
Land Degradation and Restoration

(Introduction)



Processes that (may) cause land degradation

- desertification and (long-term/frequent) drought
- soil erosion (water, wind)
- soil salinity
- soil compaction
- contamination and toxic effects of chemicals
- decrease in biodiversity
- land slides
- tectonics



Factors playing role in land degradation

- intense agriculture (ploughing, overgrazing)
- forest/timber harvesting
- growth of human population in the world
- rising living standards for billions of people
- climate and its variation
- politics and wars
- mining
- urbanization

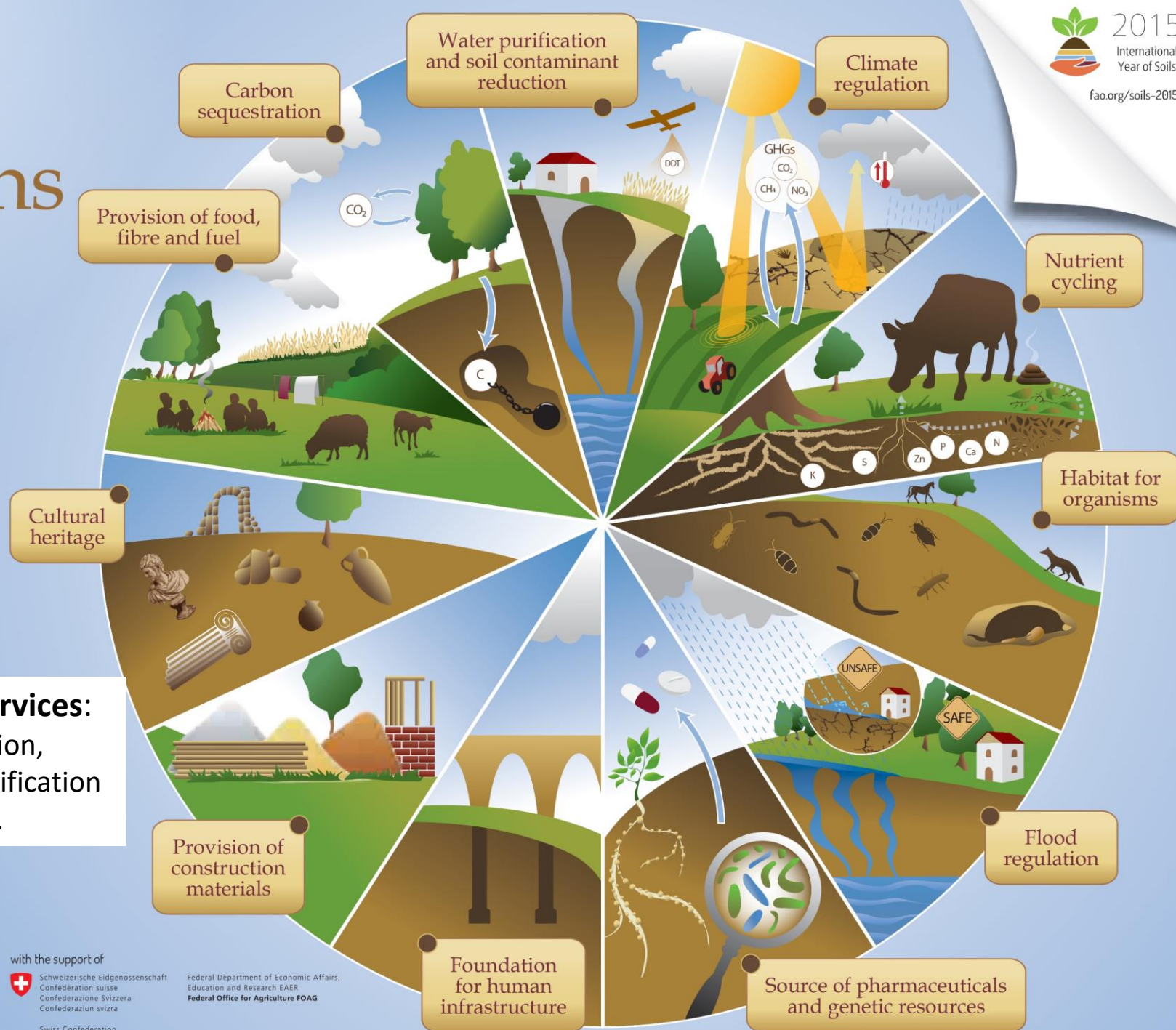


Land degradation – indicators (“symptoms”):

- decrease in net primary production in ecosystems
 - decrease of biodiversity
 - loss of ecosystems services
 - soil degradation $\approx$ land degradation
-
- when it comes to degradation of environment, the prevention is more cost-effective compared to remediation procedures
 - in many cases the land restoration is significantly hampered by economic factors, practical (technical) limitations and politics
 - as a result, many areas with degraded environment remain untreated / left for “self-recovery”

Soil functions

Soils deliver ecosystem services that enable life on Earth



Soil functions ≈ **soil ecosystem services**:
habitat for organisms, climate regulation,
nutrient cycling and supply, water purification
and retention, carbon sequestration,...



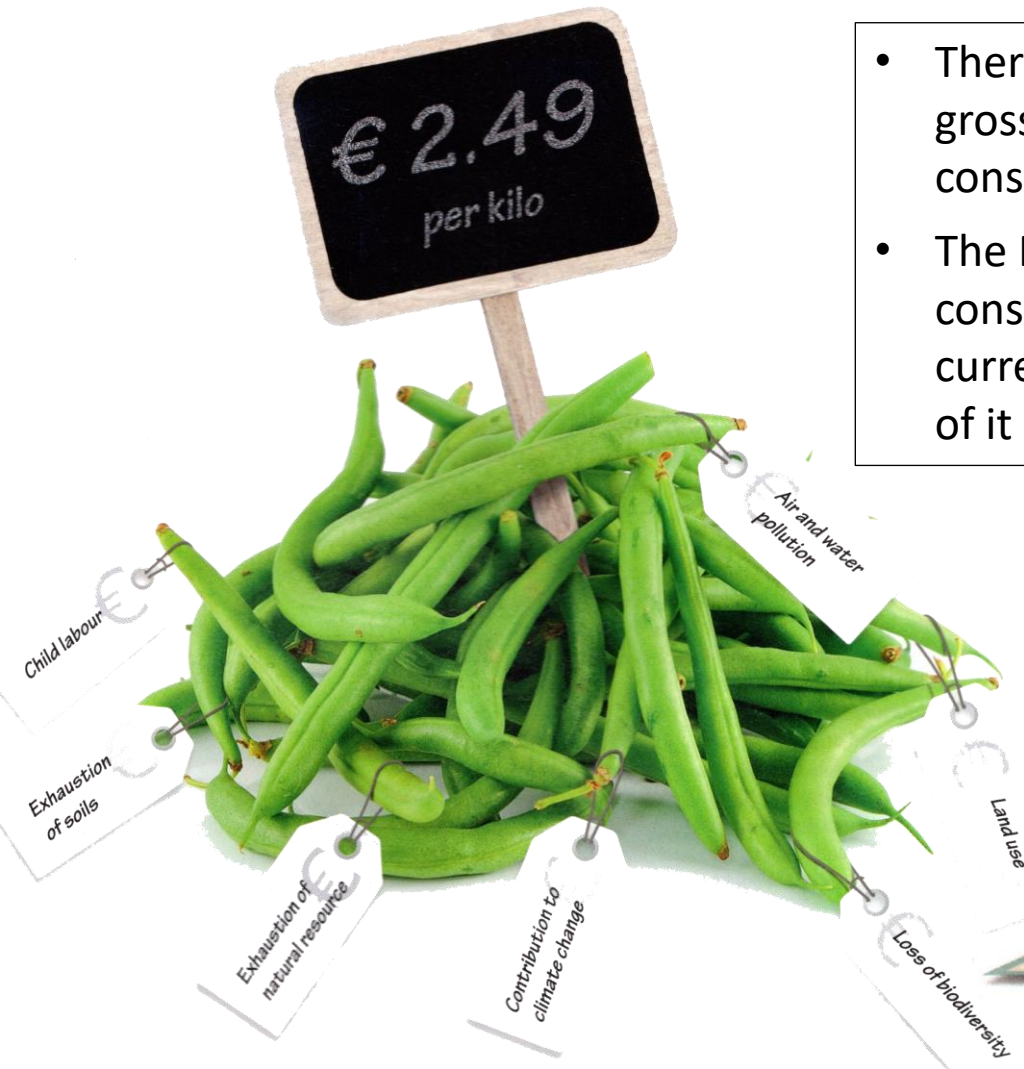
Food and Agriculture
Organization of the
United Nations

with the support of
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

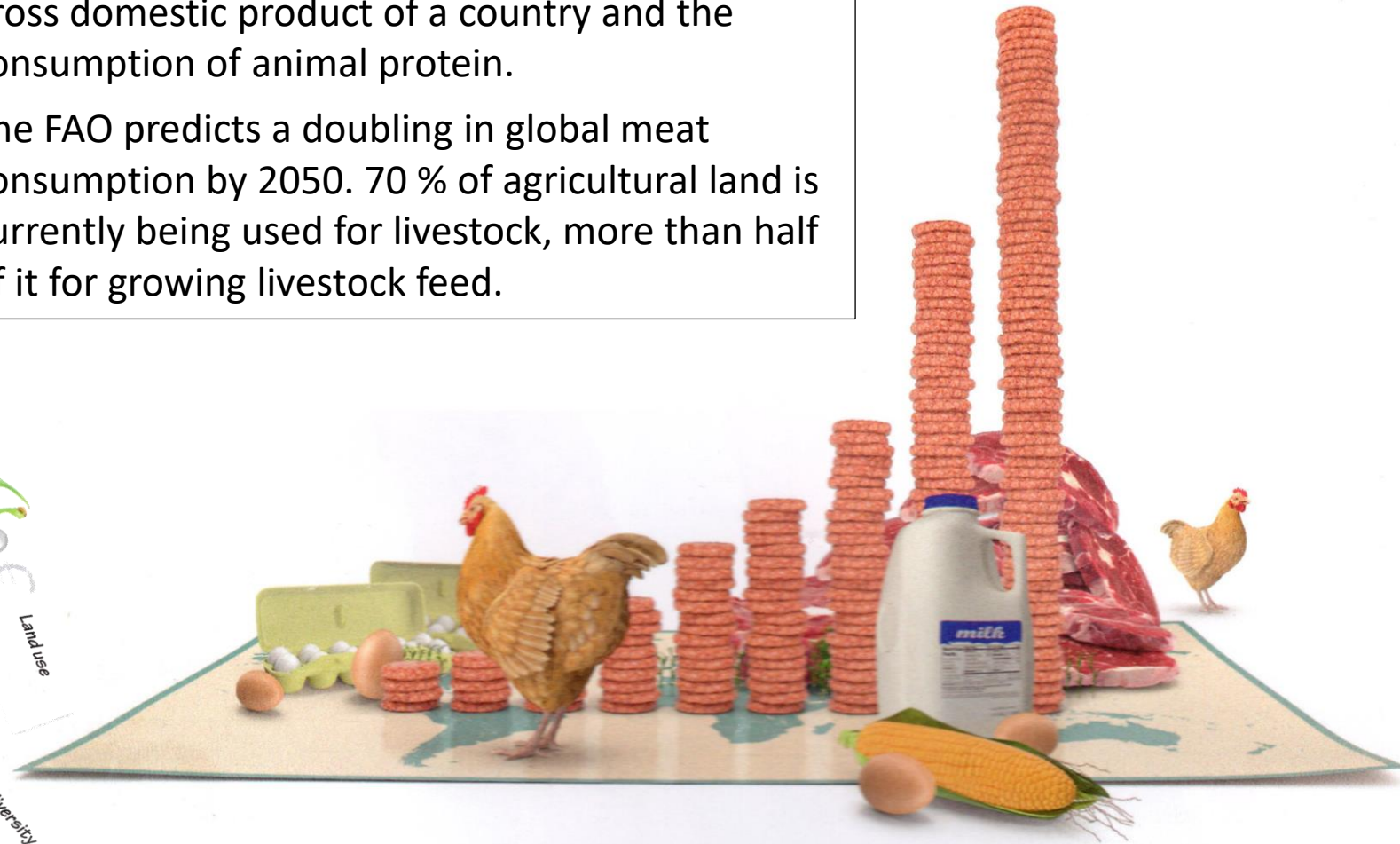
Federal Department of Economic Affairs,
Education and Research EAER
Federal Office for Agriculture FOAG

