The great green wall of China

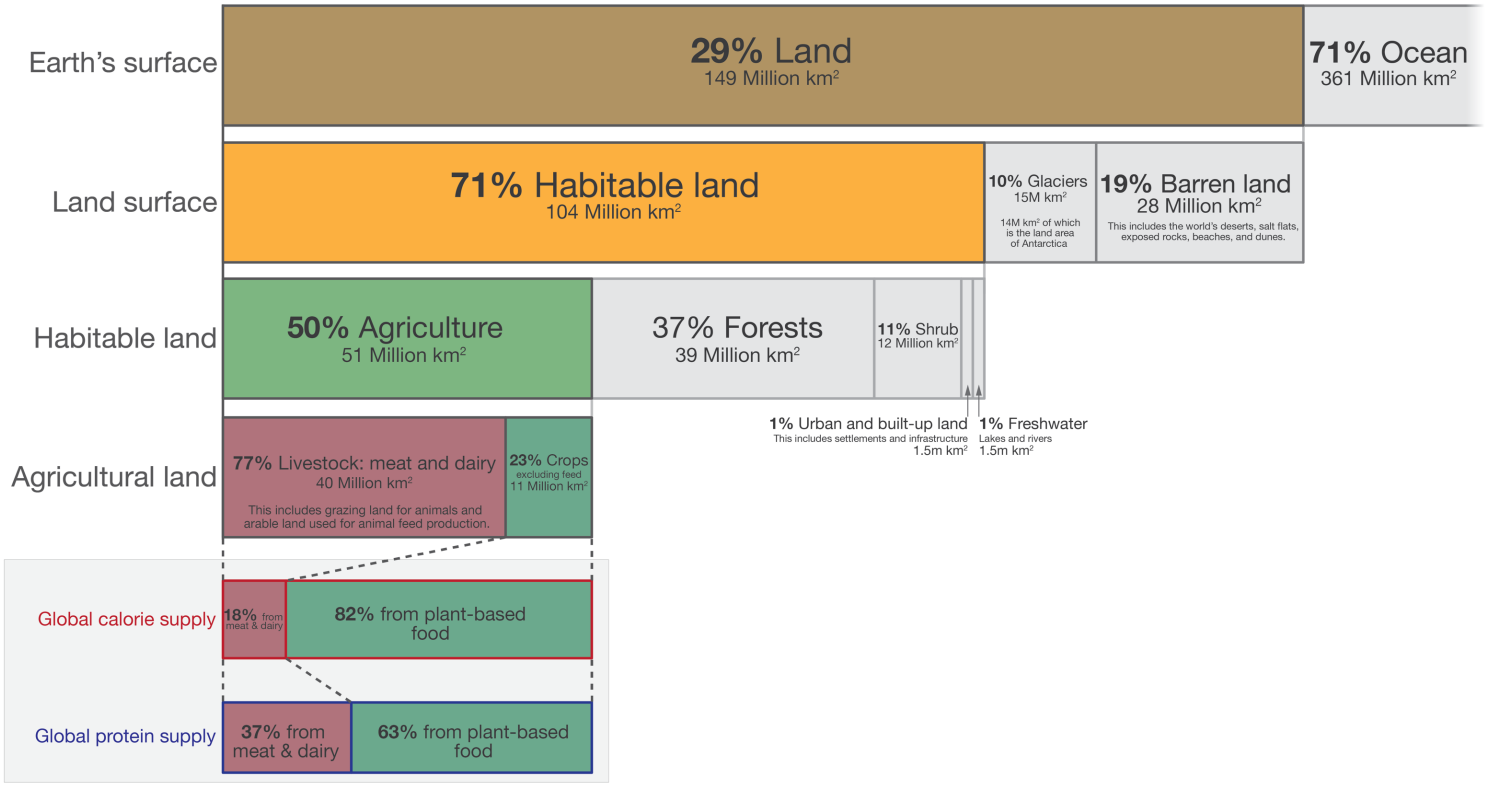
IUCN World Conservation Congress 2021

Overview

- **Context**: Dryland degradation
- **Case study**: The Great Green Wall
- **Ecological principle**: Roots and soil water uptake
- **Potential solution**: Grasslands and hydrological corridors
- **Findings from related projects**: Aforestation in the Sahel zone

Dryland degradation

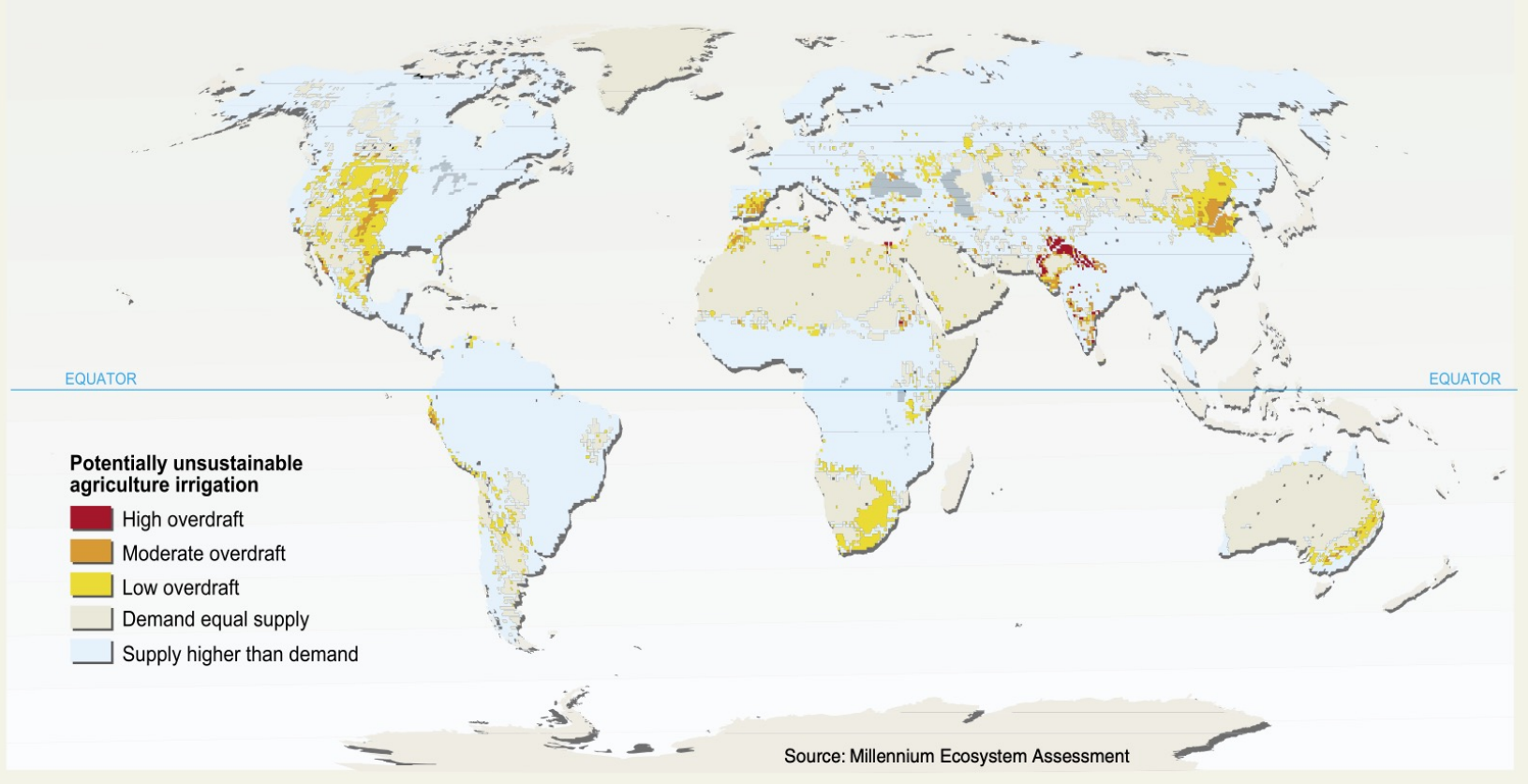
Global land use for food production



Data source: UN Food and Agriculture Organization (FAO)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

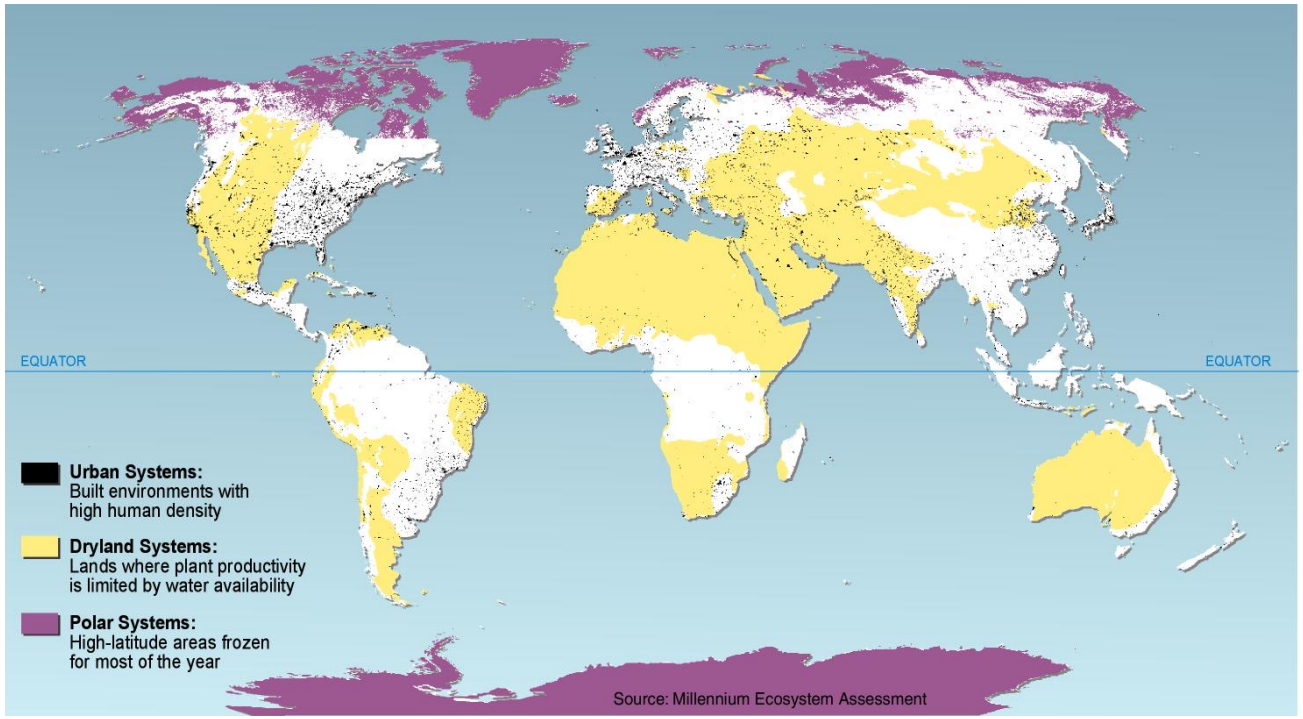
Land-use and degradation

Globally, roughly 15–35% of irrigation withdrawals are estimated to be unsustainable.



