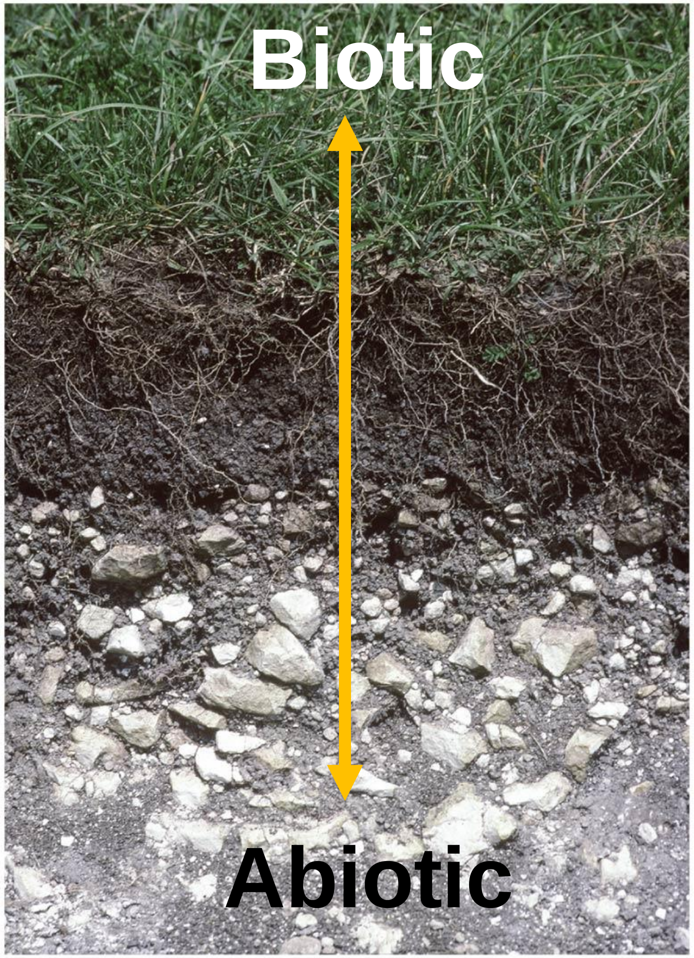
February 27, 2024 8:34 PM GMT+1 · Updated 11 hours ago

Soil is the foundation upon which terrestrial life depends

Soil includes both abiotic and biotic components
Transition from the abiotic to the biotic domains
The base of the soil is hard unweathered rock

Soil:

- the medium for plant growth
- the initial recipient of water, also controlling its fate
- a recycling system



Soil formation: weathering

Mechanical weathering results from the interaction of

- water – seeping into crevices
- temperature – if water freezes and expands, it can break the rock into smaller pieces
- wind – scours the surface with dust and sand
- organisms – plant roots can split rocks

Mechanical weathering breaks rocks and minerals into smaller particles but does not change them chemically

Soil formation: weathering

<u>Chemical weathering:</u>

Chemical weathering transforms the original rocks and minerals

- Water and respiratory CO_2 form carbonic acid
- Dissolved mineral matrix

Soil formation: climate

Climate influences soil development via the physical and chemical reactions that break down parent material

- temperature controls biochemical reaction rates
- water from precipitation is required for chemical weathering and leaching

Weathering, leaching, and plant growth

- maximized under warm temperatures and abundant water
- much less influence under cold, dry conditions

[See tropics versus deserts]

Soil formation: biology

<u>Biotic factors</u> contribute to soil formation

- Plants transfer organic carbon (from photosynthesis) into the soil
- Roots break up parent material, stabilize soil surface, reduce erosion, bring nutrients to the surface
- Animals burrow and dig into the soil, promotes advective gas exchange
- Fungi and bacteria decompose the remains of organisms, increasing organic material in the soil

Soil formation: time

Time is important in soil formation

All of the factors discussed work over long periods of time

The formation of well-developed soil may take 2000 to 20,000 years!

Therefore, soils are a precious resource!

