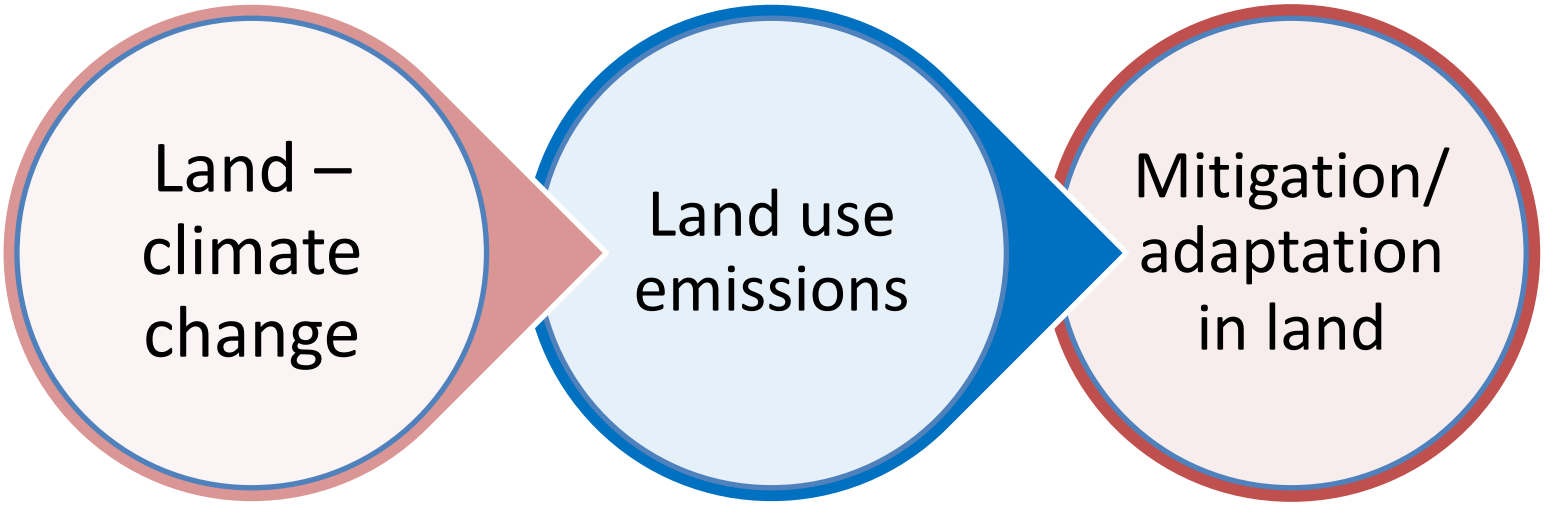
Role of Land Use in Climate Change

Rajendra Shrestha

7 March 2023

Contents


Land – climate change
Land use emissions
Mitigation/ adaptation in land

Context:

Planetary boundary framework

THE PLANETARY BOUNDARIES FRAMEWORK

Stratospheric ozone depletion

This means higher levels of UV radiation reach ground level. The appearance of the Antarctic ozone hole was proof that increased levels of man-made ozone-depleting chemical substances, interacting with polar stratospheric clouds, had passed a threshold. Fortunately, because of the actions taken as a result of the 1989 Montreal Protocol, we appear to be back on track to staying within this boundary.[38]

Biodiversity loss

Loss of biosphere integrity results in the loss of local and regional biodiversity, which makes ecosystems more vulnerable to changes in climate and ocean acidity. Currently, the extinction rate is used as a boundary measure for loss of biosphere integrity. Today, the global extinction rate far exceeds the rate of speciation.[39] If the current extinction rate is sustained, an undesired system change is highly likely.