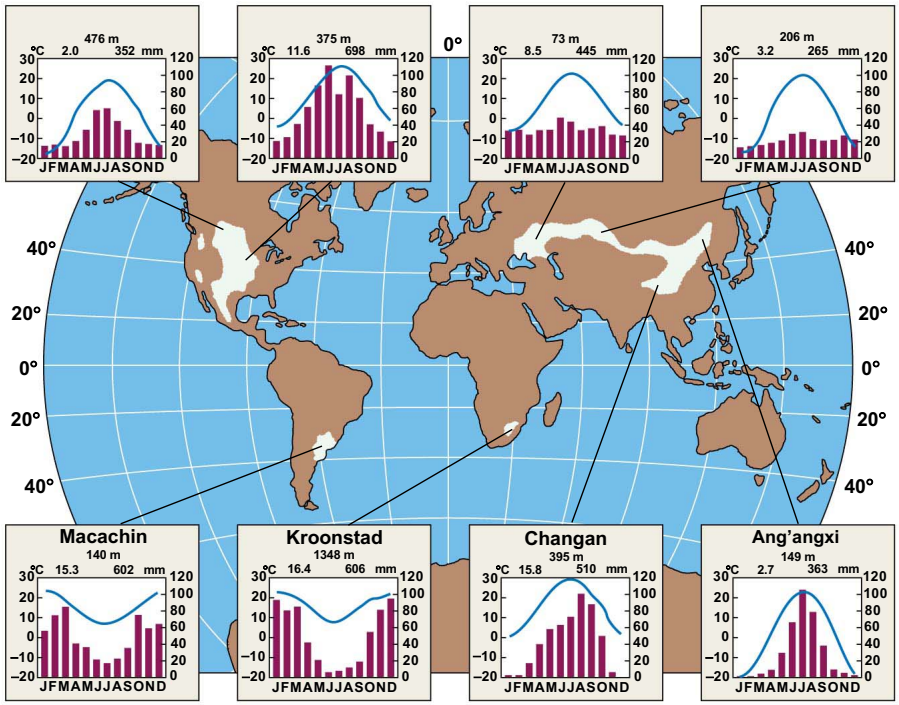
Degradation of drylands

- Drylands cover 41% of Earth's land surface and more than 2 billion people inhabit them, 90% of whom are in developing countries
- Approximately 10–20% of the world's drylands are degraded



What is a dryland?

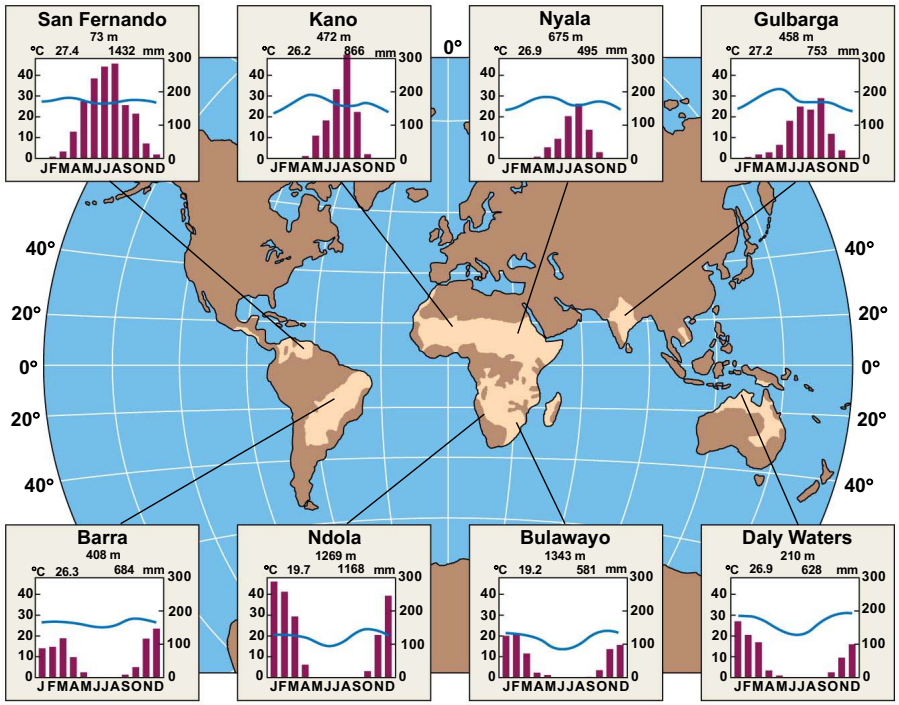
1. Grasslands



- Annual precipitation: 250–800 mm
- Fire, grazing, drought or freezing temperatures
- Typically midlatitudes, continental
- Tree growth naturally restricted

What is a dryland?

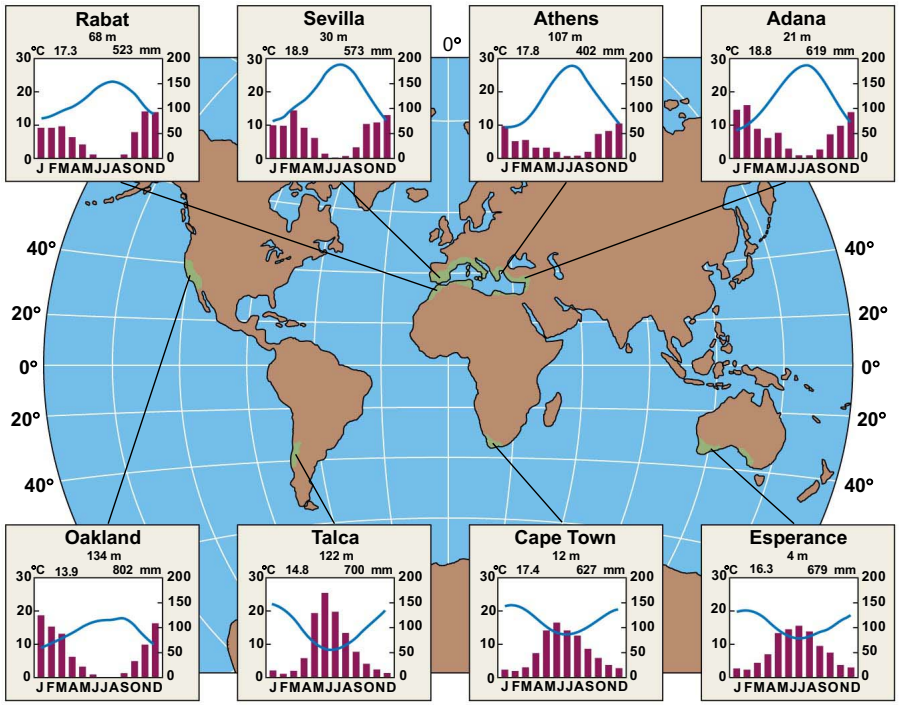
2. Savannah



- Mean monthly air temperature > 18°C
- Precipitation varying seasonally and annualy
- Drier tropics and subtropics
- Megaherbivores restrict tree growth

What is a dryland?

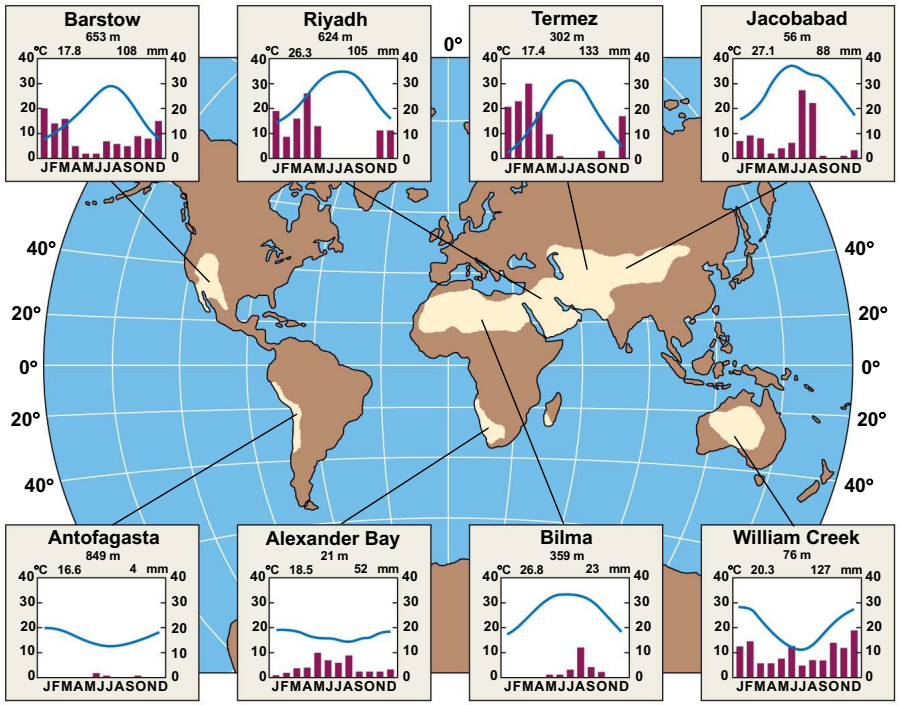
3. Shrubland



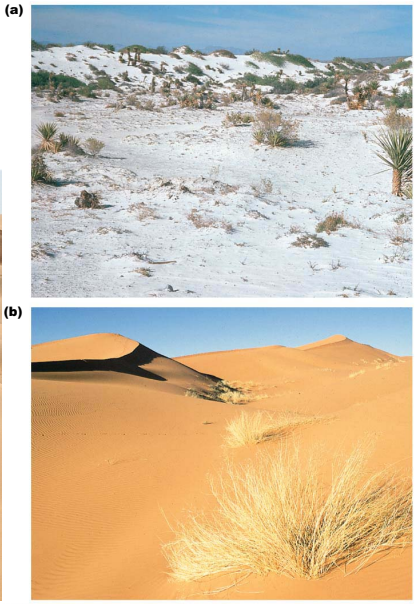
- Mediterranean climate
- Seasonal precipitation
- At western margins of continents 30°–40° latitude
- Evergreen shrubs and sclerophyllous trees

What is a dryland?