Agriculture, population growth, increase of living standards

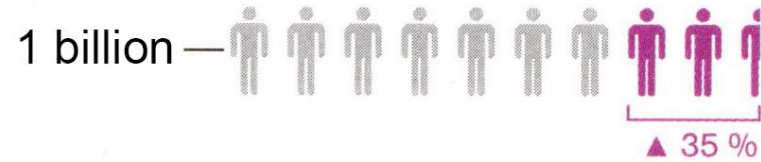
intense agriculture providing food and fiber for billions of people → environmental “debt”



- There is a significant positive correlation between gross domestic product of a country and the consumption of animal protein.
- The FAO predicts a doubling in global meat consumption by 2050. 70 % of agricultural land is currently being used for livestock, more than half of it for growing livestock feed.



By 2050, human population will likely increase by 35% (FAO)



Current agricultural production needs to double to provide enough food



Why? apart from population growth, FAO predicts that living standards of people will increase as well >> consumption of more animal protein (meat, milk, eggs)

Growth of demand
for daily intake of
proteins per one
human in the year 2050:

developed countries



developing countries



the least developed countries



(Typical) agricultural landscape with conventional management practices

there is a room for improvement:

- less ploughing / tillage
- more biodiversity
- diversification of agricultural area → spatially more variable landuse/landscape
- support water retention
- optimal use of agrochemicals (amount and timing of application should be based on exact data)

attributes of conventionally managed soils:

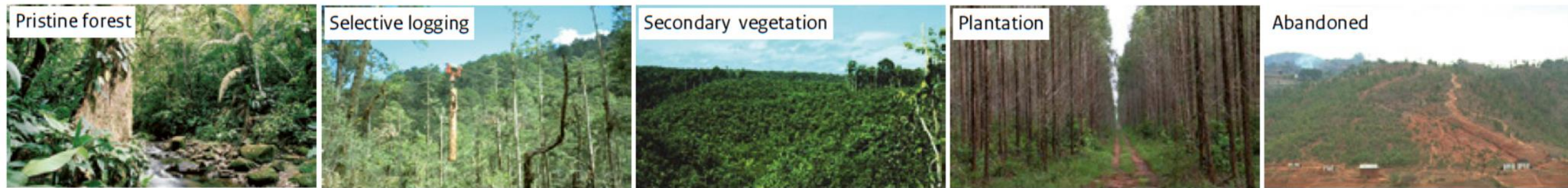
- long-term ploughing / tillage
- monoculture cropping system
- without vegetation cover during substantial part of the year
- low biodiversity and limited biological activity
- “plough pan” formation
- water erosion (in hilly areas)
- wind erosion (in lowlands)
- observable trend of decreasing nutrient availability and organic carbon content / budget

Using land exclusively for production of food and fiber → loss of ecosystem services

Grassland



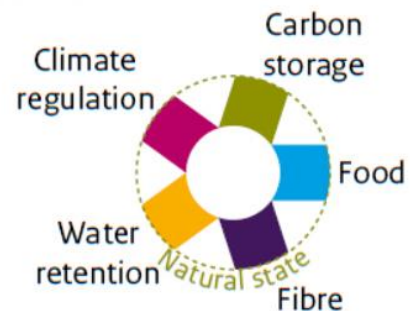
Forest



Intensification
of use



Natural state



Extensive land use



Intensive land use



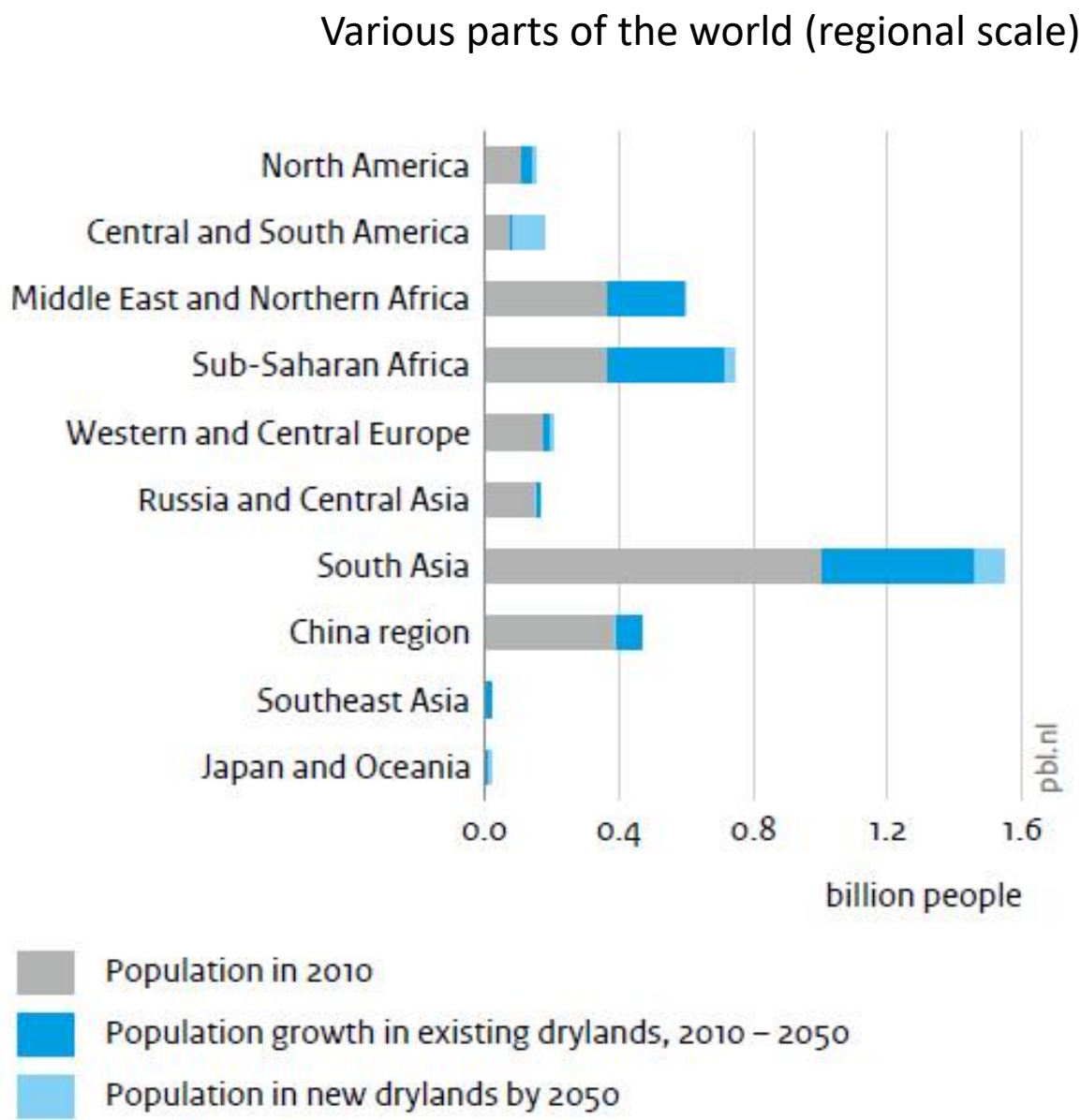
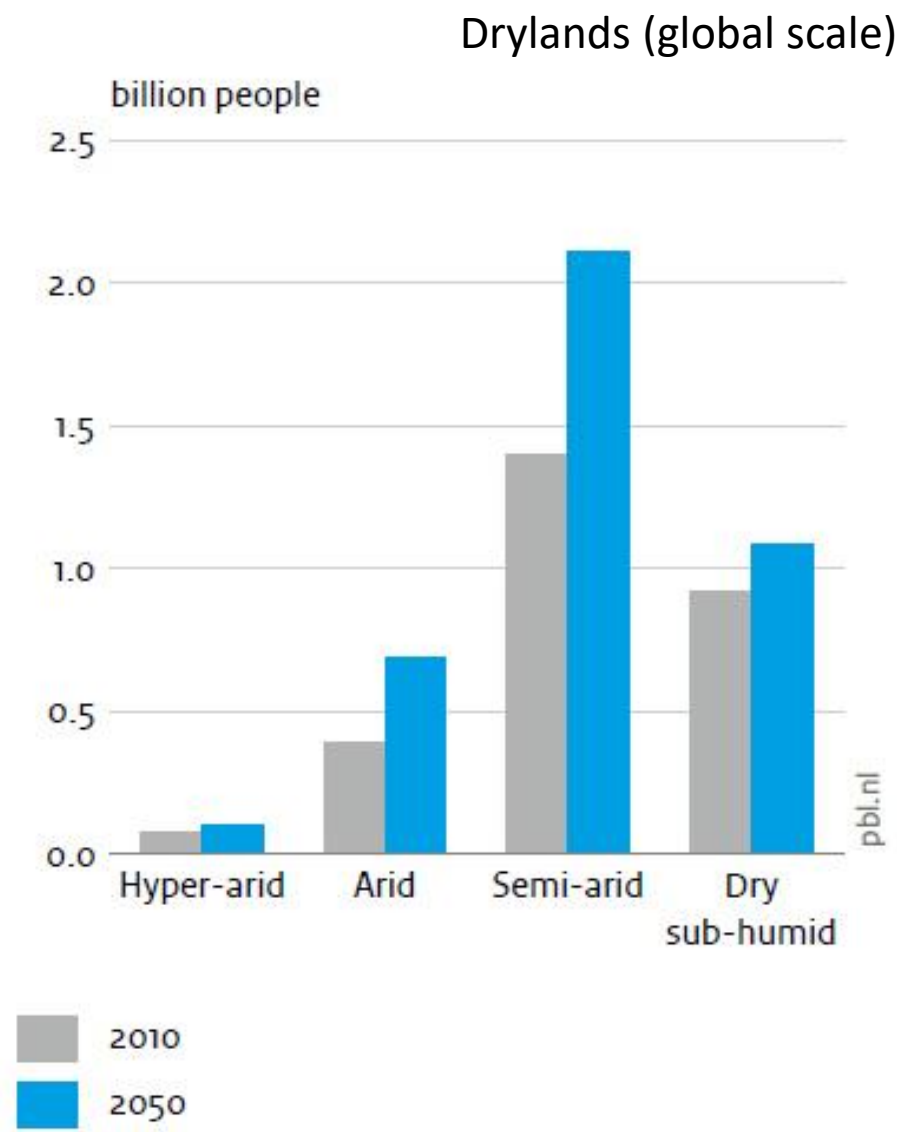
Overall function loss