Chemical pollution and release of novel entities

This includes microplastics, pesticides, heavy metal compounds and radioactive materials. Persistent organic pollution, for example, has caused dramatic reductions in bird populations and impaired reproduction and development in marine mammals.[40]

Climate change

This is measured by CO_2 concentration in the atmosphere, with a suggested boundary of 350 parts per million (ppm) above the pre-industrial level.[41] We've now surpassed 390 ppm CO_2 in the atmosphere. The loss of summer polar sea-ice is almost certainly irreversible. This is one example of a well-defined threshold that, when breached, gravely impacts the Earth system.[42]

Ocean acidification

This is a reduction in the ocean's PH due to CO_2 absorption: around one-quarter of our CO_2 emissions dissolve in the ocean.[43] This makes it difficult for essential marine life to survive. Unlike most other human impacts on the marine environment, which are often local in scale, this boundary has global ramifications. It is also an example of how tightly interconnected the boundaries are, as atmospheric CO_2 concentration is the underlying variable for both the climate change and ocean acidification boundaries.

Freshwater consumption

This is measured in terms of 'blue' and 'green' water. Blue water is the freshwater held in surface reservoirs. Green water is the fraction of rainfall that is absorbed by soil to feed plants. The freshwater cycle is closely linked to climate change and its boundary mirrors that of the climate boundary. A water boundary related to consumptive freshwater use and environmental flow requirements has been proposed to maintain the overall resilience of the Earth system.[44]

Land system change

This is driven primarily by agricultural expansion and intensification. Humanity may be reaching a point where further agricultural land expansion at a global scale may seriously threaten biodiversity and undermine the regulatory capacities of the Earth system. The Planetary Boundaries framework proposes that no more than 15% of global usable land should be converted to cropland.[45]

Biogeochemical flows: cycles of nitrogen and phosphorus

Nitrogen and phosphorus are both essential elements for plant growth, but activities like agriculture, poor wastewater management and fossil fuel use convert more atmospheric nitrogen into reactive forms than all of the Earth's terrestrial processes combined. A significant fraction of these nutrients make their way to the sea, and can push marine and aquatic systems across ecological thresholds of their own,[46] while impacting human health.

Atmospheric aerosol loading

This is impacted by GHG emissions and land-use change that releases dust and smoke into the air. Shifts in climate patterns and monsoon systems have already been seen in highly polluted environments, giving a quantifiable regional measure for an aerosol boundary.[47]