4. Desert



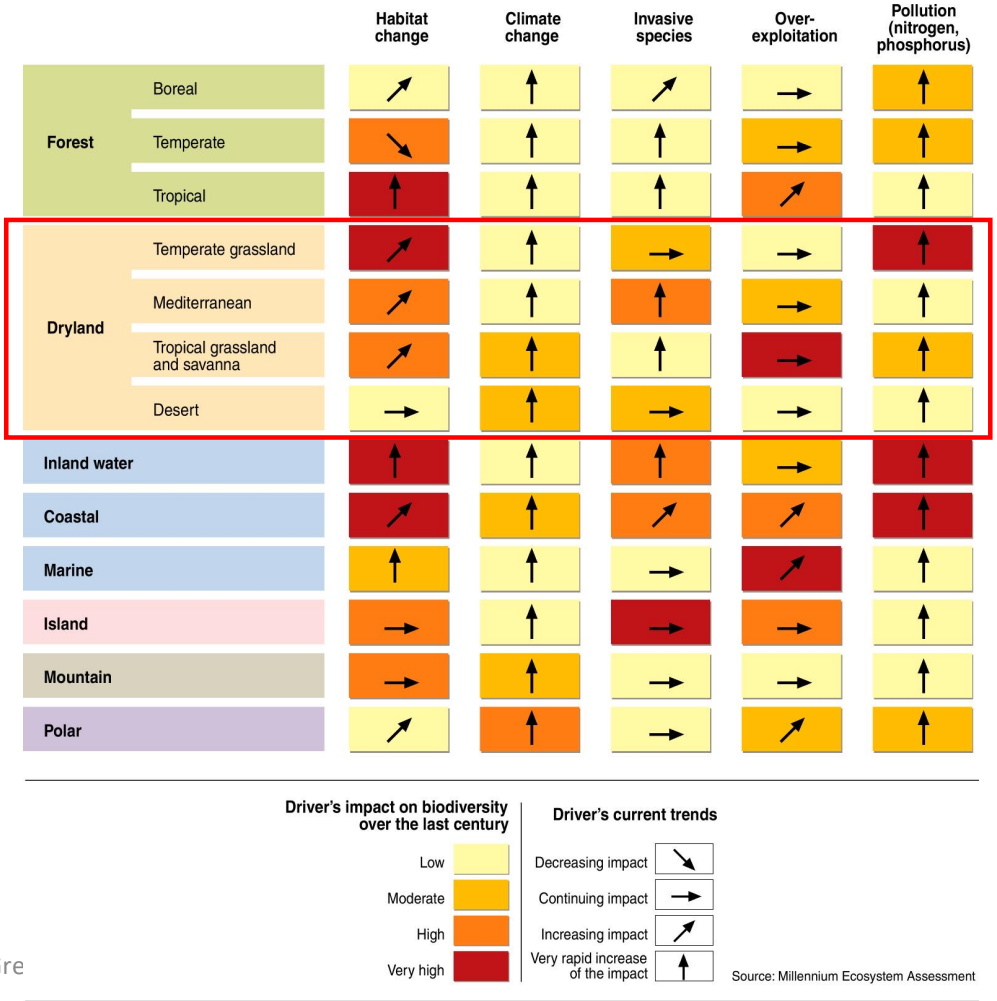
cold desert vs. hot desert



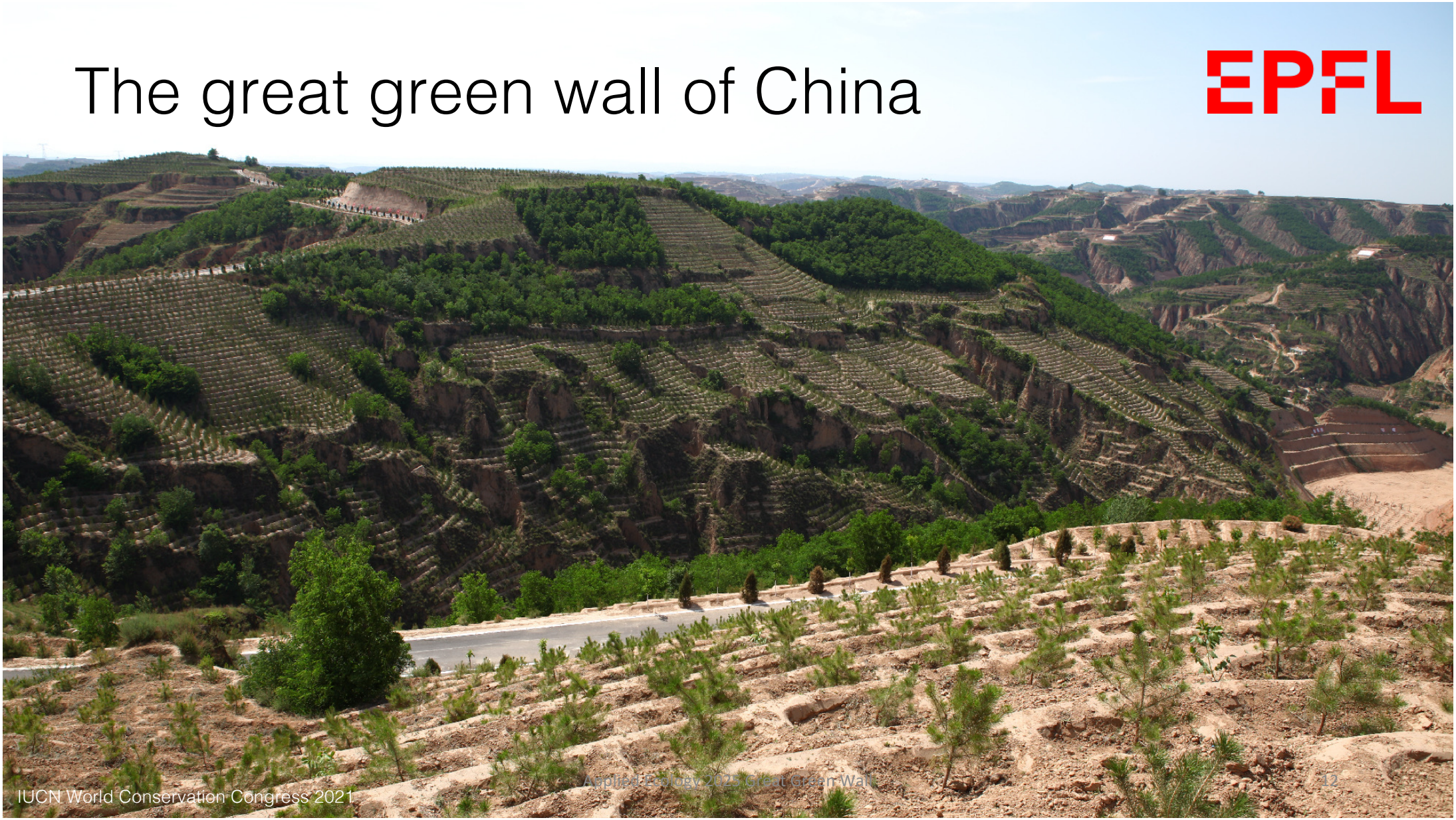
- 35% of the Earth's landmass
- Low precipitation, temperature hot or cold
- Cold ocean currents create arid climate
- Plants in low densities, mostly shrubs

Drivers of dryland degradation

- Most drivers of ecosystem degradation remain constant or are growing in intensity
- In deserts, climate change is one of the major concerns
- In other drylands habitat change, nutrient input and species invasion are the largest concern.



The great green wall of China



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Dryland degradation in China

- 28 % of China are deserts
- Annual loss of 2'500 km^2 to desert
- Threatening 100 Mio. People
- Increases temperature of nearby Beijing

wikipedia

nature

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NEWS | 21 September 2022

China's extreme weather challenges scientists trying to study it

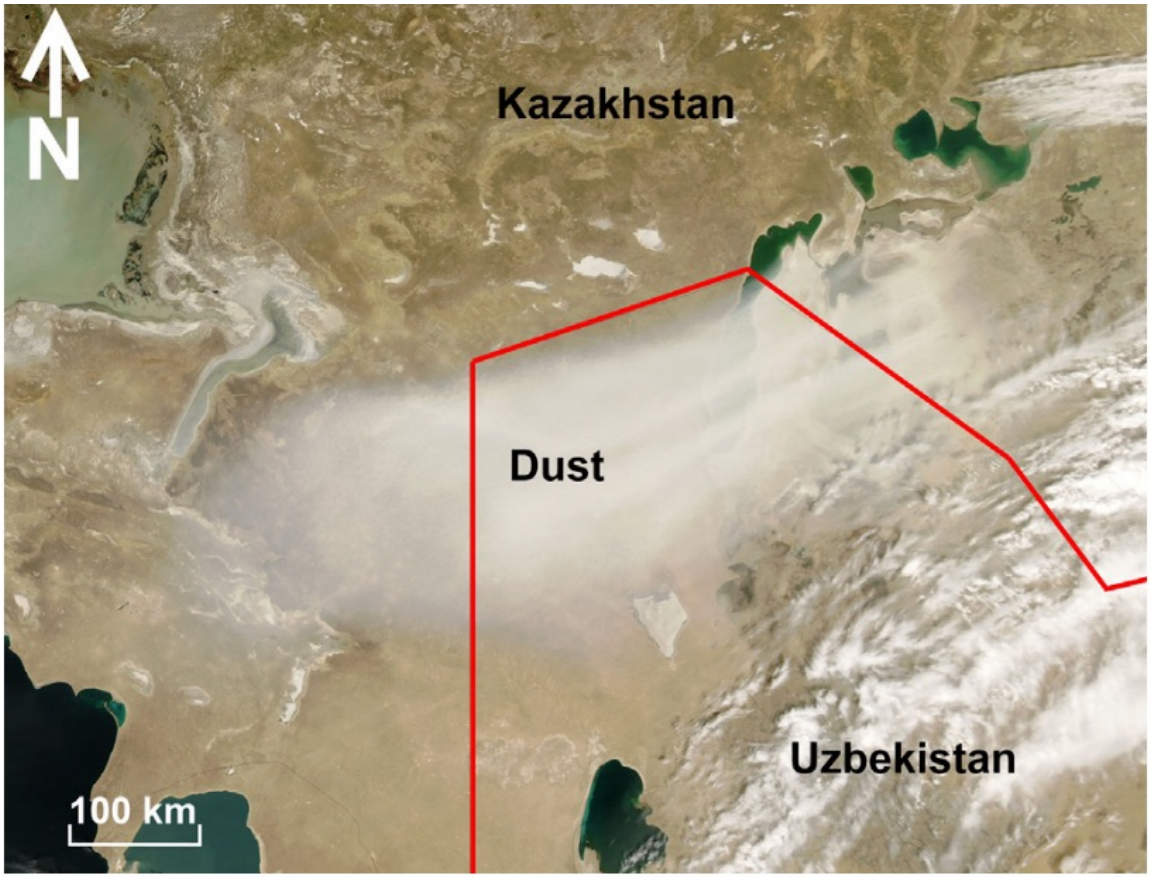
A severe heatwave in parts of China exacerbated a drought and fuelled wildfires.

Smriti Mallapaty

Extreme drought caused water levels in China's largest freshwater lake, Poyang Lake, to drop by almost 10 metres between June and August. Credit: Shen Junfeng/VCG via Getty

Natural phenomenon: Yellow Dragon

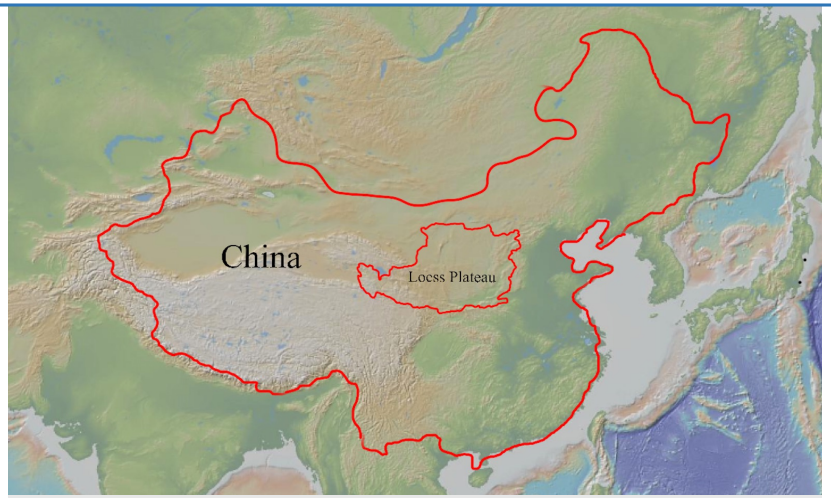
- Dust storms affect large parts of north-east asia in spring.
- From the Gobi desert and the plains of northern China and Kazakhstan, transported by winds to the east
- The phenomenon is not new, and has been reported since 1150 B.C.