Area with negative productivity trend, corrected for climate change, 1982 – 2010

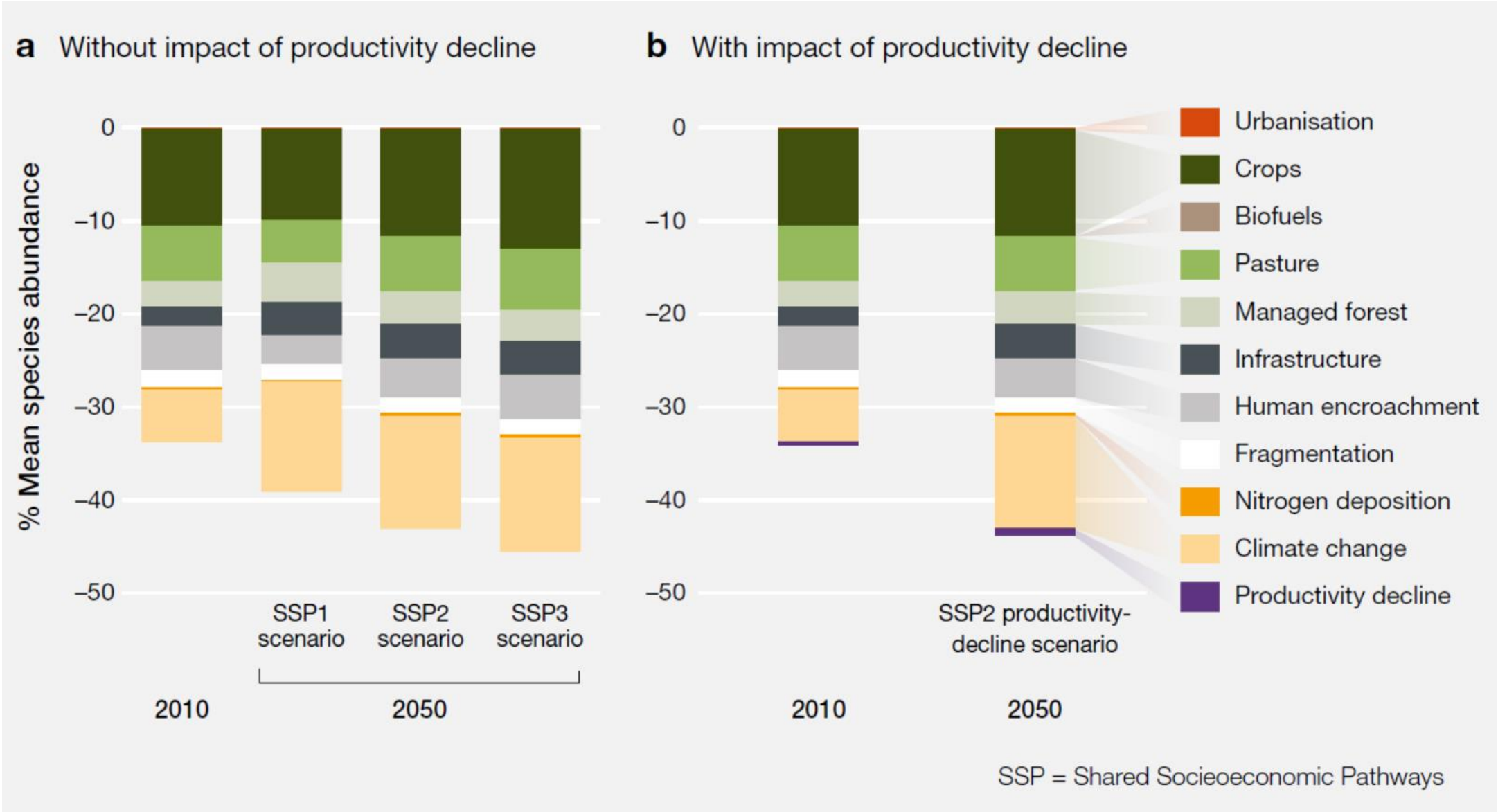


Actual (2010) vs. projected (2050) population:



source: Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity. 2017. Netherlands Environmental Assessment Agency, The Hague

Actual (2010) vs. projected (2050) biodiversity loss (assuming three different scenarios):



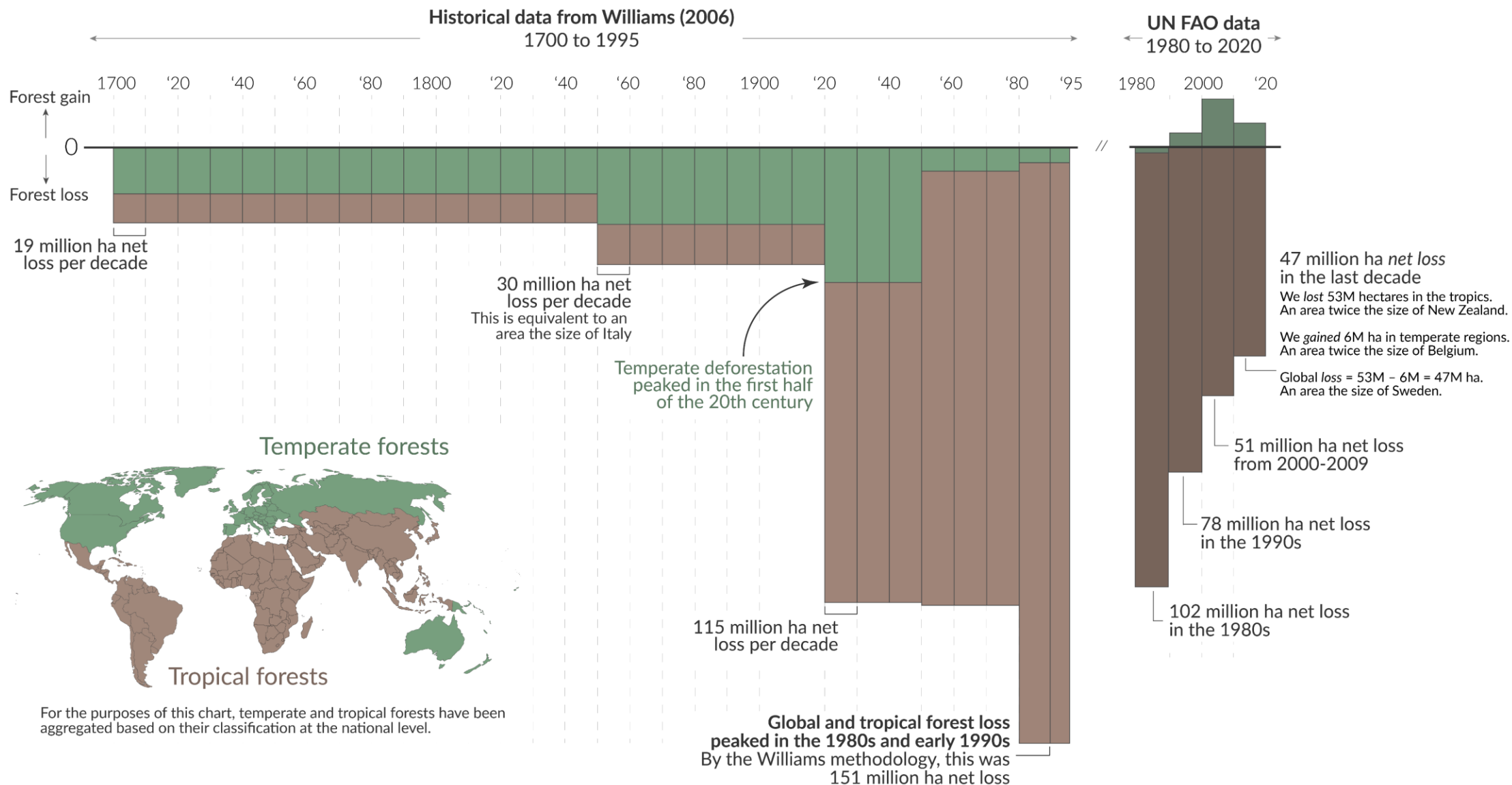
source: Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity. 2017. Netherlands Environmental Assessment Agency, The Hague

Deforestation



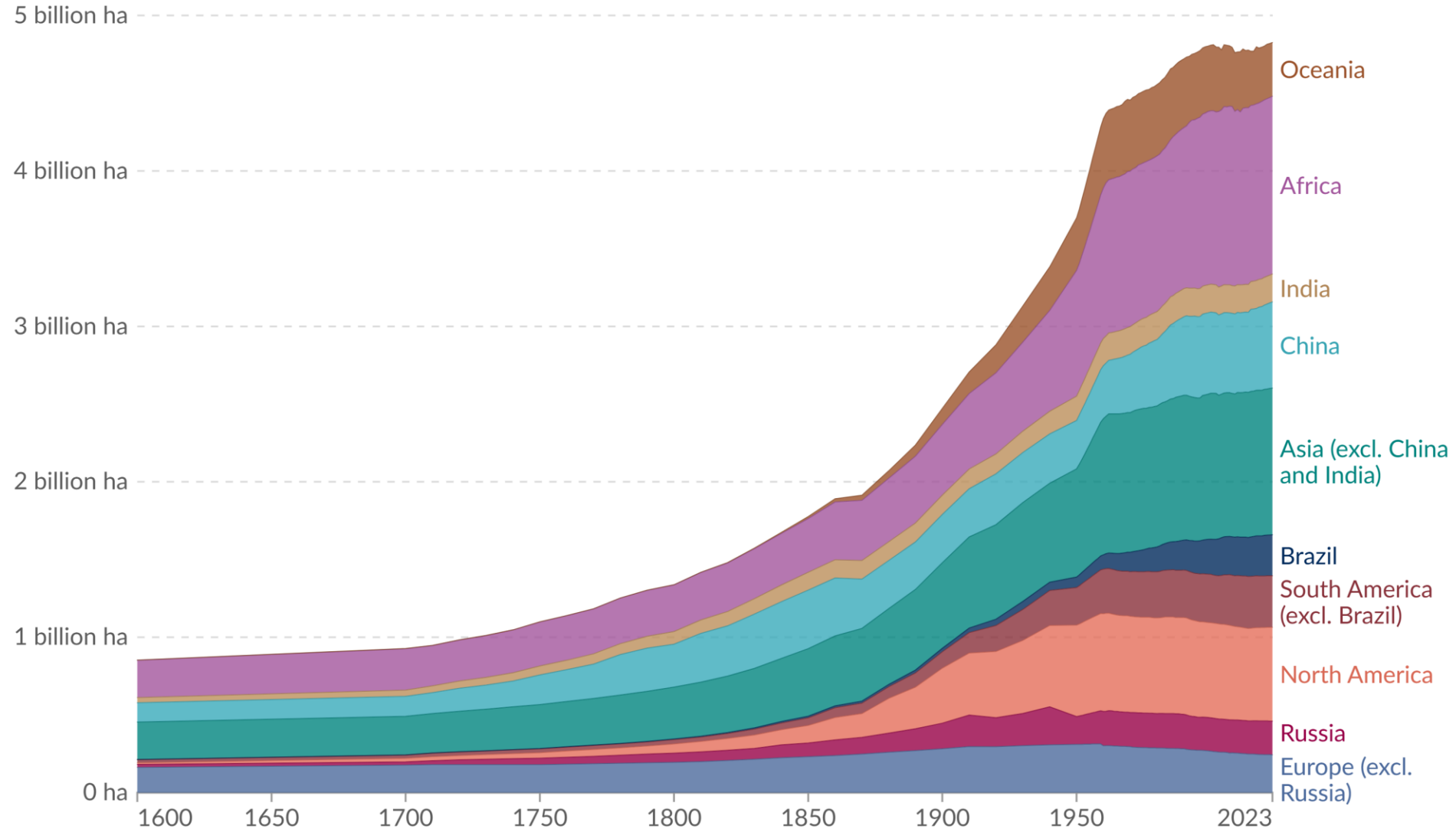
Decadal losses in global forest over the last three centuries