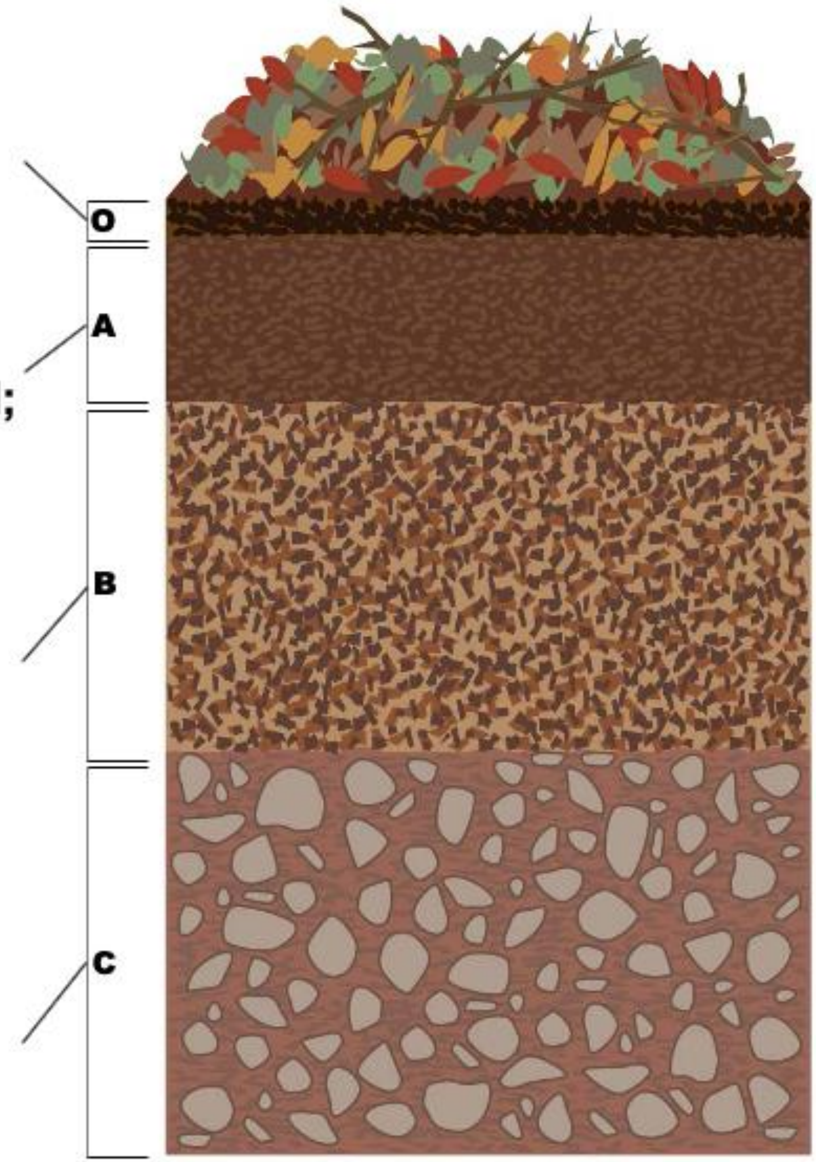
The soil has horizontal layers or horizons

Organic layer: dominated by organic material, consisting of undecomposed or partially decomposed plant materials, such as dead leaves

Topsoil: largely mineral soil developed from parent material; organic matter leached from above gives this horizon a distinctive dark color

Subsoil: accumulation of mineral particles, such as clay and salts leached from topsoil; distinguished based on color, structure, and kind of material accumulated from leaching

Unconsolidated material derived from the original parent material from which the soil developed



Physical soil characteristics

Soil texture relates to the proportion of different-sized soil particles, the distribution of which partly a results from parent material and soil-forming process

Classification of soil texture is based on proportions of:

sand – 0.0 to 2.0 mm
silt – 0.002 to 0.05 mm
clay – less than 0.002 mm

Clay content controls

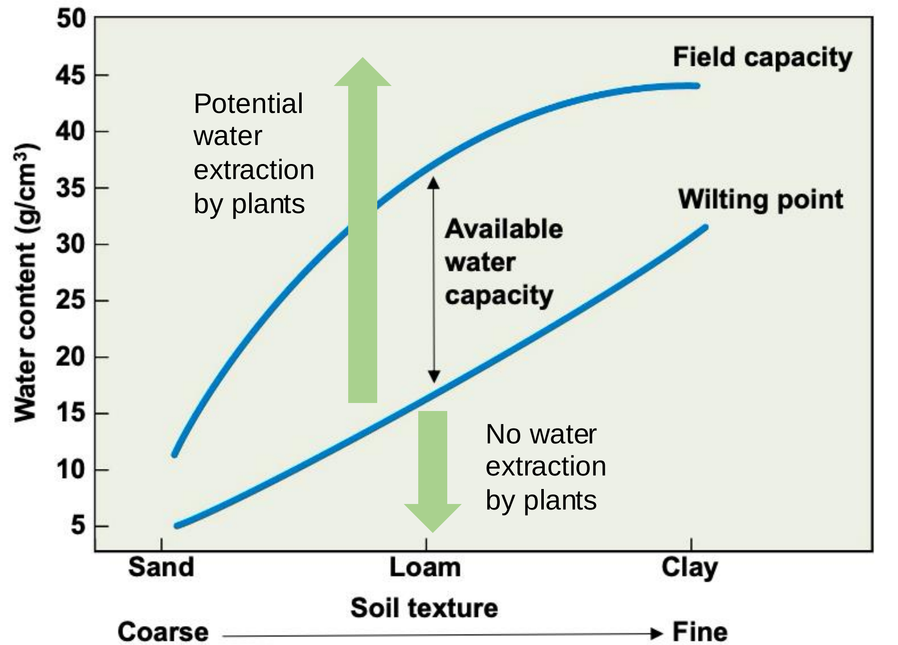
- exchange of ions between particles and solution and hence fertility
- water-holding capacity