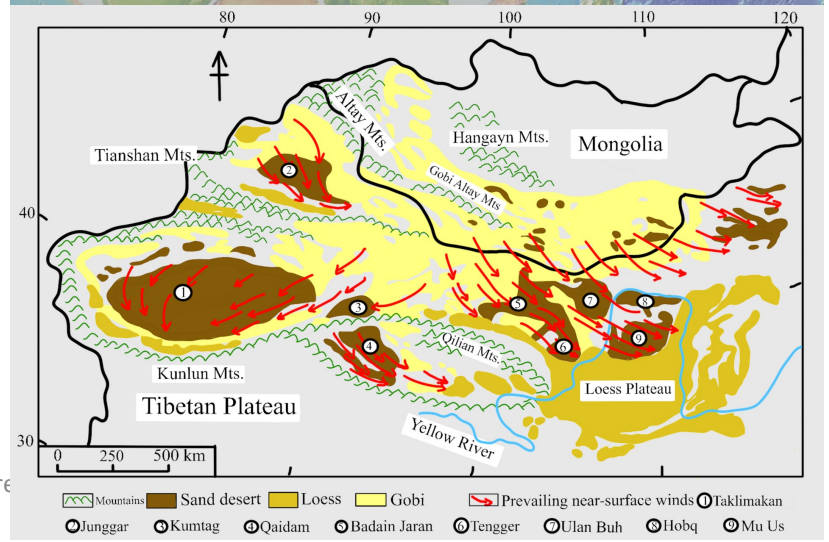


Groll 2013, Aeolian Research

Aeolian loess deposition

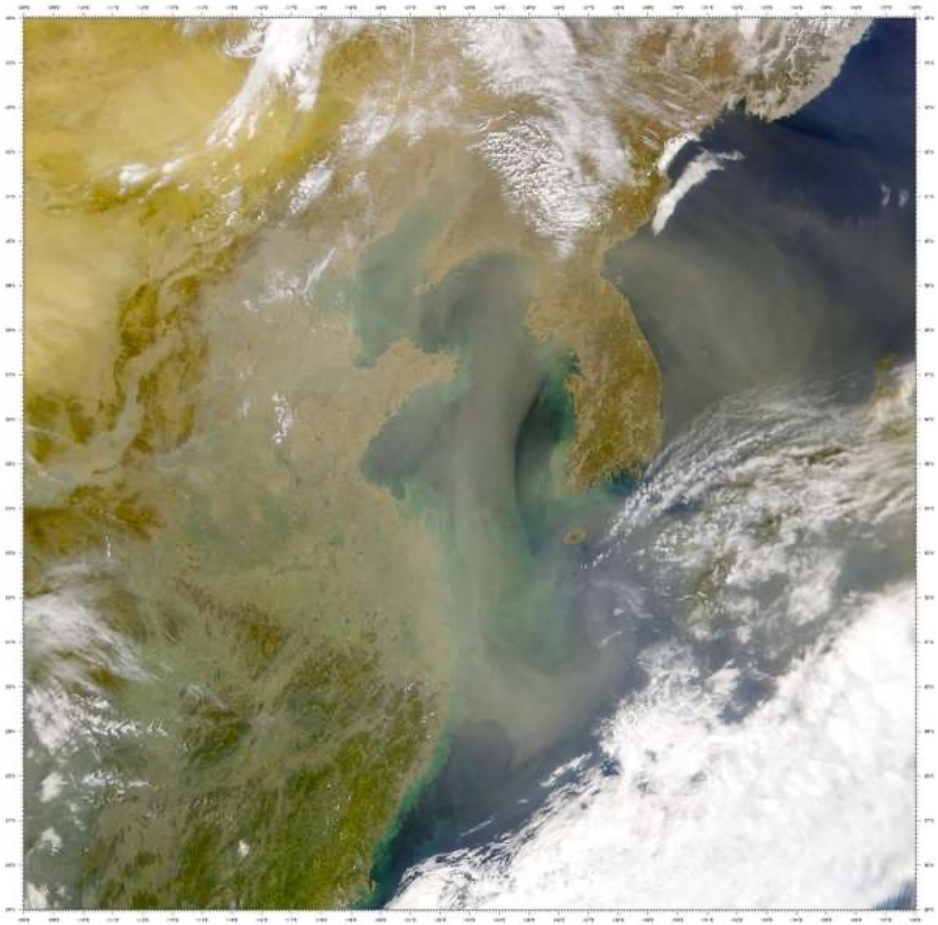
- Thickest and largest loess plateau in the world
- Deposition of loess started 2.4 million years ago
- Up to 300 m thick deposits





Yellow Dragon

- Problem increased due to the aridification of the Aral region (overexploitation of water for cotton plantations) and other areas in Central Asia
- Rapid industrialisation of China: the winds contain industrial pollutants that are harmful (e.g. sulfur)

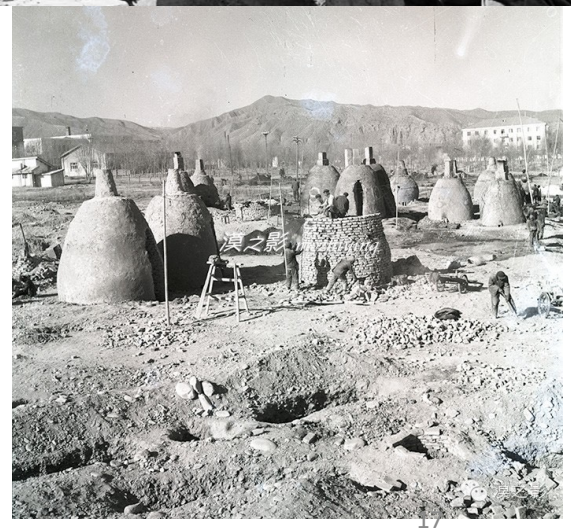


Yellow dragon over NE China, wikipedia

Human-made dryland degradation in China

Deforestation in China:

- Land reform 1950–1955 to restructure ownership and wealth: forests were confiscated and collectivised
- "Great Leap Forward" (1957–1964): mass deforestation (wood use for massive steel production), sharp decline of forest cover, ca. 55 million people killed
- "Cultural Revolution" (1966–1976): food production was prioritised, 24% of China's total forest area was cut down to be replaced by agricultural land



Backyard steel furnaces during the "Great Leap Forward"

Richardson 1990, Forest and forestry in China
https://blogs.ubc.ca/umbreenbutt/forestry-under-agricultural-policy-1949-to-1976/

The great green wall of China

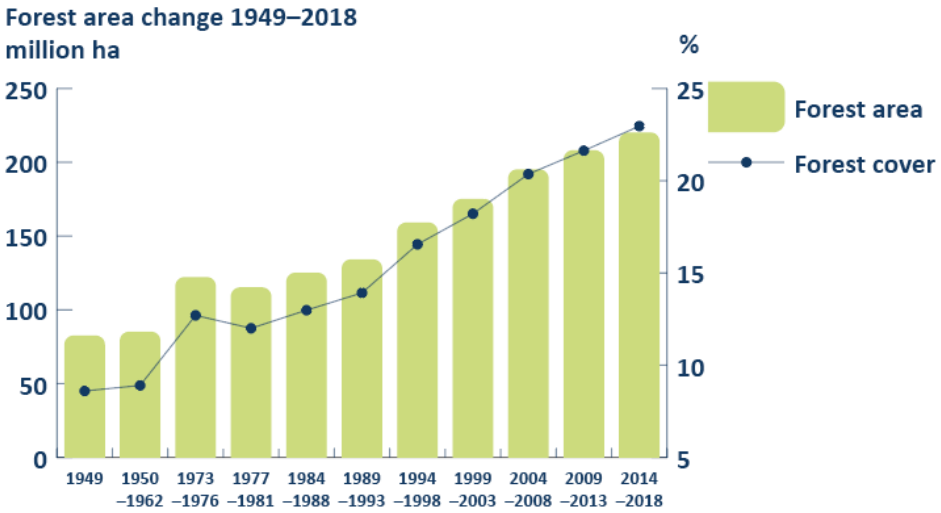
Basic information:

- Worldwide largest aforestation project
- Start of the Project: 1978 (until 2050)
- Plantation of an area ~ size of Germany
- Protect from sandstorms coming from the north: "Yellow dragon" (e.g. towards Beijing, Korea, Japan)
- Protects from desertification

The Economist

A wall of trees

- Forest plantation reduces wind speeds and soil erosion
- Plantation of trees, bushes and grassland over a length of 4'800 km with a width of several 100 km
- Doubling of forested area in China since 1990



Aforestation efforts in the Mu Us Desert. (Baijitan Nature Reserve)

IUCN World Conservation Congress 2021
Huebner 2022, J of Geoscience and Environmental Protection

A wall of trees

Problems:

- Non-native tree species could lower the water table through their water consumption
- Sometimes poor survival rates
- The Asian long-horned beetle destroys 5'000 km^2 of the aforested monocultures annually

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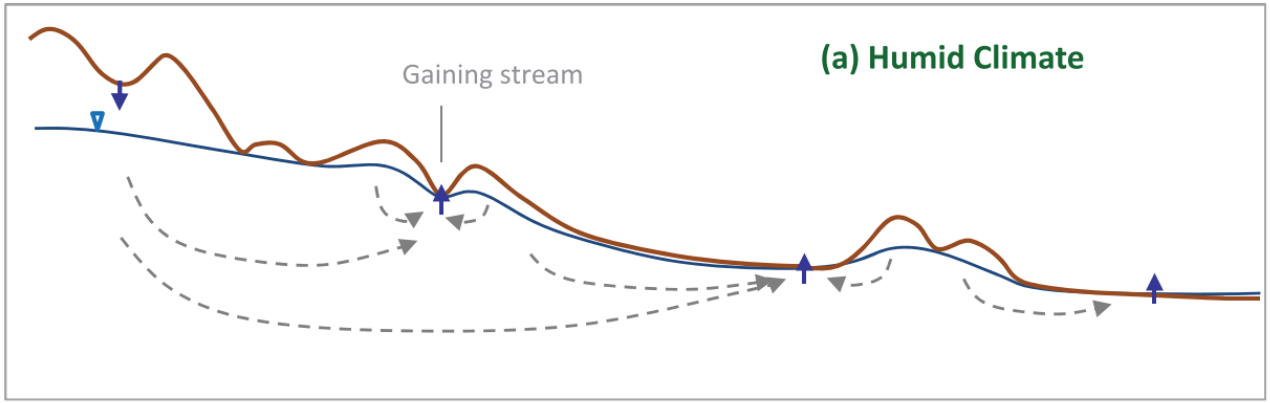
Huebner 2022, J of Geoscience and Environmental Protection

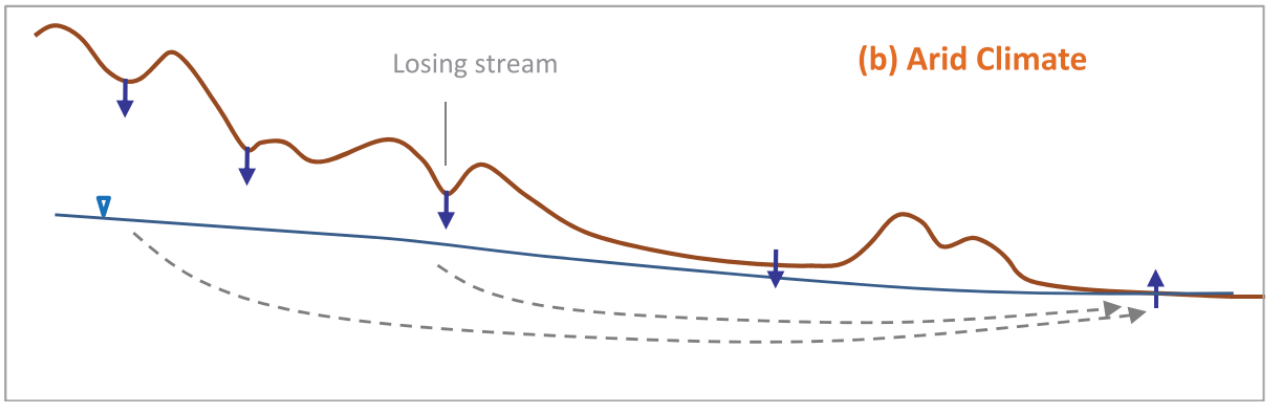
Roots and soil water uptake

Soil water in drylands

(a) In a humid climate, the water table is high and discharges into streams with both shallow/short and deep/long flow paths