Legend: Safe; Close to overshooting; Overshot

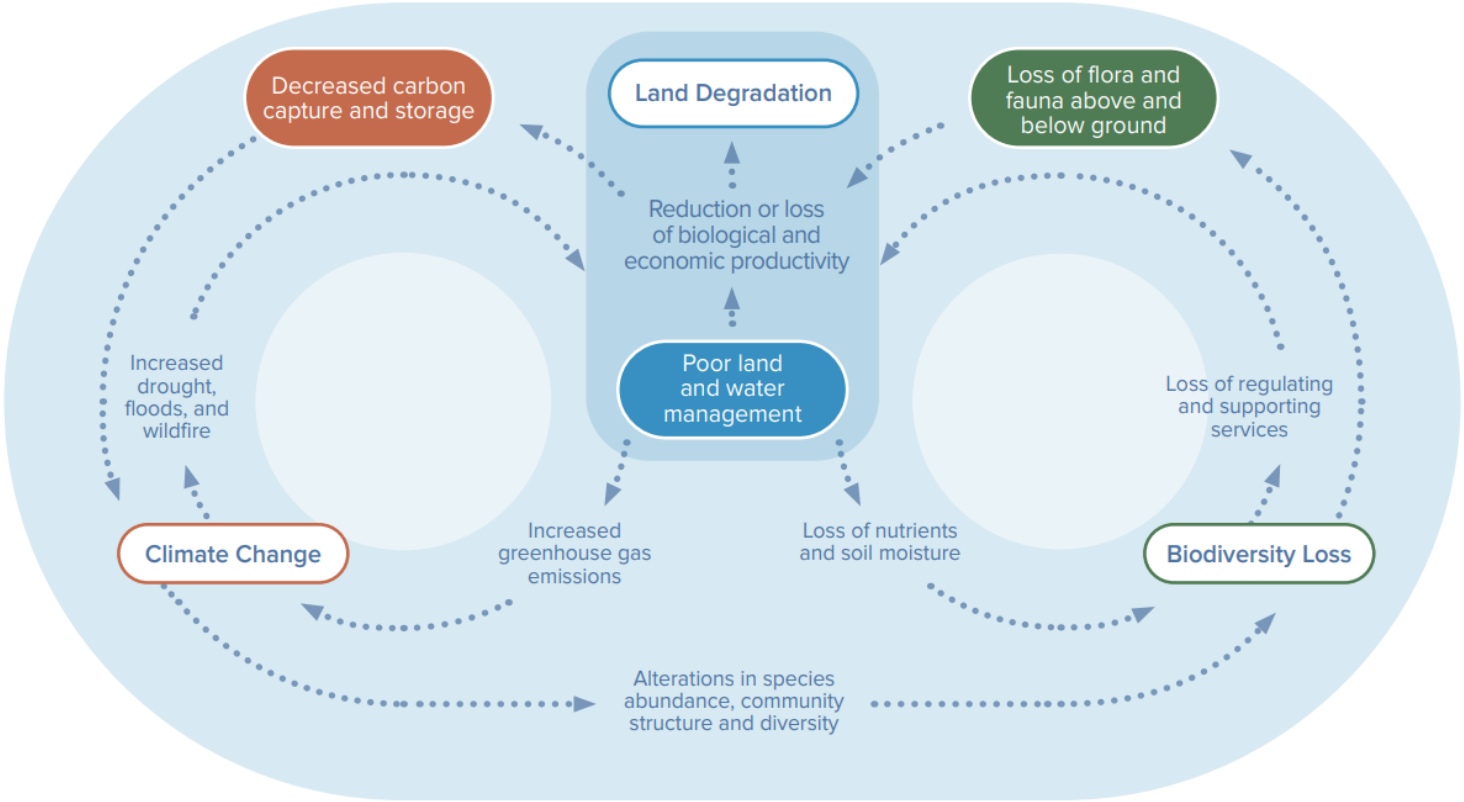
Land system change

This is driven primarily by agricultural expansion and intensification. Humanity may be reaching a point where further agricultural land expansion at a global scale may seriously threaten biodiversity and undermine the regulatory capacities of the Earth system. The Planetary Boundaries framework proposes that no more than 15% of global usable land should be converted to cropland.[45]

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, & J. Foley. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*.14(2) 32. http://www.ecologyandsociety.org/vol14/iss2/art32/

Land - Climate change – Biodiversity

Feedback loops



Source: Millennium Ecosystem Assessment, 2005.

Land-Climate link

Multiple processes and feedbacks involved when land surface and the atmosphere interacts, all of which may vary simultaneously.

I. **Land use/cover changes (including changes of vegetation type)**
   - modify the characteristics of the regional atmospheric circulation and the large-scale external moisture fluxes
   - influence fluxes and GHGs emissions which directly alter atmospheric composition and radiative forcing properties

II. **Land degradation**
   - aggravates CO_2-induced climate change through the release of CO_2 from cleared and dead vegetation and through the reduction of carbon sequestration potential of degraded land

What is land?

Definitions

Land: an area of the earth's surface including all elements of the physical and biological environment that influence land use. Thus, it refers to landforms, climate, hydrology, vegetation and fauna.