Decadal forest loss is measured as the average net loss every ten years, in hectares. This is deforestation minus increases in forest area through afforestation. There is no single dataset that applies a consistent or transparent methodology for deforestation over centuries. Two different datasets are therefore shown: these still show the overall development and transition of deforestation from temperate to tropical areas, but magnitudes should not be combined at the crossover point.



Agricultural area over the long-term, 1600 to 2023

Total areal land use for agriculture, measured as the combination of land for arable farming (cropland) and grazing in hectares.



Deforestation vs. Forest degradation

- Many **countries have lost** and then **regained forests** over millennia: nearly half (47%) of France was forested 1000 years ago; today that's just under one-third (31.4%). The same is true of the United States; back in 1630, 46% of the area of today's USA was covered by forest. Today, that's just 34%; 1000 years ago, 20% of Scotland's land was covered by forest. By the mid-18th century, only 4% of the country was forested.
- net forest change = deforestation – forest regrowth (in hectares)
- **Deforestation** = forest loss (in hectares)
- Deforestation is the complete removal of trees for the conversion of forest to another land use. The trees are not expected to regrow.
- On contrary **forest degradation** refers to thinning of the canopy — a reduction in the density of trees in the area — but without a change in land use. The changes to the forest may be, and often are, temporary — it is expected that trees will (re)grow.
- While deforestation takes place mainly in tropics, forest degradation pertains to various climatic zones and geographic areas

Why we lose forests?

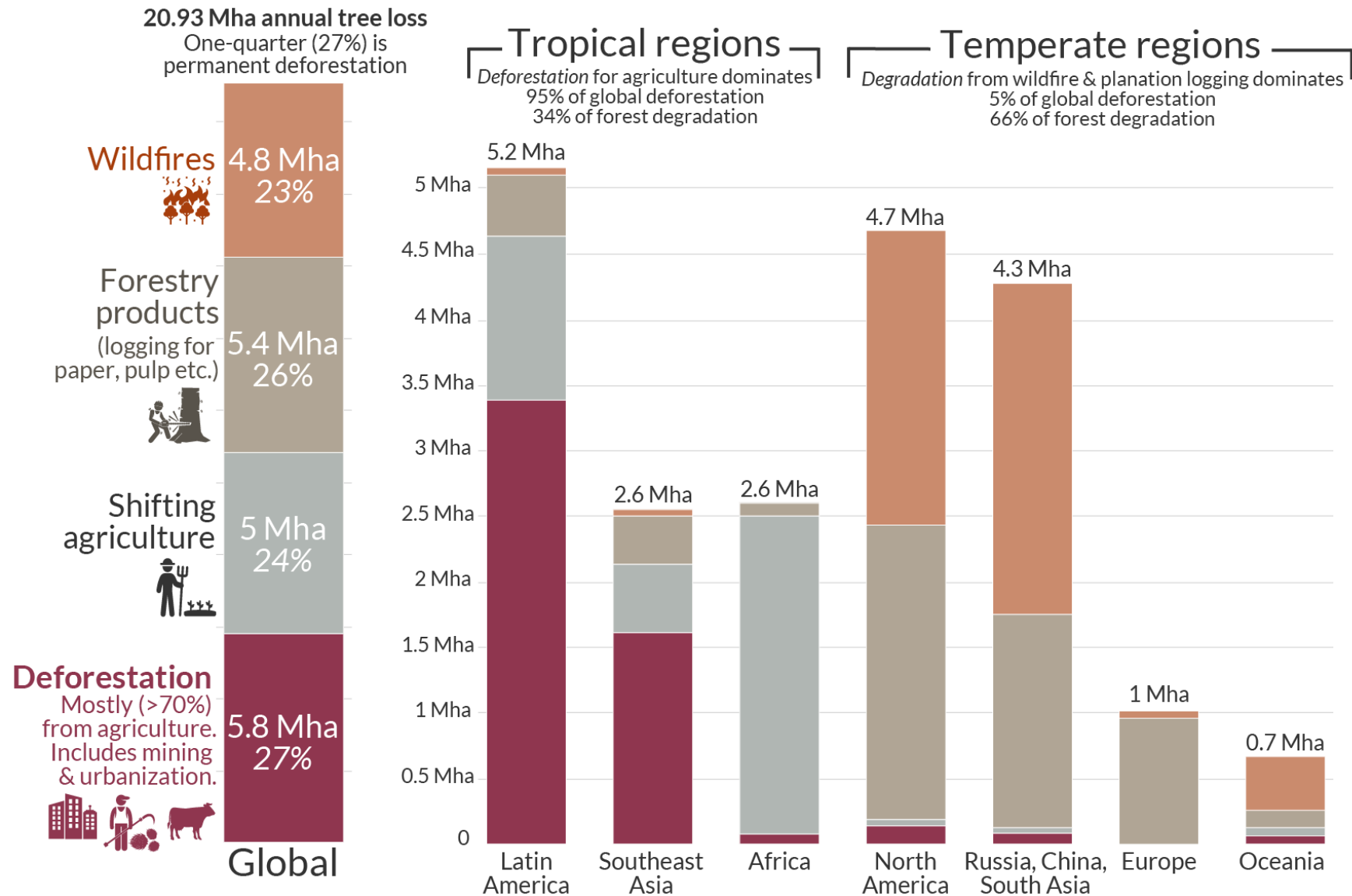
- **Commodity-driven deforestation:** the long-term, 'permanent' conversion of forests to other land uses such as agriculture (including oil palm and cattle ranching), mining, or energy infrastructure.
- **Forestry production:** the logging of managed, planted forests for products such as timber, paper, and pulp. These forests are logged periodically and allowed to regrow.
- **Wildfires:** destroy forests temporarily. When the land is not converted to a new use, forests can regrow in the following years.
- **Shifting agriculture:** the small- to medium-scale conversion of forest for farming, which is later abandoned so that forests regrow. This is common in local subsistence farming systems where populations will clear forest, use it to grow crops, and then move on to another plot of land.
- **Urbanization:** the long-term, permanent conversion of forests to towns, cities, and urban infrastructure such as roads.

Global forest loss: deforestation vs. forest degradation

Forest loss is defined as the combination of deforestation and forest degradation.

Deforestation involves the abrupt transition from land with trees to land without trees with no subsequent regrowth.

Forest degradation refers to thinning of the canopy and loss of carbon without a change in land use. Forest is expected to regrow.



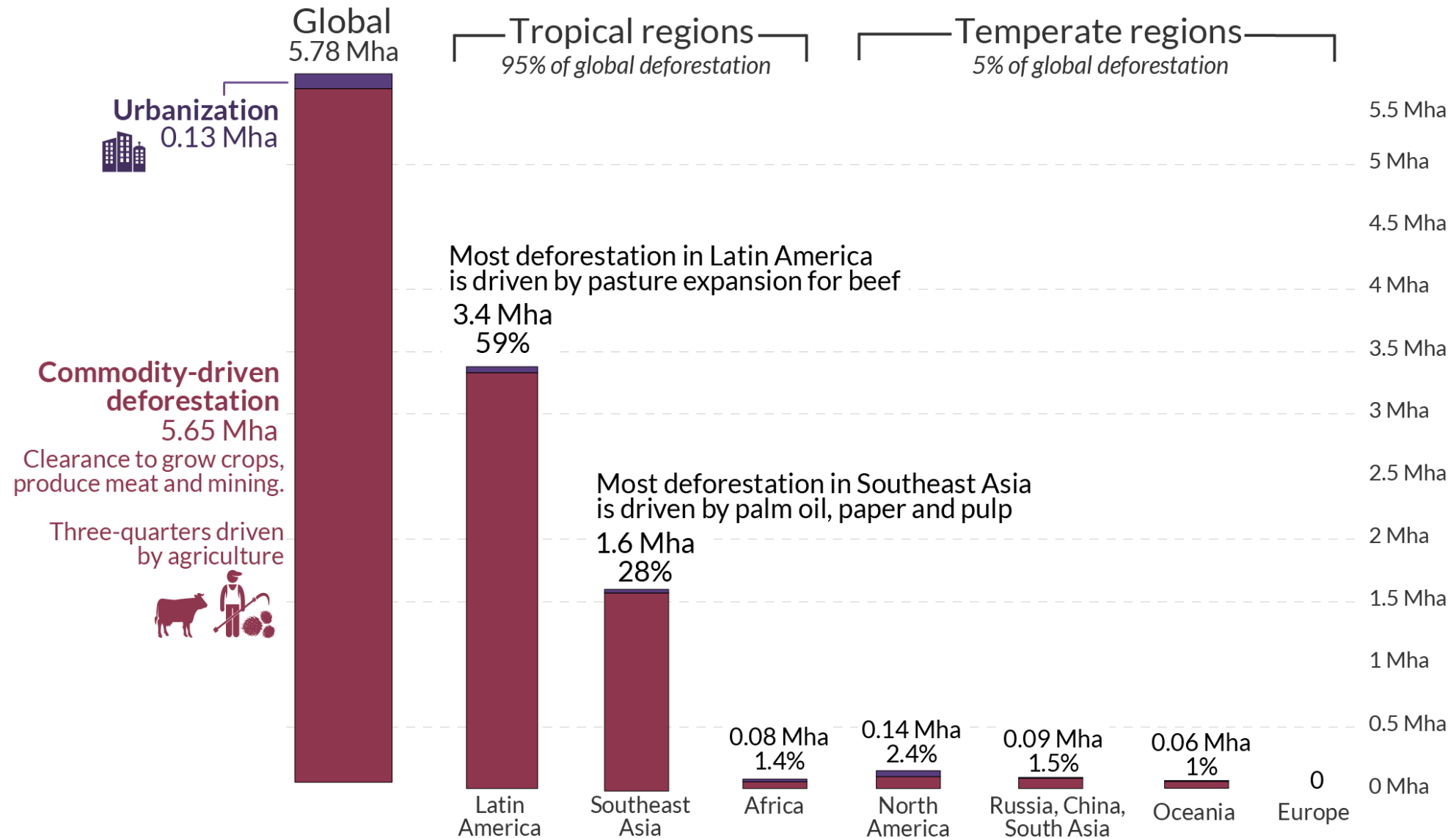
Data source: Philip Curtis et al. (2018). Classifying drivers of global forest loss. *Science*.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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Nearly all of global deforestation occurs in the tropics