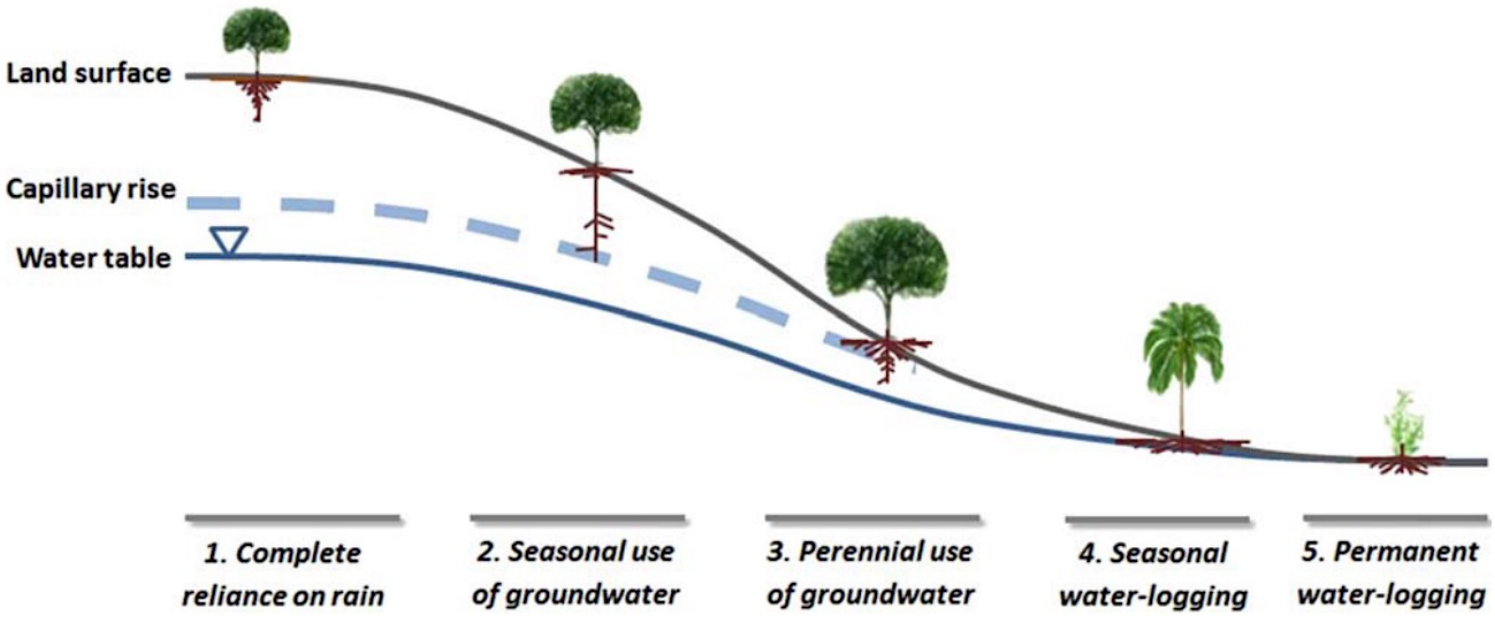
(b) In an arid climate, the water table is low and streams lose their water via seepage into the bed sediments with deeper and longer flow paths.



Fan 2015, Water Resources Research

Rooting depth is related to water table depth

Maximum rooting depths follow the depth of the water table where/when the latter is accessible.



Fan 2015, Water Resources Research

Tree water uptake in drylands (Yatir forest):

Higher surface rock cover and stoniness resulted in higher soil water concentration. This extended the time above wilting point by several months across the long dry season.

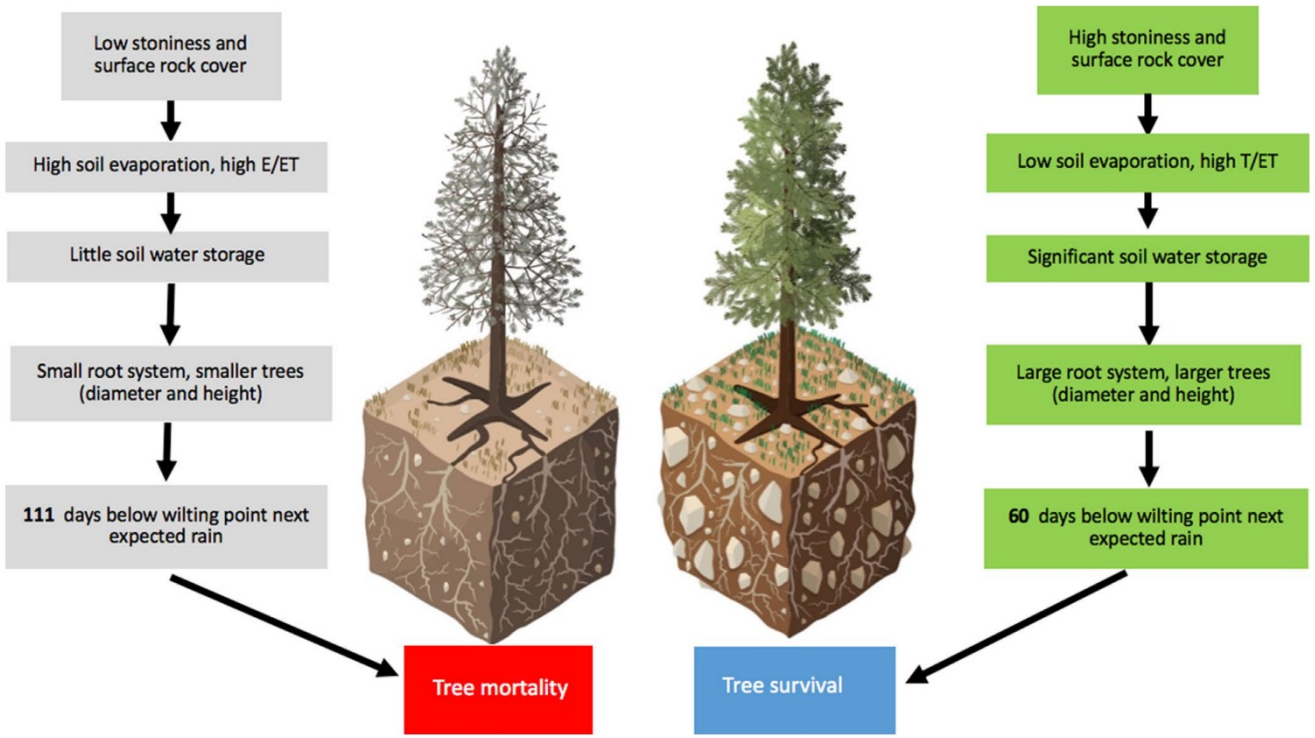
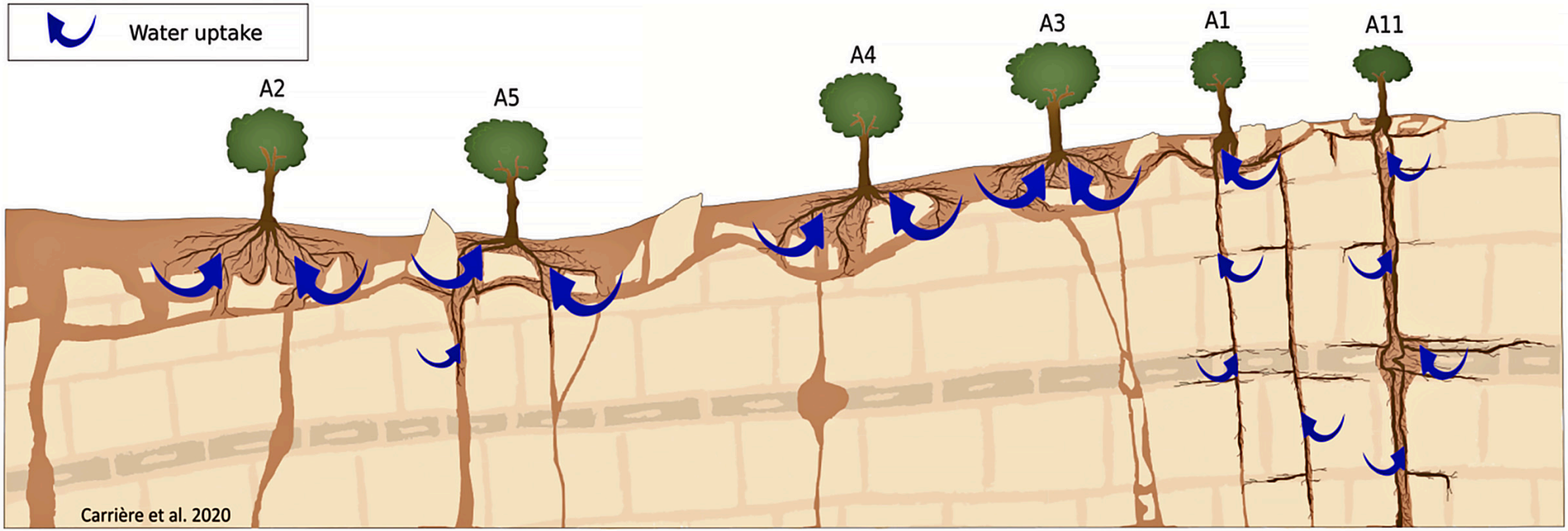


Fig. 6: A proposed conceptual sequence to mortality or survival associated with observed site variability in stoniness and rock cover, indicating the simulated shortening in of the period with no transpirable soil moisture content in the study site where seasonal drought can last well over 6 months.

Preisler 2019, Functional Ecology

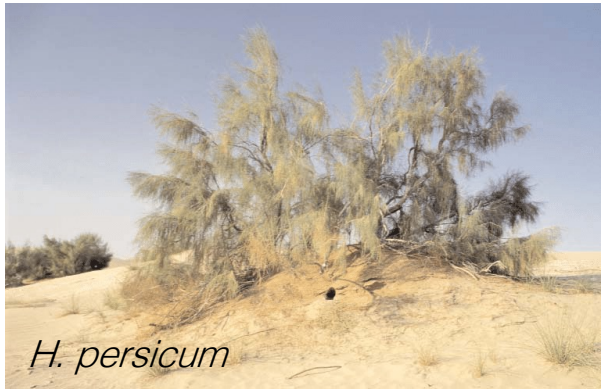
Tree water uptake in drylands (Southern France):

Water uptake of oak (*Quercus ilex*) in a Mediterranean forest growing on karst soil. Trees with less favorable upper soil (0–2 m) conditions adapt their root systems to exploit deep water reserves more intensively to enhance their drought tolerance.



Water uptake depth in desert plants

- *Haloxylon ammodendron* and *Haloxylon persicum* are the dominant species in the Gurbantünggüt Desert (10–150 mm annual rainfall) in Xinjiang (China)
- Important plant to fixate sand
- *H. ammodendron* grows at inter-dune lowland and *H. persicum* grows at the sand dune
- How can they survive there?