Land cover: observed (bio)physical cover on the earth's surface. Urban, Water, Wetland, Barren land, Tundra (shrub/bush), Agriculture, Rangeland, Forest

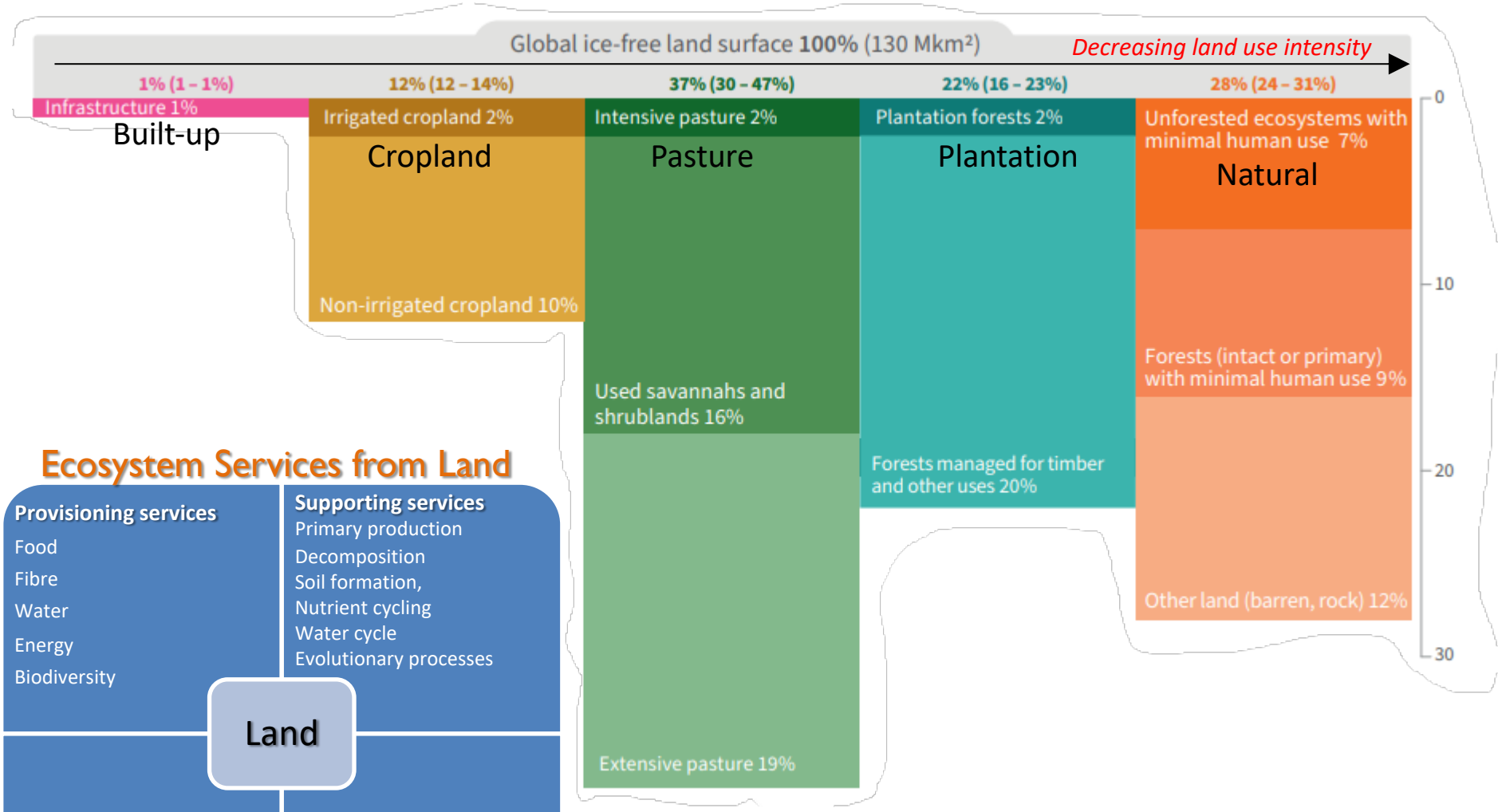
Land use: management of land to meet human needs. This includes arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it.

Land use/cover change or Land Change: a general term for the human modification of Earth's terrestrial surface.