Water-holding capacity is an essential feature of soils

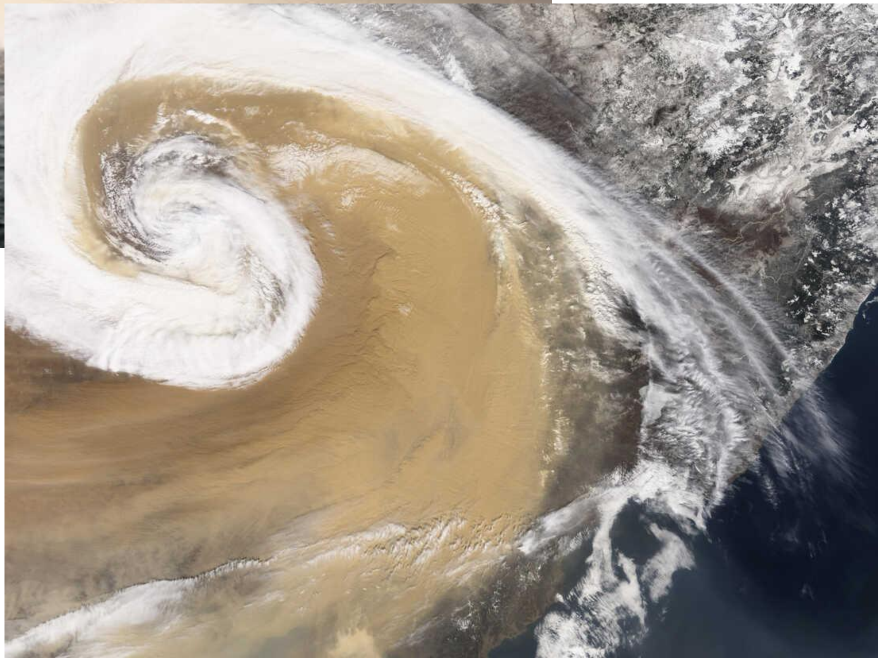
<u>Available water capacity</u> (AWC): difference between field capacity and wilting point

<u>Field capacity:</u> Water fills all of the pore spaces and is held within the soil by internal capillary forces. Varies with texture, lower in coarse soils and higher in fine soils.

<u>Wilting point:</u> Soil moisture level below which plants can no longer extract water; water remains in the soil but is held too tightly by the soil for the plant to take up



Applied Ecology
Soil erosion



A satellite captured a 2001 dust storm swirling over China. The storm eventually crossed the Pacific and reached the United States.

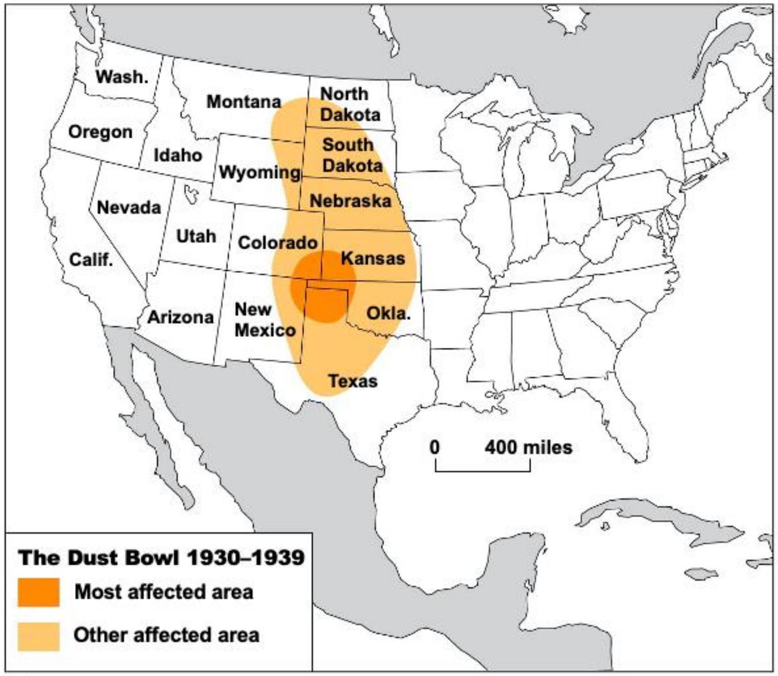
Soil erosion is a threat to agricultural sustainability