Gurbantünggüt Desert, Xinjiang

Water uptake depth in desert plants

- In spring, topsoil was humid
  - *H. ammodendron* mainly used shallow soil water
  - *H. persicum* mainly used middle soil water
- In summer, topsoil was dry
  - *H. ammodendron* mainly used groundwater
  - *H. persicum* mainly used deep soil water.
- The ability to exploit a deep, reliable water source makes it possible for *H. ammodendron* to survive long periods without rain

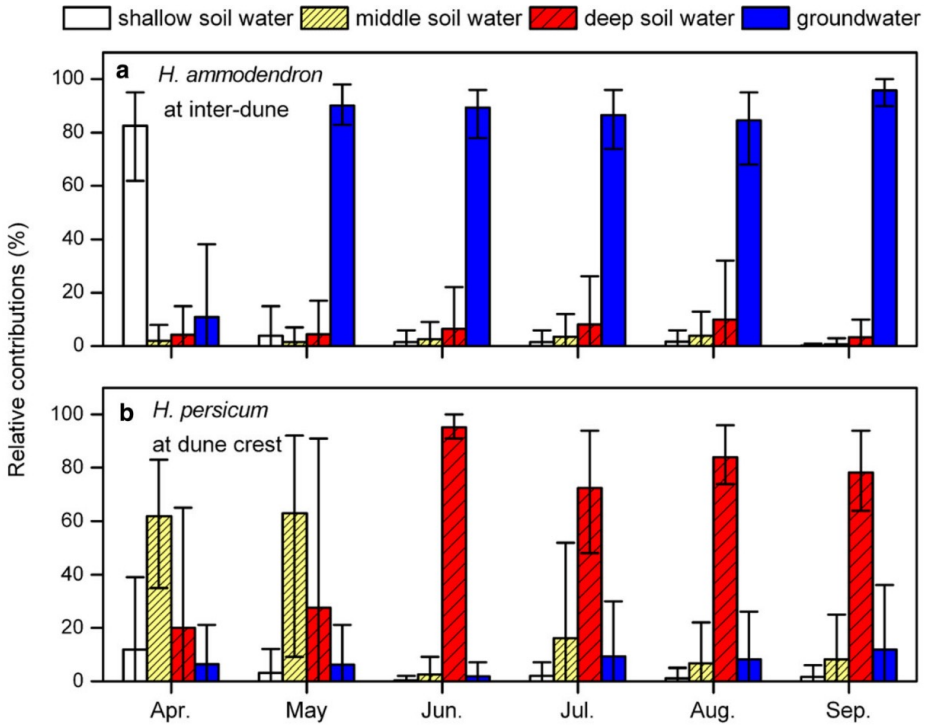


Fig. 4 Monthly changes in percentage contribution of potential water sources for H. ammodendron at inter-dune (a) and H. persicum at dune crest (b)

Dai 2015, Plant and Soil

Water uptake depth and non-native plants

- Screening introduced species (*Hippophae rhamnoides*) for sand fixation
- Large-scale afforestation may reduce the soil water availability of deep soil layers
- This can increase the water stress for sand-fixation plants, cause dieback and mortality

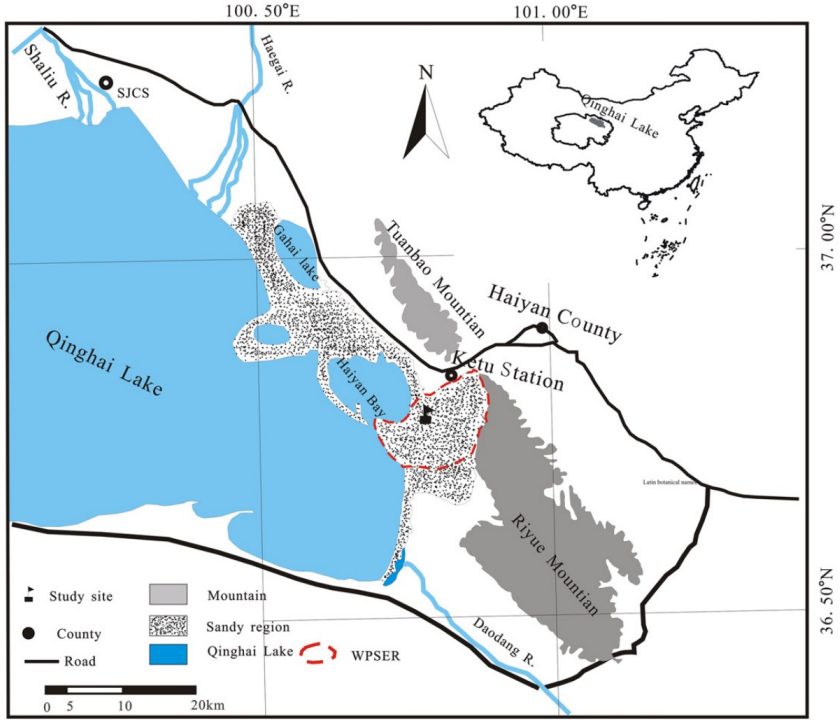


Fig. 1. Geographic location of study area.

Wu 2016, Science of the Total Environment

Water uptake depth and non-native plants

- The introduced shrub (*H. rhamnoides*) was switching between water from shallow and deep soil layers
- The native plants mainly relied on water from the shallow layer (0–30 cm) throughout the growing season
- Different use of soil water of the two species might limit competition and allow for coexistence.

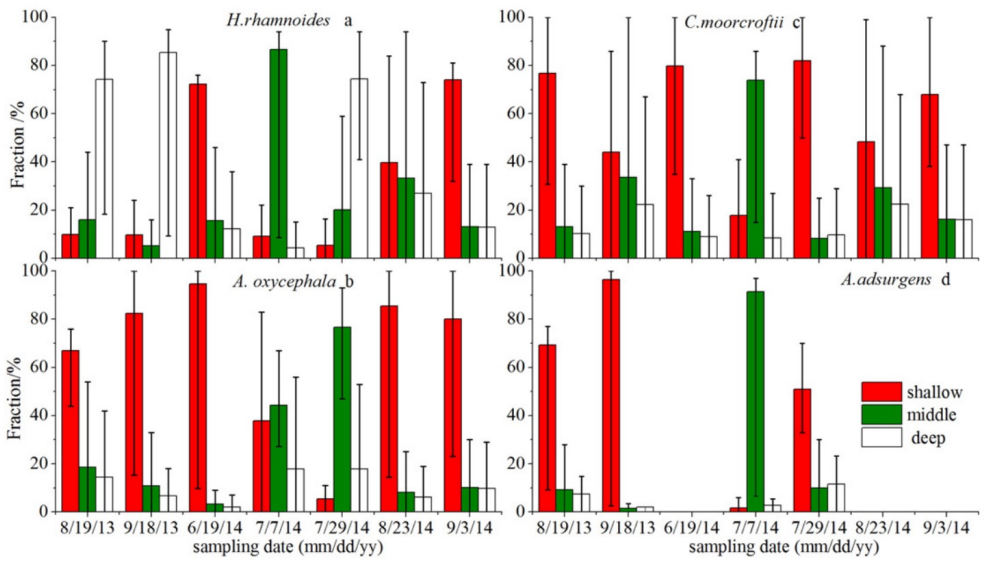
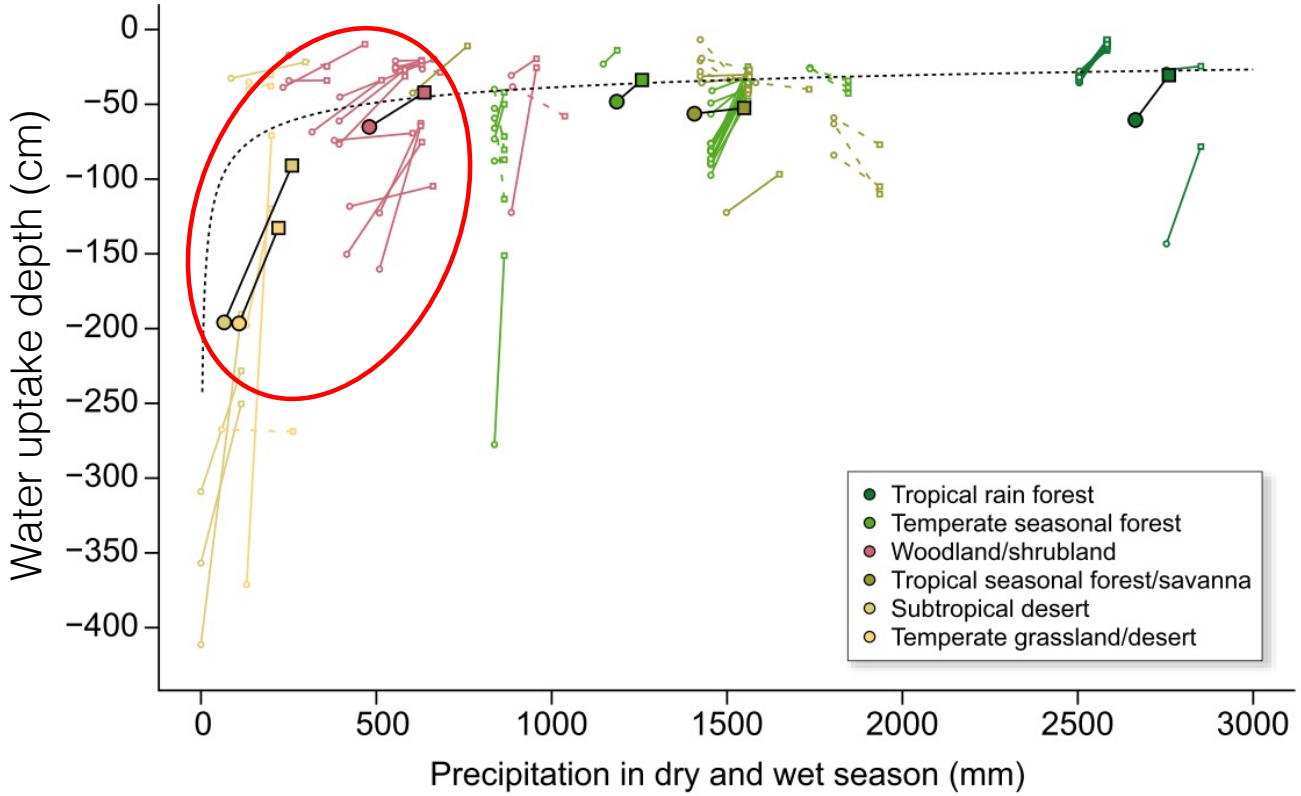


Fig. 6. Seasonal variations in fraction ofuptake from three potential soil water source for introduced shrub (H. rhamnoides, a), natural shrub (A. oxycephala, b) and herbs (C. moorcroftii,c and A. adsurgens, d). Column height represents the mean value of fraction ofuptake and vertical bar represents the range ofmaximum and minimum. Both are derived from the mixing isotope IsoSource.