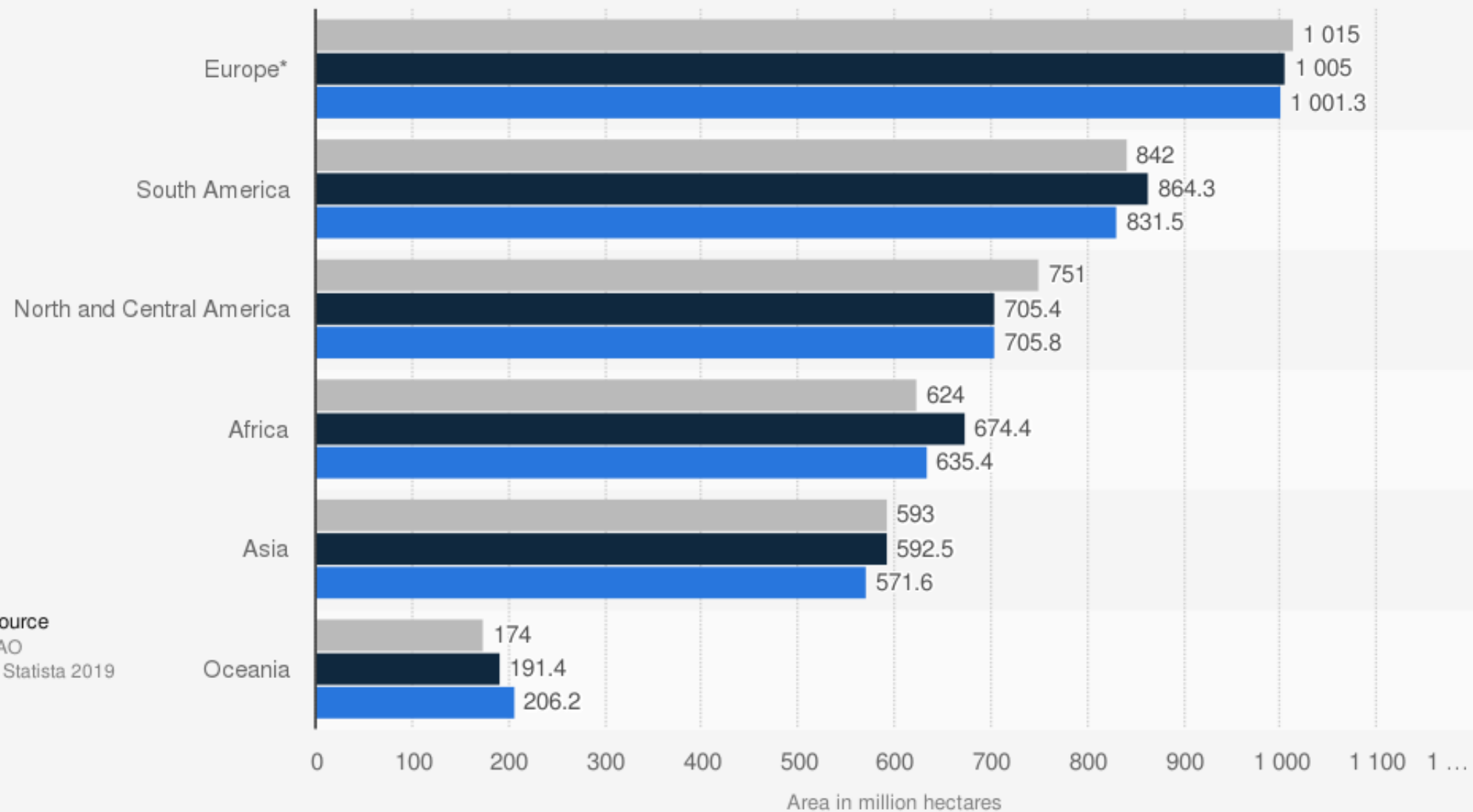
Deforestation is the permanent conversion of forest to another land use (such as agriculture or urban land). This is distinct from forest degradation – the logging of managed tree plantations, or wildfires – which is a temporary thinning of the canopy, and forests are expected to regrow.



Deforestation (large forest biomes)

- From the global perspective significant forest ecosystems are occurring in Amazon, central Africa, north America (Canada), central-north and south-east Asia → the forests in these areas are (or at least had been) **“spatially continuous”**
- The most of deforestation has been carried out in tropics; main drivers of deforestation in the tropical areas are commodities produced by agriculture and forestry (beef, vegetable oils, cocoa, coffee, wood, fiber and paper) and fire impact
- Throughout history deforestation has been often “supported” by fire (“slash and burn approach”)
- Maps showing change in global forest cover:
<https://glad.earthengine.app/view/global-forest-change>

Forest area worldwide in 2005, 2010 and 2015, by continent (in million hectares)



Source
FAO
© Statista 2019

Additional Information:
Worldwide; FAO; 2005, 2010 and 2015

● 2005 ● 2010 ● 2015

Forest ecosystem's functions

- CO₂ assimilation, biomass synthesis and O₂ production
- prevent soil from erosion
- habitat for various organisms
- transfer of water to atmosphere
- large – continuous forests contribute to precipitation at regional level (they help to maintain “their own” climate)
- forests trap and redistribute solar energy
- support of water infiltration and recharge of aquifers
- large forests contribute to water filtration

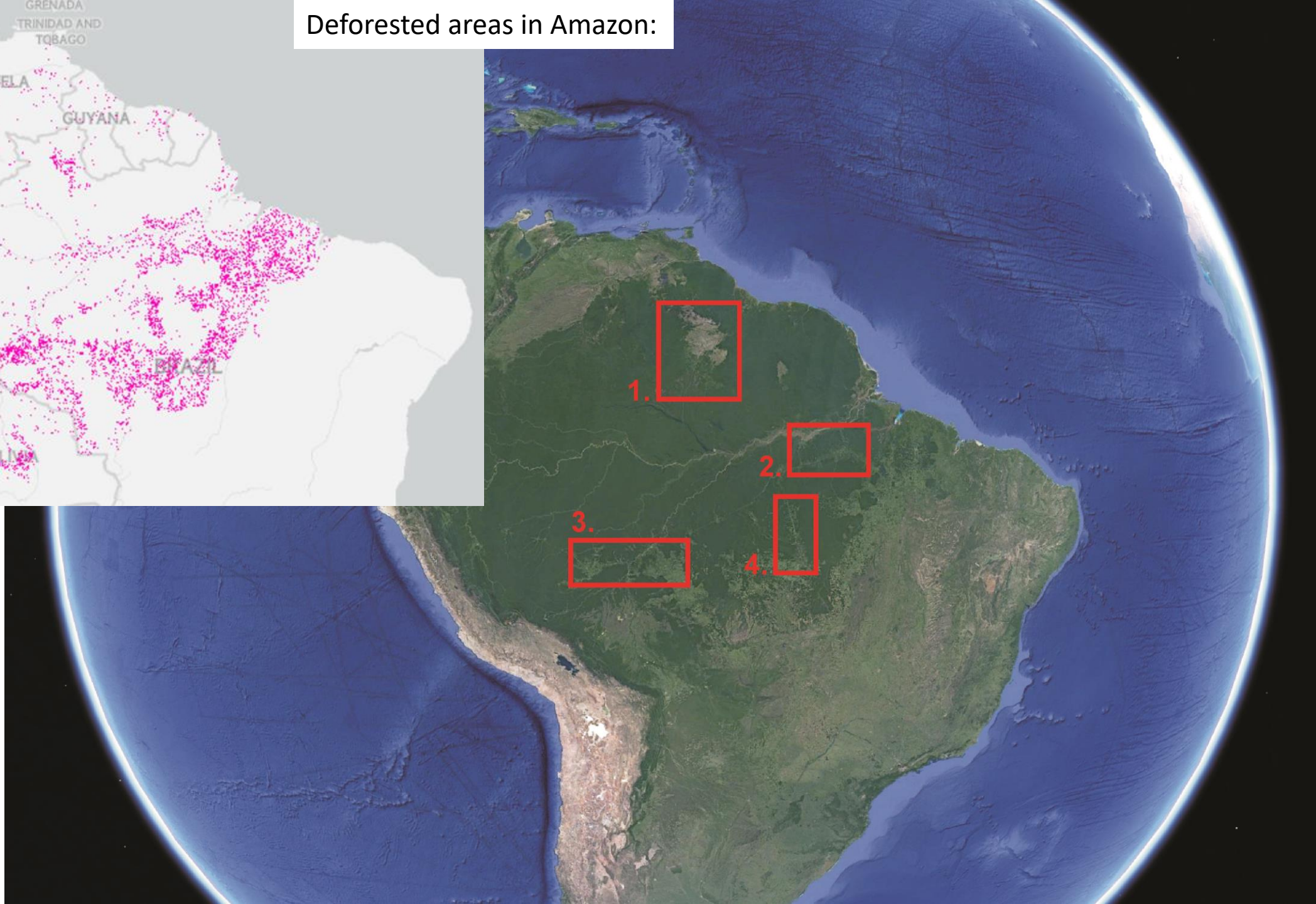
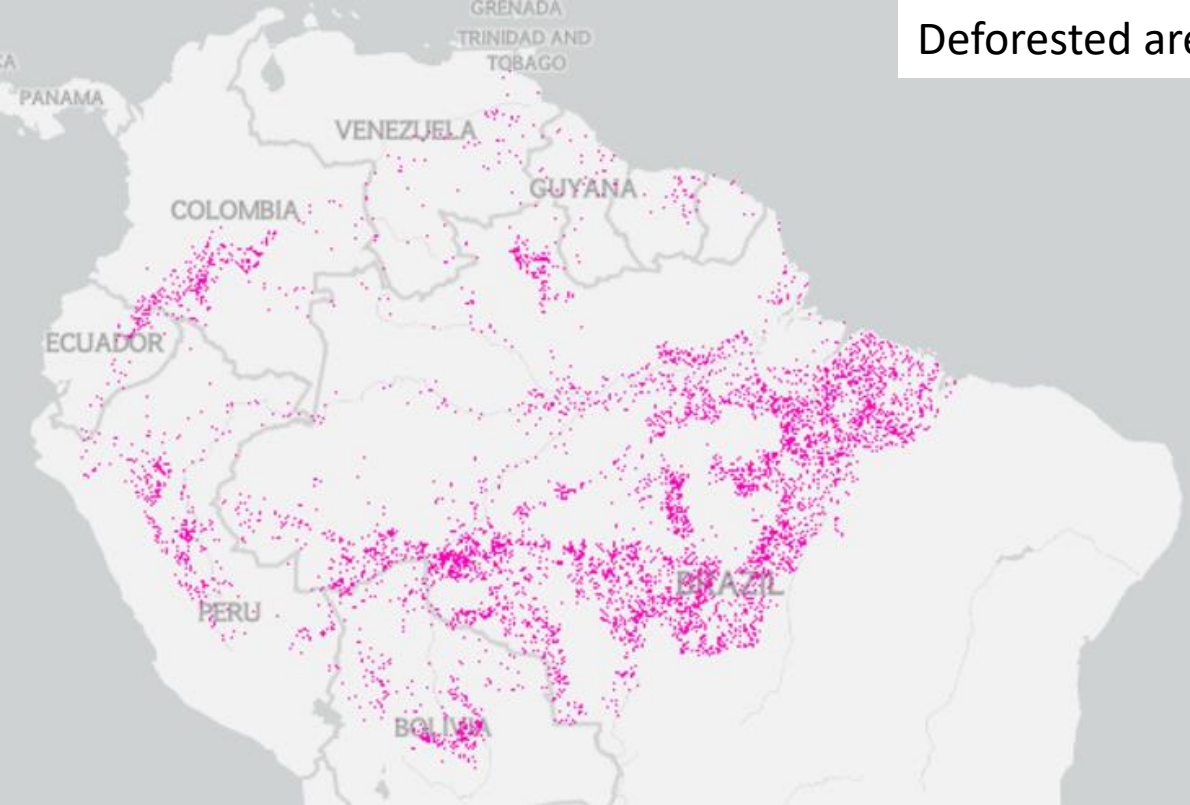
Forest ecosystem (effect of climate and hydrologic regime)