Major land changes

- Agriculture and Forestry
- Urbanization
- Infrastructure development
- Energy production
- Mining and quarrying

Different uses of the global ice-free land area



Ecosystem Services from Land

Provisioning services
- Food
- Fibre
- Water
- Energy
- Biodiversity

Supporting services
- Primary production
- Decomposition
- Soil formation,
- Nutrient cycling
- Water cycle
- Evolutionary processes

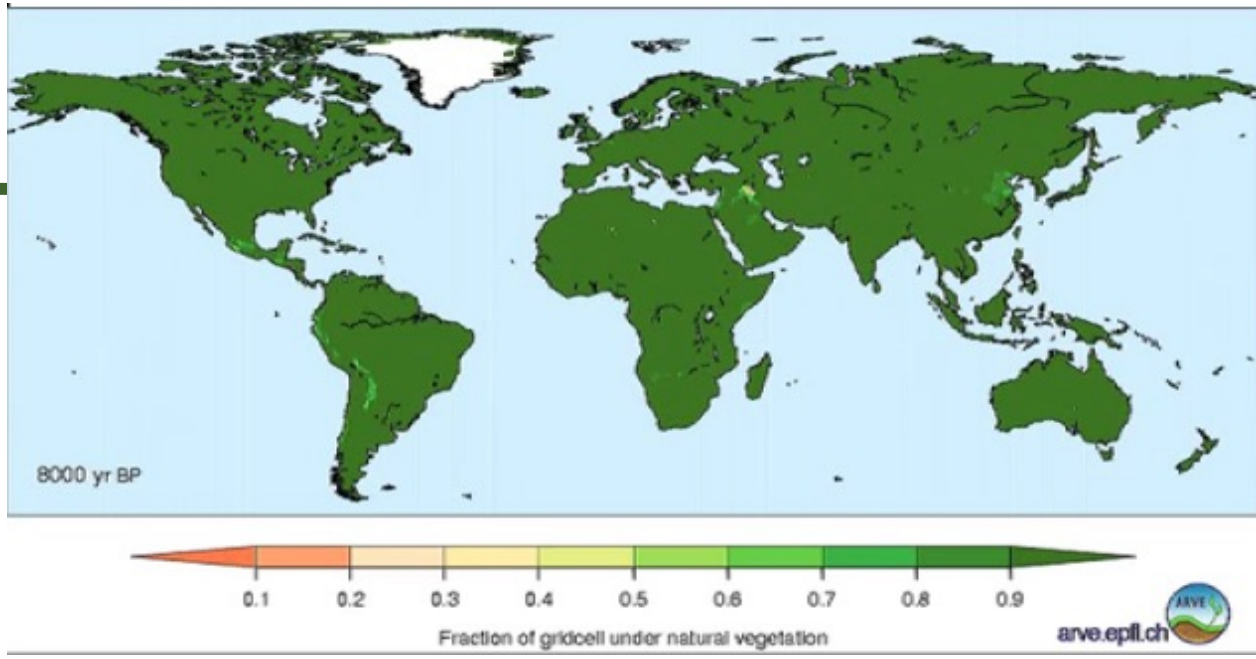
Land

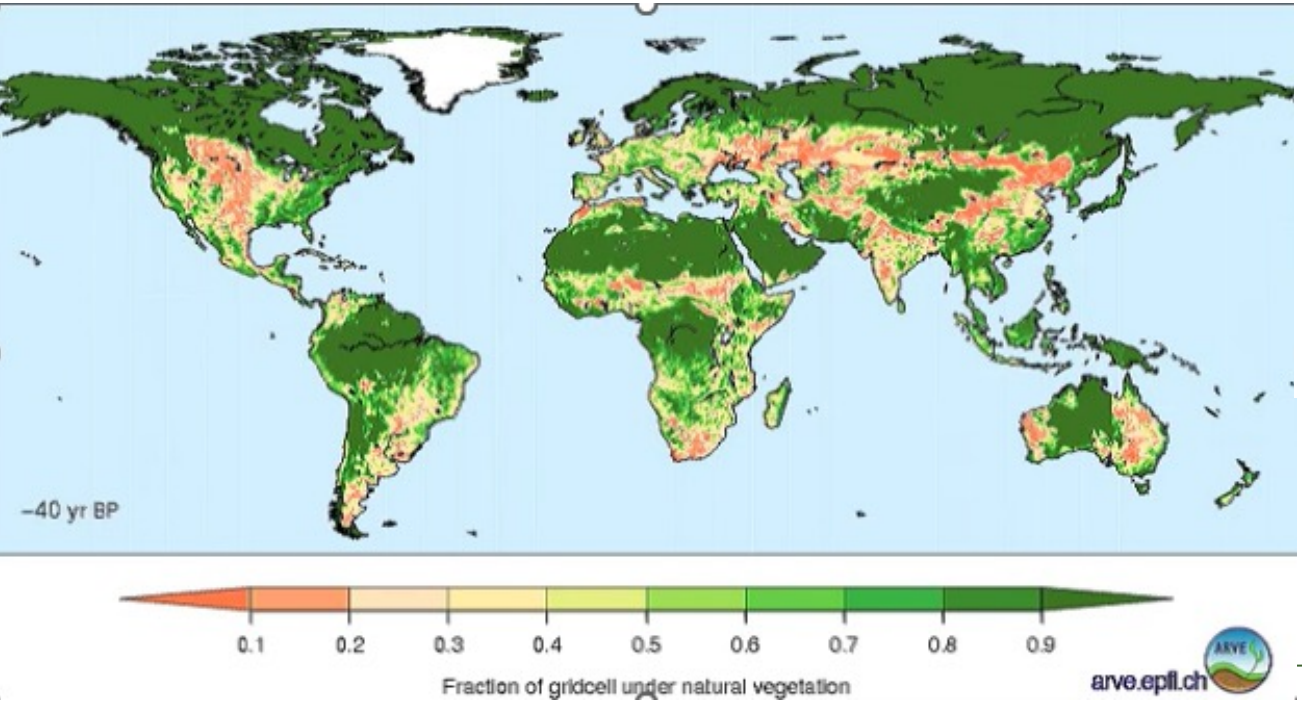
Regulating services
- Climate regulation
- Pollution control
- Air, soil and water quality
- Pollination

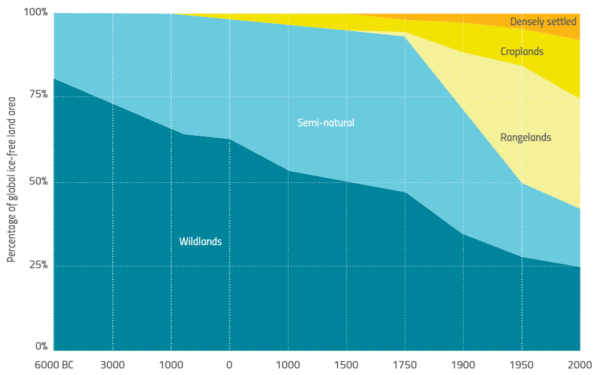
Cultural services
- Recreation
- Tourism
- Spiritual
- Religious