Wu 2016, Science of the Total Environment

Root responses to drought: water uptake depth

Trees can switch between shallow and deep-water sources depending on soil water availability

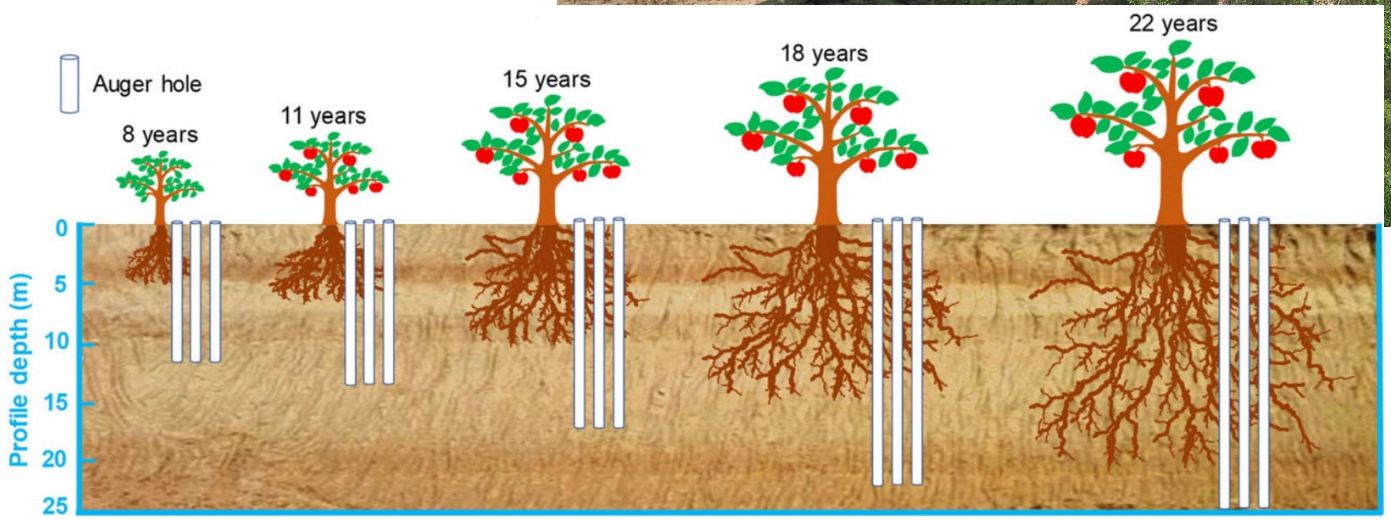


Bachofen et al. 2024

Water uptake of orchards vs. grasslands

- Apple orchards planted on farmland, replacing wheat and corn
- Trees are mining resident old water
- Water deficits are not replenished during the life-span of the orchard, thus one-way mining of the soil water

Chinese loess plateau
(up to 300 m loess)

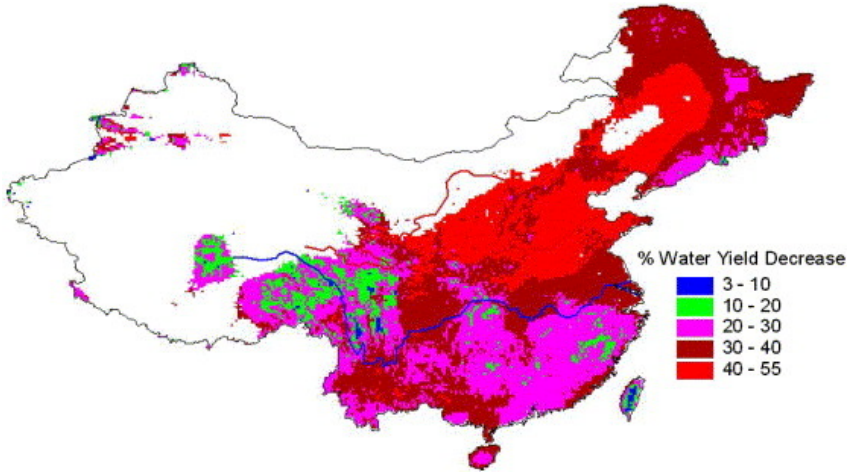


Li et al. 2019, Hydrological Processes

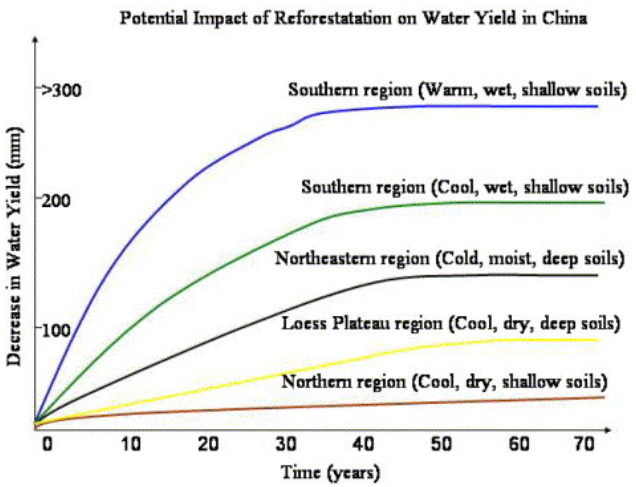
Grasslands and hydrological corridors

Problems with tree plantations

- The deep root system of planted trees is lowering the water table and making it harder for native grasses and other species to survive
- Drying of the surface soils is followed by the depletion of deep soil water
- This leads to lowering of the water table
- High rates of tree mortality when tree roots can no longer reach deep soil water



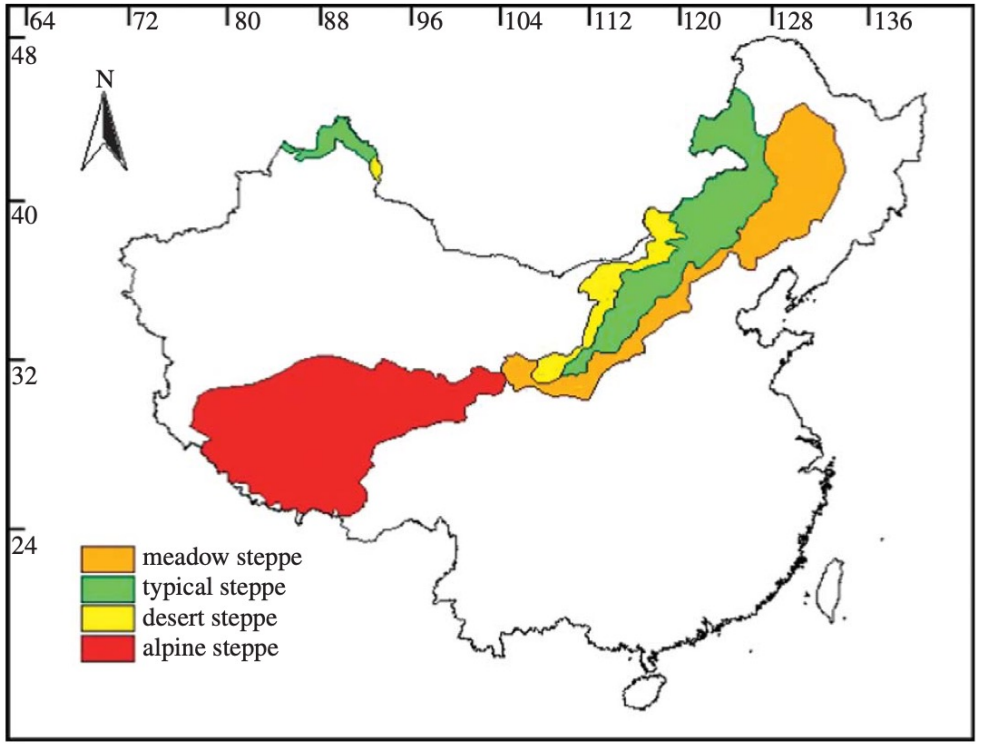
Sun et al. 2005, J of Hydrology



Huebner et al. 2020, J of Agr Food and Dev

Grasslands instead of forests?

- Lower density of vegetation will increase soil moisture and better uptake of rare precipitation
- Low density allows development of good root system that can break up soil compaction, allowing for infiltration and storage of water
- Grassland restoration may be an alternative to the plantation of trees in areas with less than 380 mm precipitation.



Distribution of grasslands in China by ecosystem types.
Kang et al. 2007

Huebner et al. 2020, J of Agr Food and Dev

Combination of grassland, tree and agriculture?

- Vegetation belts serve as “**hydrological corridors**” to keep the humidity in the air and soil
- Optimize the self-supportive climatic feedback of new large scale vegetation
- Avoid overuse of water: grass- and bushland is flanked by native shrub or tree belts
- Allow natural succession and avoid hydrological and ecological pitfalls of earlier plantations

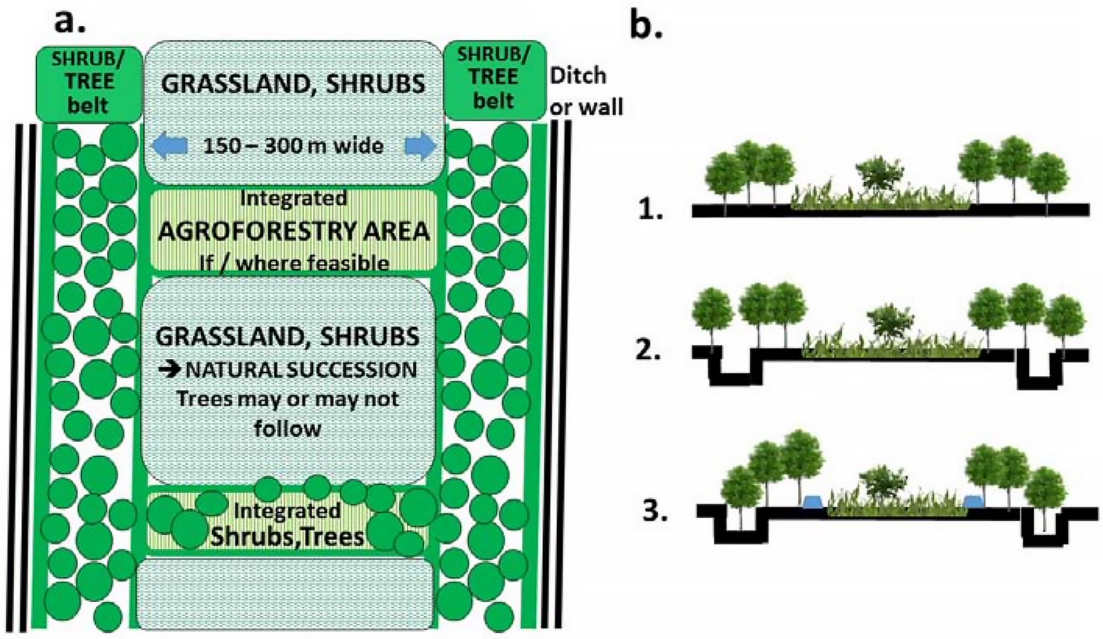


Figure 2: a: Connective hydrologic corridor, top view. Two flanking shrub/ tree belts with grass-. and bushland between them, the possibility for natural succession. Where feasible, areas of agroforestry and tree belts can be integrated.
b: Cross-section of the hydrologic corridor, without (1) or with (2) addition of ditches, and addition of earth wall (3). Part of the shrubs/ trees may be planted on the bottom of ditches for additional protection (3).