- In arid and warm areas, where evapotranspiration rate exceeds precipitation → not optimal conditions for forests
- However, if the water supply is provided from the subsurface (shallow water table), and at the same time, water mineralization is low → forest may thrive

Deforestation in Amazon

- Continuous forest has been fragmented → decrease of water retention capacity, and loss of forest's ability to maintain its "own" humid climate → onset of dry conditions and desiccation
- "slash and burn" approach → CO₂ production
- Recorded data suggest that forest in amazon has become a net producent of CO₂ during several past years (it produces more CO₂ compared to CO₂ assimilated via photosynthesis)
- It is not clear whether this is because the rate of photosynthesis has slowed down in drier conditions, or whether the produced CO₂ originates from decomposing organic matter in soil
- the climate has been humid in the Amazon area during several thousands of years (or even more), which have caused the accumulation of organic matter in near-surface; as climate becomes drier, the rate of decomposition and soil respiration increases, causing liberation of carbon into the atmosphere

Deforested areas in Amazon:



1.



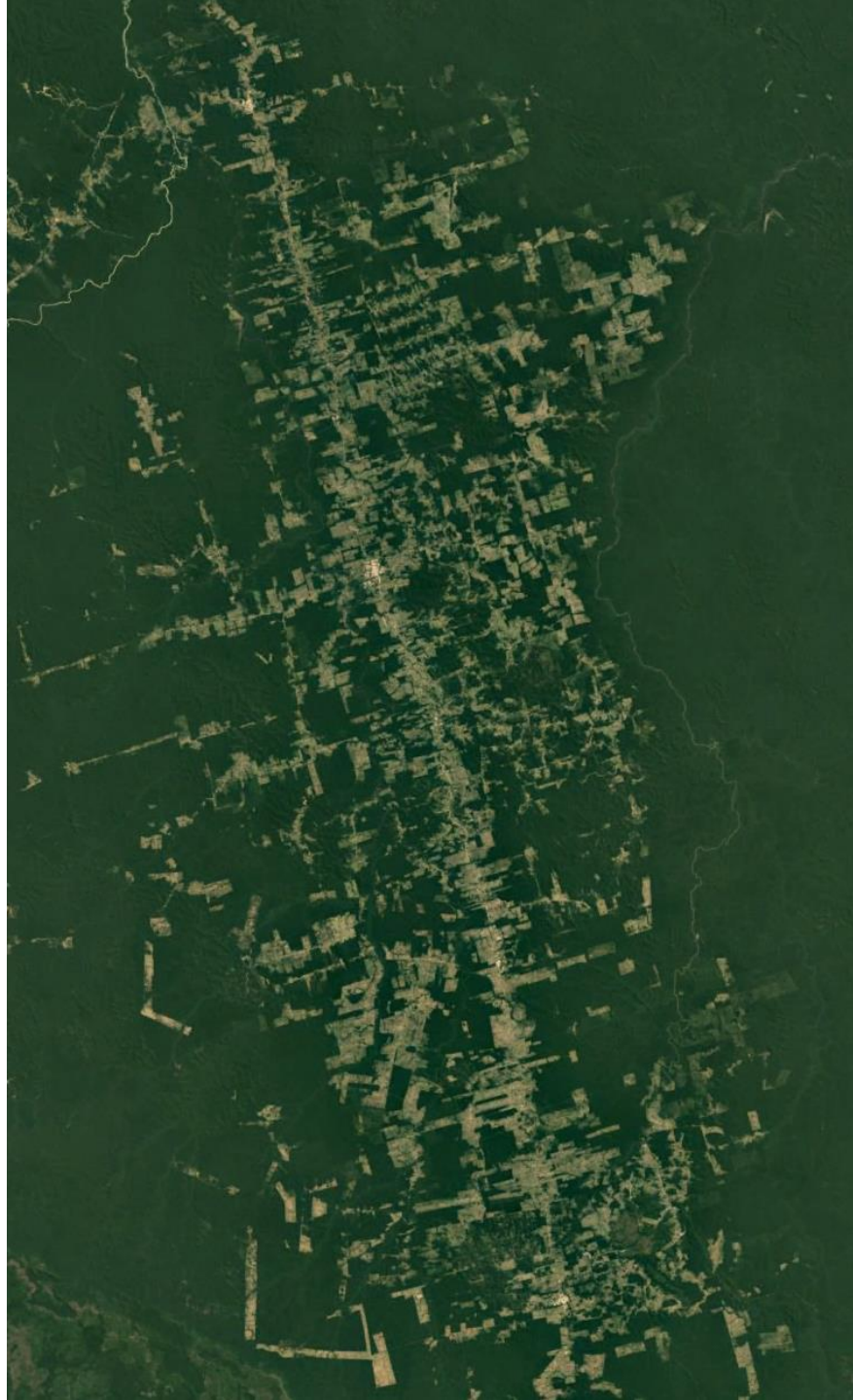
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3.

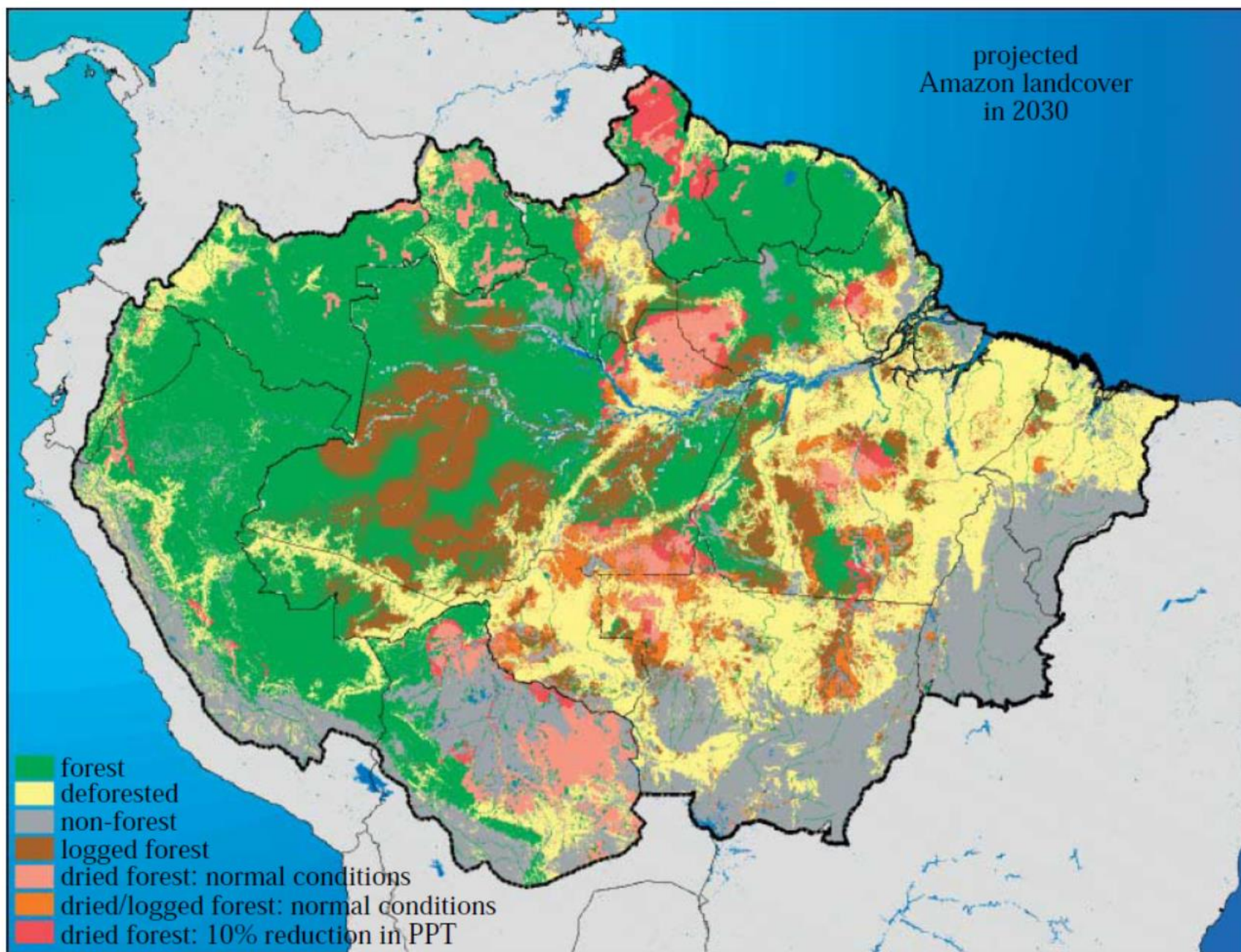


4.



- deforested areas in the Amazon are converted to agricultural land (pastures or croplands)
- similarly as in the other humid tropical regions, prescribed fires are often used as a part of deforestation
- since there is a lot accumulated carbon in labile form occurring near “forest floor”, substantial part is lost as CO_2 also due to the fire impact
- although fire produces ash, which provide inorganic nutrients (in readily available form) and alleviate (buffer) soil acidity, it is just short-term benefit, as most of the ash is washed away from soil by precipitation waters





Nepstad et al. (2008)
Interactions among Amazon
land use, forests
and climate: prospects for a
near-term
forest tipping point.

<http://doi.org/10.1098/rstb.2007.0036>

A map of Amazonia 2030, showing drought-damaged, logged and cleared forests assuming the last 10 years of climate are repeated in the future. See text for further details. PPT, precipitation.