Tilling the land removed the sod
- grass-covered surface soil
- mat of fibrous grass roots
- holding the soil together

In the 1930s, extended periods of severe drought and winds

The topsoil was dry and easily eroded by the wind

Resulted in dust storms; region became known as the Dust Bowl

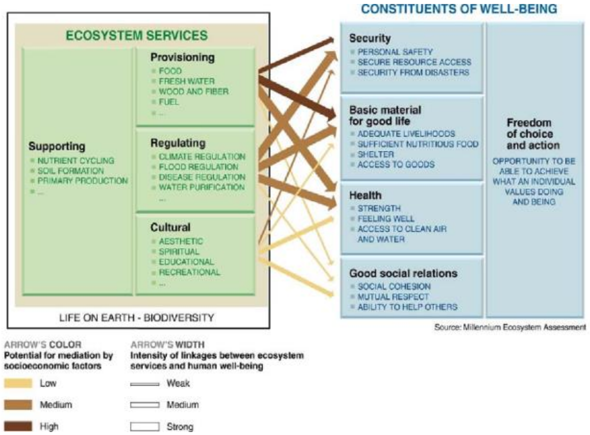


(a)

Soil erosion is a threat to agricultural sustainability

These storms:

- buried homes and farm equipment
- killed livestock
- were a serious human health risk
- left millions of acres of farmland useless
- left about 500,000 Americans homeless
- led to mass migration
- 2.5 million people are estimated to have left the Great Plains and moved to other areas of the United States



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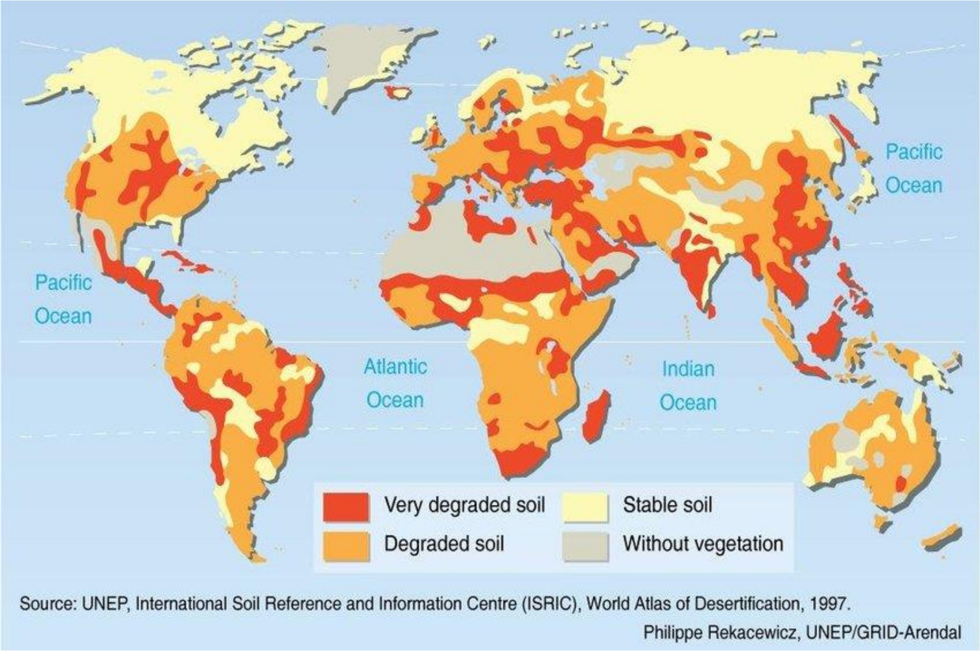
Soil erosion is a threat to agricultural sustainability

Today, up to 50% of the land surface is used for agriculture.