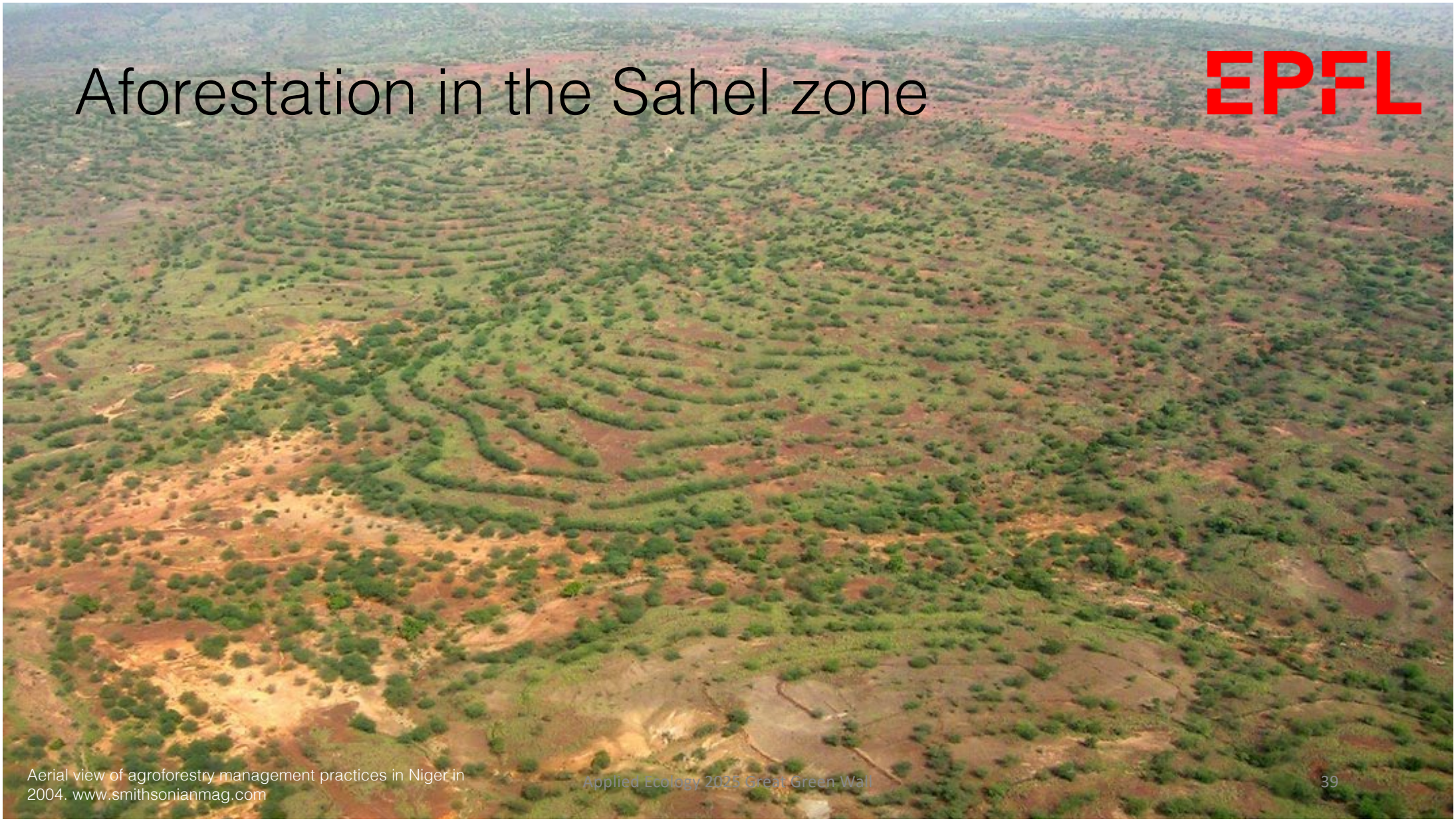
Huebner et al. 2020, J of Agr Food and Dev

Combination of grassland, tree and agriculture?

Contrast between historical and present scenery along the old course of the Yellow River. a) salinization land and sand-laden wind in the 1960s and b) present forest shelter belt along the cultivated land ridges along the old course of the Yellow River.

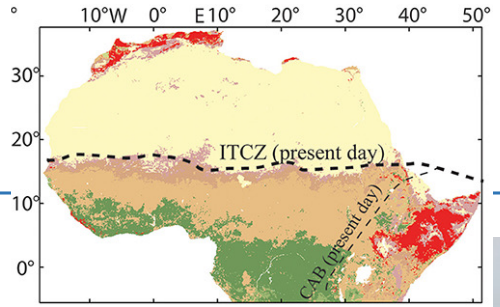
Zhuang et al. 2016

Aforestation in the Sahel zone



Aerial view of agroforestry management practices in Niger in 2004. www.smithsonianmag.com

Desertification in the Sahel zone



- High dependence of rain-fed agriculture
- Poor land management techniques, overgrazing, lack of water conservation strategies and human-initiated bushfires create desertification
- For instance, in Nigeria, livestock populations grew 11-fold between 1950 and 2006, with >66 million animals greatly exceeding the capacity of the grasslands
- In many regions, the primary source of cooking fuel is wood harvested from forests

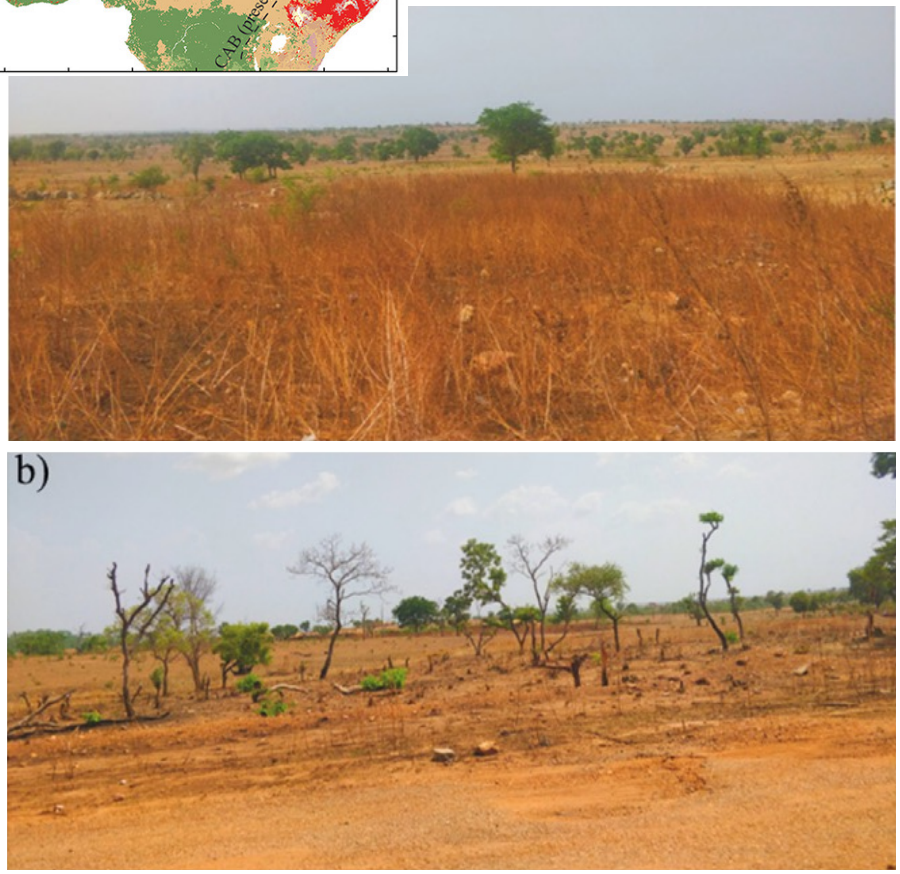
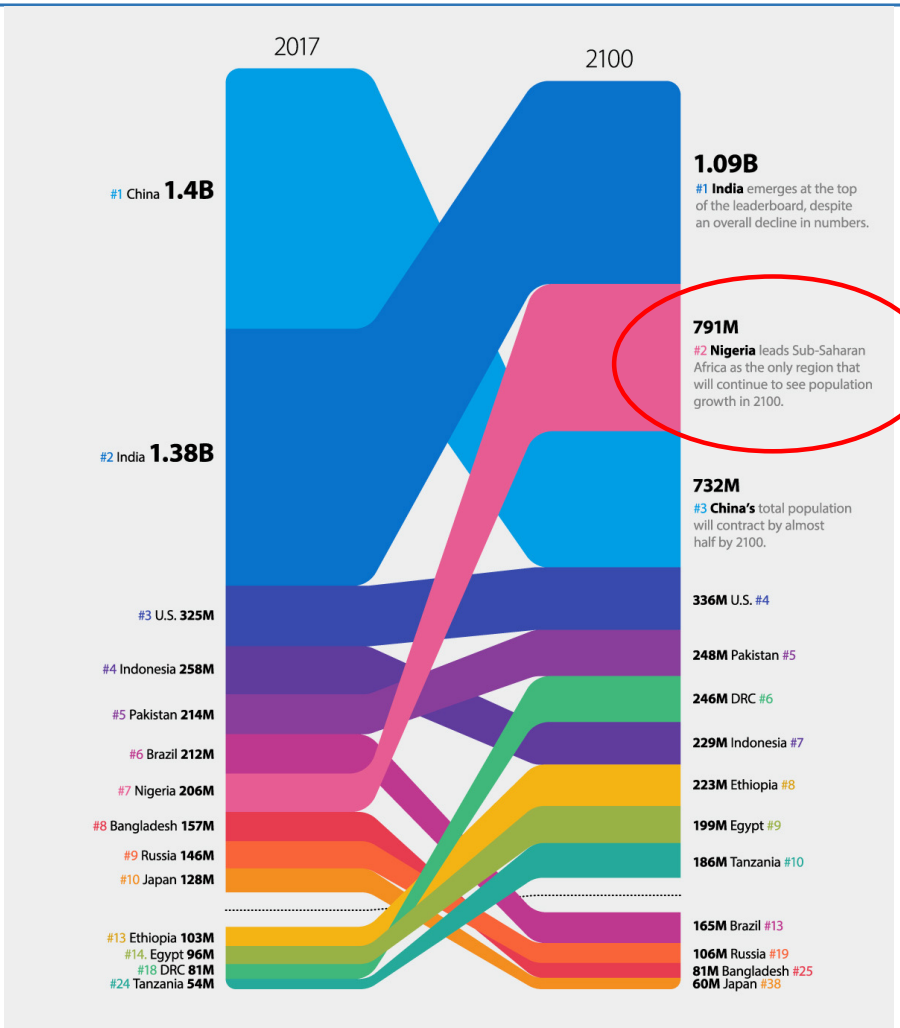


Fig. 6. Degraded savannah in Niger state (a) cleared land in Lavun LGA (b) logged and burnt woodland patch in Agwara LG

Adenle 2022, Environmental Challenges

Resource use and population growth



Source: The Lancet

Aforestation of the Sahel zone

- Aforestation of Sahel is planned since 2005, areas over 7500 km from coast to coast across Africa
- Aim: band of trees from Senegal to Djibouti
- Trees sh
  - m
  - re
  - re
  - ameliorate local microclimate and humidity for agriculture
- Initially proposed in the 1980s
- Only two out of 11 countrie are implementing measures

"If all the trees that had been planted in the Sahara since the early 1980s had survived, it would look like Amazonia,"

World Resources Institute

www.un.org/sustainabledevelopment

O'Connor, 2014, Sustainability

Huebner 2022, J of Geoscience and Environmental Protection

Aforestation of the Sahel zone

Restorers plant native saplings in a Great Green Wall pilot project trial site in Mali. Based on the success of these saplings, a similar strategy of restoration would be followed across the Great Green Wall Initiative.

https://news.mongabay.com

Agroforestry is a major component of the Great Green Wall, where restoration agencies work with local communities. This is a system maintained by the women's association of vegetable producers in Dimbale, Mali.

Key lessons from Sahel aforestation

- Land restoration and food production must be linked
- Innovation by local people, using indigenous knowledge
- A single technique or practice alone is rarely enough
- Technical options must be flexible, adaptable, and testable by farmers under local conditions
- Innovations need to provide swift benefits – in the first or second year – to win support

Restoration efforts should focus on growing plants that are used as food or medicine by the communities, like this 'nutrition garden' in Burkina Faso.

Global Land Outlook 2022, UN Convention to Combat Desertification

Should we do large-scale aforestation?

We should consider intact grasslands as important for climate change mitigation

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

https://www.theatlantic.com/science/archive/2022/07/climate-change-tree-planting-preserve-grass-grasslands/670583/