There is a significant potential of secondary forest for trapping vast amounts of CO₂ from the atmosphere. It is much higher compared to original 'pristine' forest, which was basically in the climax stage. However, deforested areas are being used mainly for agricultural production (growing crops, pastures) and not for growing the trees.

CARBON BALANCE IN THE AMAZON

The Amazon region plays a major role in the global CO₂ balance, Drought has big implications for carbon sequestration by the tropical rainforest, and that is the key to more precise forecasting of the global climate.

Amazon forest

The Amazon forest is the largest rainforest on earth (5.5m km²), spread over 9 countries.



Annual rainfall in the Amazon

2000 mm



Annual rainfall in the Netherlands

880 mm



Secondary forest

Vast amounts of CO₂ are absorbed by the vegetation that regrows on open tracts of land after felling, fire or farming. In this secondary forest the biomass is restored to its original level.

All the secondary forest in Latin America (most of it in the Amazon) can sequester 31 gigatons of CO₂ in the next 40 years.

That is just as much as was produced in the countries of Latin America between 1993 and 2014.

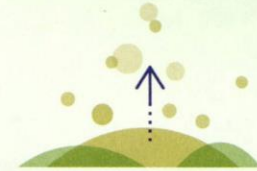
31 Gton

CO₂ absorption and emissions

Under stable conditions in the Amazon, when numbers of new seedlings and tree deaths are equal, absorption and emissions of CO₂ are more or less balanced:



The large amounts of water, heat and sunlight make for abundant plant growth, leading to CO₂ storage.



When plants are broken down, for example due to microbes which digest dead wood, CO₂ is released.

CO₂ production during drought

The weather is becoming drier in the Amazon. This slows the growth of plants and causes die-off, so that less CO₂ is stored while more is released.

0.9-1.8 Gton

CO₂ emissions by the Amazon in dry conditions (5 - 10 x the annual emissions of the Netherlands)

35 Gton

Annual global emissions of CO₂ from the burning of oil, gas and coal

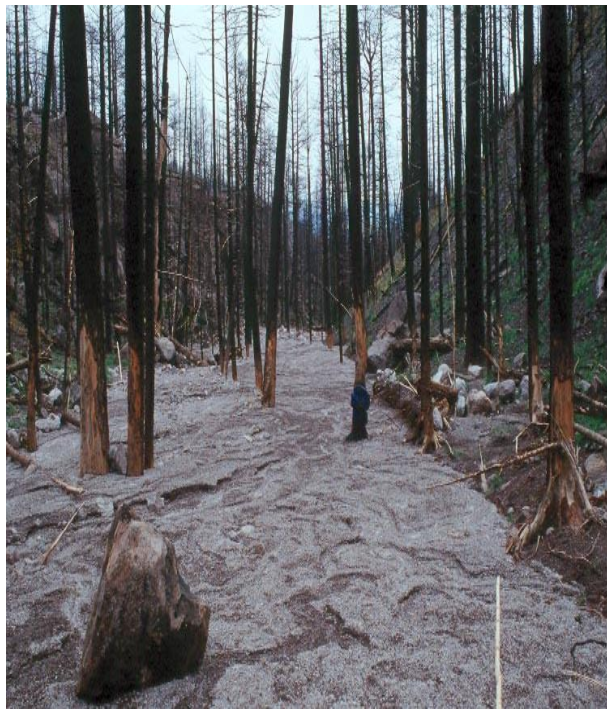
Ecological research shows in detail which species are present.

The capacity of secondary forest to absorb CO₂ is 11 times bigger than that of virgin rainforest.

11X

Effects of fire on forest ecosystems (negatives)

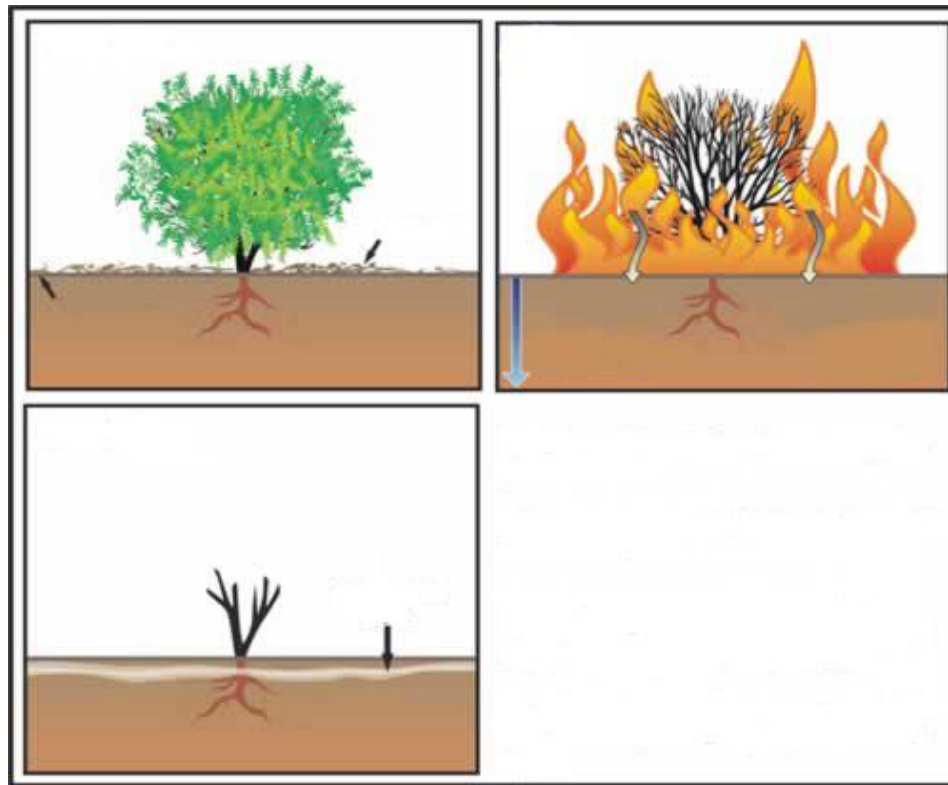
- direct threat due fire/smoke/dust/soot
- temporary (?) destruction of biotopes
- loss of biomass and nutrients (especially N - volatilization)
- CO₂ production
- loss of vegetation cover → erosion
- decrease of water retention capacity of ecosystem/area
- lower infiltration rate / soil water repellency occurrence



soil erosion
and
soil water repellency (SWR)
after forest fire



coarse-textured forest soils,
with higher portion of SiO_2 ,
often show water repellent
character even without the
fire impact; SWR is caused by
nonpolar organic
compounds/structures which
originate from biomass



nonpolar compounds (such as waxes) may evaporate during fire impact; since the source of heat is coming from above, they move few cm downwards where they condensate and create water repellent layer

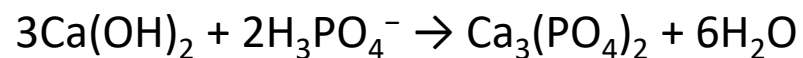


surface runoff and
water erosion after
fire in eucalypt forest
(Australia)

Effects of fire on forest ecosystems (positives?)

- not all effects imposed by fire on ecosystem are negative
- prescribed fires are used as management tool in the forestry
- there are plant communities that are adapted to fire impacts in the (semi)arid environments that show relatively quick recovery after fire occurrence
- ash production → ash contain nutrients in readily available form (P, K, Ca, Mg); except of N (nitrogen content in soil and ecosystem always decreases due to fire impact)
- ash ameliorates soil acidity since it has alkaline pH
- overall fire impact on the ecosystem depends on fire intensity, but also on type of fire (crown, surface, subsurface)

..however, some of P may react with Ca in alkaline conditions to form insoluble forms:



Prescribed fires in forestry

- getting rid of fuel load: prevention of big – ‘catastrophic’ fires
- moderate fire impact supports biodiversity and creation of new habitats (it promotes new growth of plants, attracting herbivores, which in turn attracts predators; open spaces created by fire are also beneficial for ground-nesting birds and certain small mammals)
- dense – overgrown vegetation is home of insects and pathogens that affect tree health negatively
- helps to maintain the balance between different types of vegetation; fire may be used to suppress invasive species
- neutralizing effect on acidic soils
- produces nutrients in available (soluble) forms

..obviously, onset of fire should be well planned, taking into account the weather conditions (humidity, wind, etc.), soil moisture, as well as parameters of vegetation to be burned