Crop land is highly susceptible to erosion
- usually, vegetation is removed and soil is plowed before planting crops, destabilizing the soil surface
- crop land is often left without vegetation between plantings – bare soil



About 80 percent of agricultural land has moderate or severe soil erosion; can reduce productivity or land may be abandoned

nature geoscience
FOCUS | PROGRESS ARTICLE
PUBLISHED ONLINE: 18 APRIL 2010 | DOI: 10.1038/NGEO838

The impact of agricultural soil erosion on biogeochemical cycling

John N. Quinton[1*], Gerard Govers[2], Kristof Van Oost[3] and Richard D. Bardgett[1]

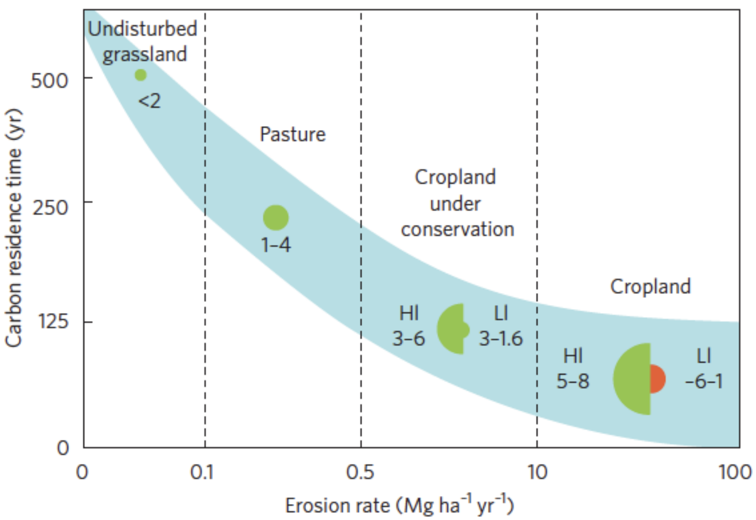


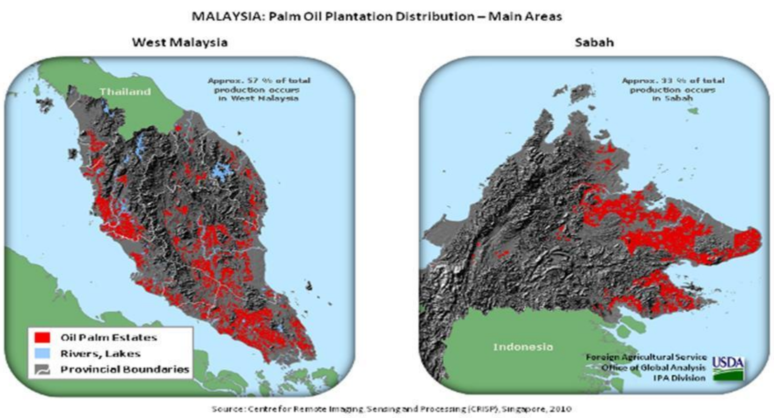
Figure 2 | Interplay between soil erosion, land use/soil management and carbon cycling at sites of erosion. The blue shaded area reflects possible combinations of carbon residence time (1/decomposition rate) and erosion rates as a function of land use/management. The numbers (g C m^{-2} yr^{-1}) and size of the circles represents the maximum size of the carbon sink (positive, green) or source (negative, red) (see Supplementary Information S2). For croplands, the data represent high-input systems (HI, low sensitivity of yield decline to erosion, 4% per 0.1 m erosion) and low-input systems (LI, high sensitivity of yield decline to erosion, 15% per 0.1 m erosion).

Agricultural land use reduces the residence time of organic carbon in soils and increases erosion rates of sediments, carbon and nutrients

Nutrients have to be brought back in the form of synthethic fertilizers

This is energy consuming, leads to eutrophication and is not sustainable

Oil palm plantations



- Loss of native tropical forests
- Draining tropical peats and loss of organic carbon
- Production of greenhouse gases (CO_2, CH_4)
- Erosion of soils
- Ecosystem and landscape deterioration

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Deforestation, our lifestyle, ecosystem health, planetary boundaries

https://www.nature.com/immersive/d41586-023-02599-1/index.html

Feature

A sliver of rainforest separates the grounds of a sawmill from fields on the outskirts of Santarém, Brazil.

TROUBLE IN THE AMAZON

Climate change, deforestation and other human threats are driving the rainforest towards a tipping point of survival. Researchers are racing to chart the Amazon's future. **By Daniel Grossman. Photography by Dado Galdieri**

EPFL