crown fire

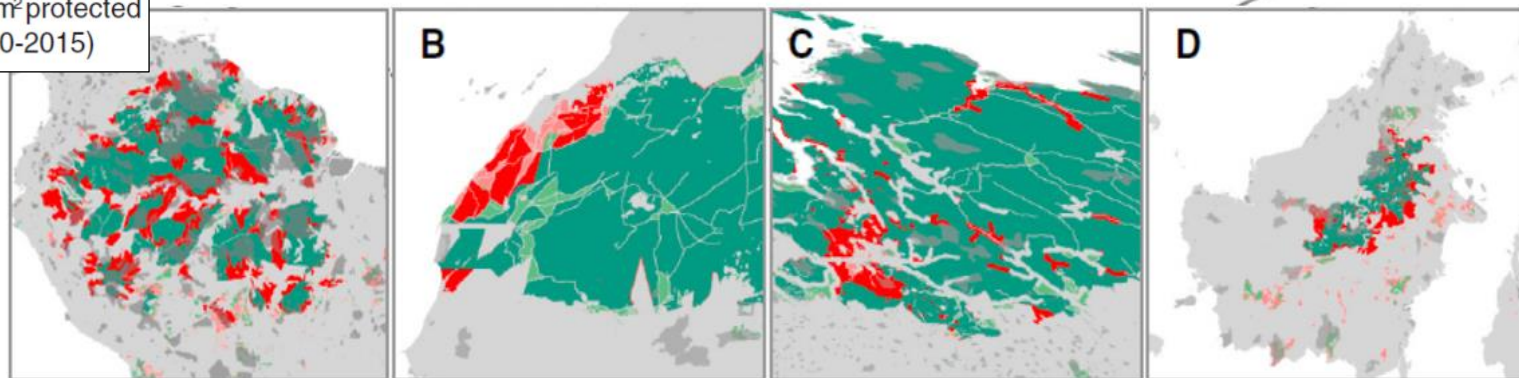
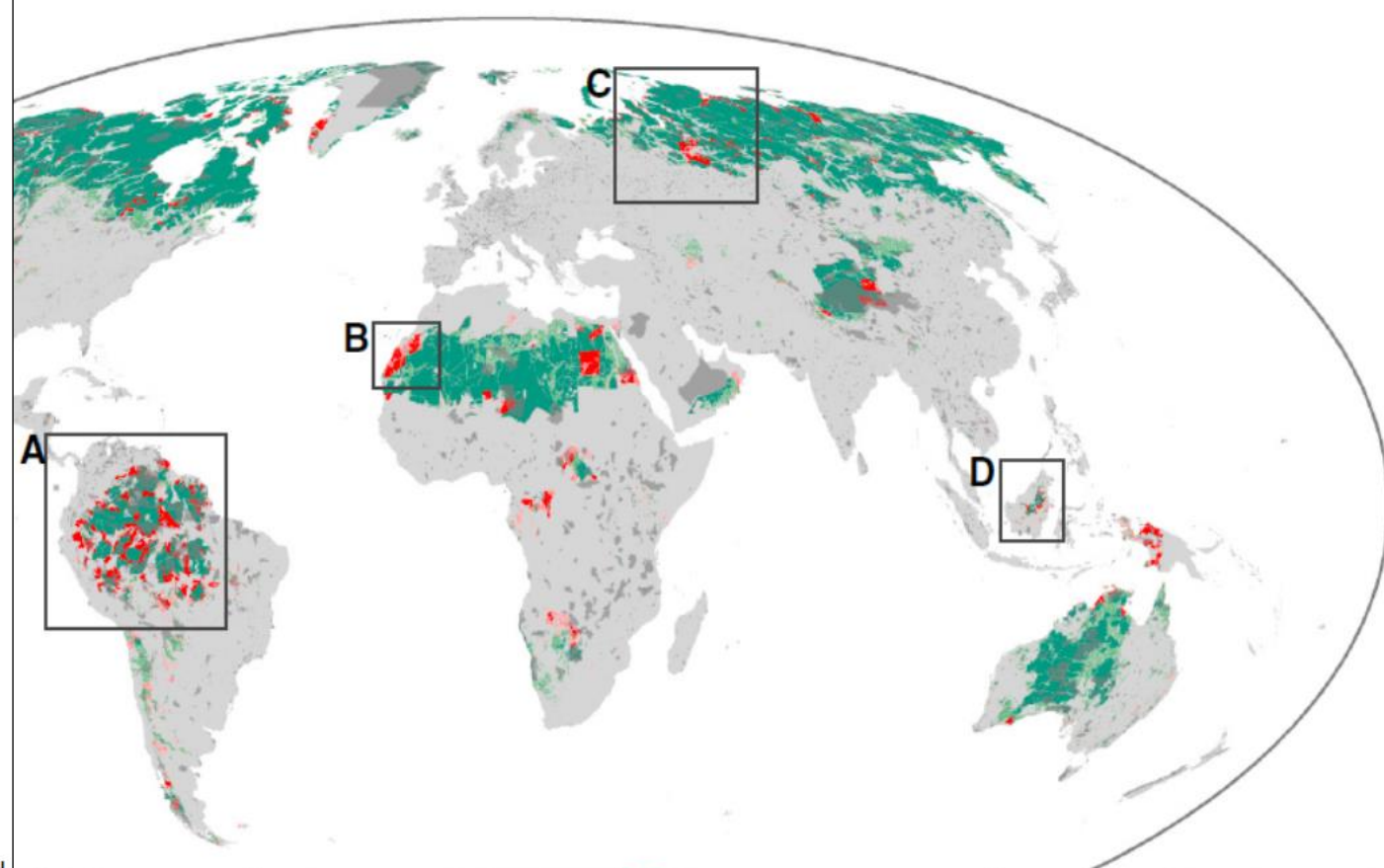
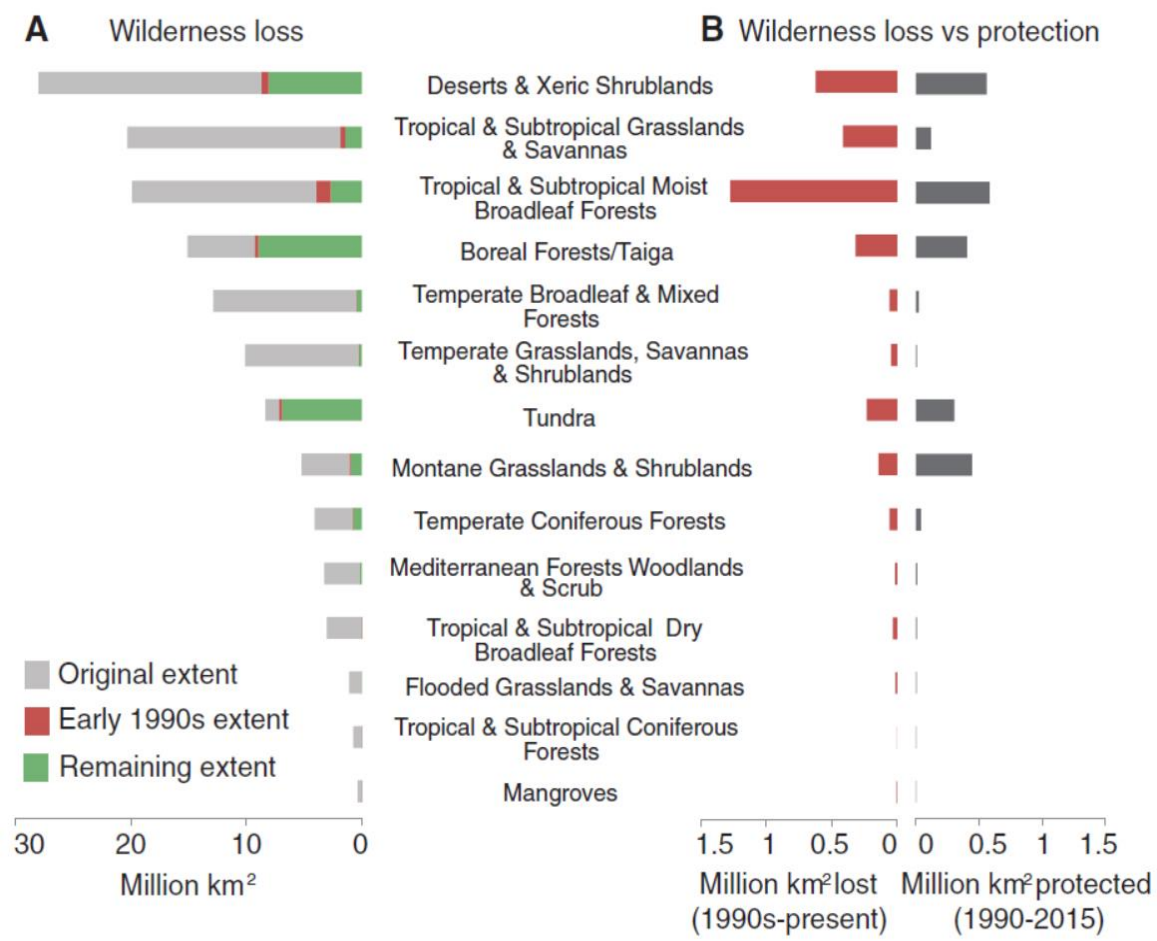


surface fire



subsurface fire





Loss / Change of Wilderness Areas since 1990s

(Watson et al., 2016)

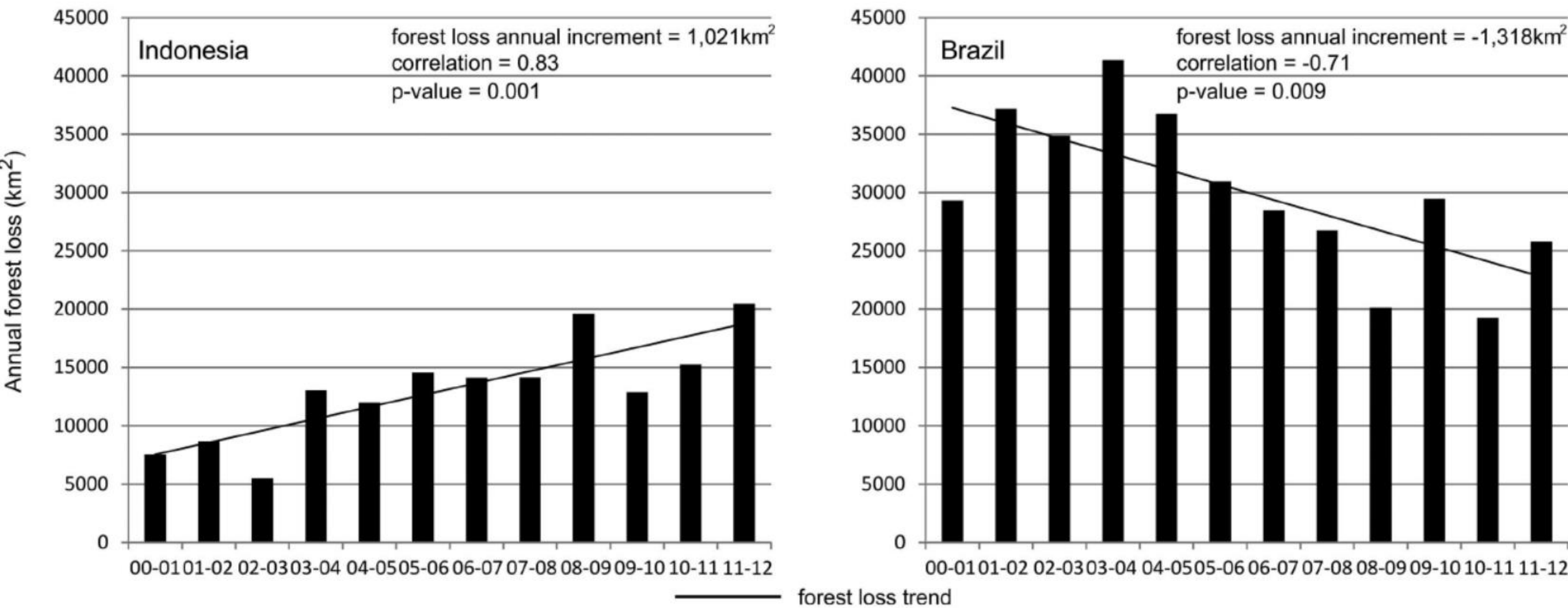
<http://dx.doi.org/10.1016/j.cub.2016.08.049>

21st. Century Forest Cover Change (Hansen et al. 2013; <https://doi.org/10.1126/science.1244693>)

- From 2000 to 2012: A total of 2.3 million km² of forest were lost due to disturbances and 0.8 million km² of new forest established. The tropical domain experienced the greatest total forest loss of the four climate domains (tropical, subtropical, temperate, and boreal), as well as the highest ratio of loss to gain (3.6 for >50% of tree cover), indicating the prevalence of deforestation.
- Tropical rainforest ecozones totaled 32% of global forest cover loss, nearly half of which occurred in South American rainforests.
- Recently reported reductions in Brazilian rainforest clearing over the past decade were confirmed, as annual forest loss decreased on average 1318 km²/year. However, increased annual loss of Eurasian tropical rainforest (1392 km²/year), African tropical moist deciduous forest (536 km²/year), South American dry tropical forest (459 km²/year), and Eurasian tropical moist deciduous (221 km²/year) and dry (123 km²/year) forests more than offset the slowing of Brazilian deforestation.
- Of all countries globally, Brazil exhibited the largest decline in annual forest loss, with a high of over 40,000 km²/year in 2003 to 2004 and a low of under 20,000 km²/year in 2010 to 2011. Of all countries globally, Indonesia exhibited the largest forest loss (1021 km²/year), with a low of under 10,000 km²/year from 2000 through 2003 and a high of over 20,000 km²/year in 2011 to 2012.

21st. Century Forest Cover Change

(Hansen et al. 2013)



Annual forest loss totals for Brazil and Indonesia from 2000 to 2012. The forest loss annual increment is the slope of the estimated trend line of change in annual forest loss.