Global land cover change

from 8000 BP to -50 BP



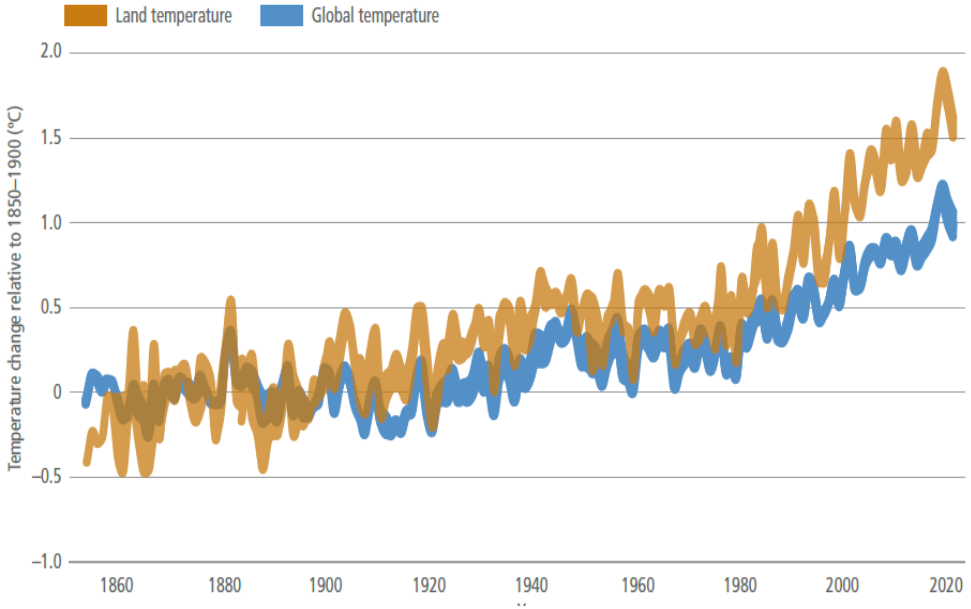




Transformation of biosphere over 8000 years

Ellis et al., 2013

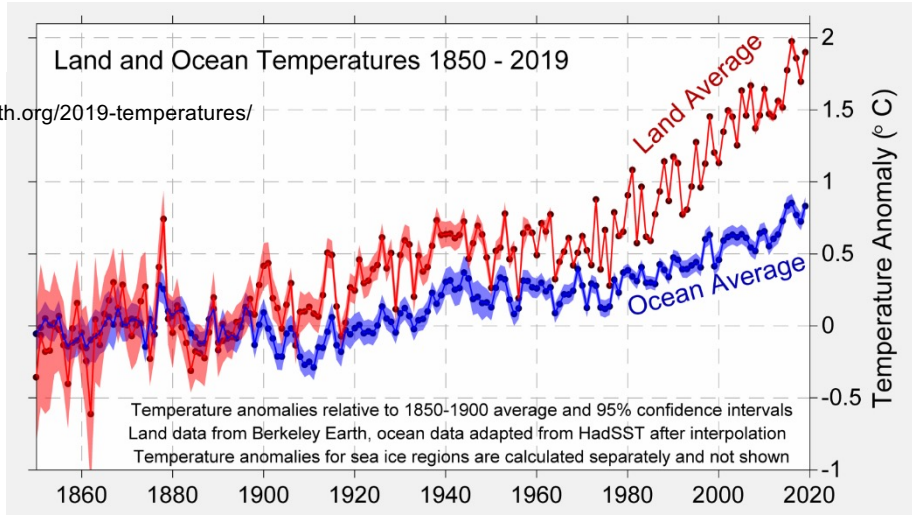
Climate (Temperature) change on Land



Globally averaged LSAT has risen faster (**1.53**°C) than the global mean surface temperature (**0.87**°C) from the preindustrial period (1850–1900) to the present day (1999–2018).

Evolution of land surface air temperature (LSAT), Global mean surface temperature (GMST), and Ocean average

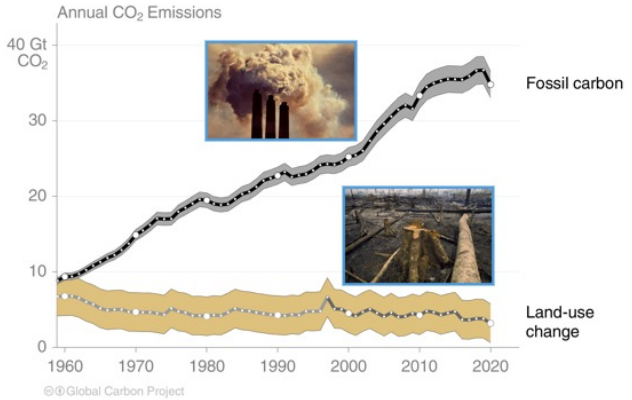
http://berkeleyearth.org/2019-temperatures/



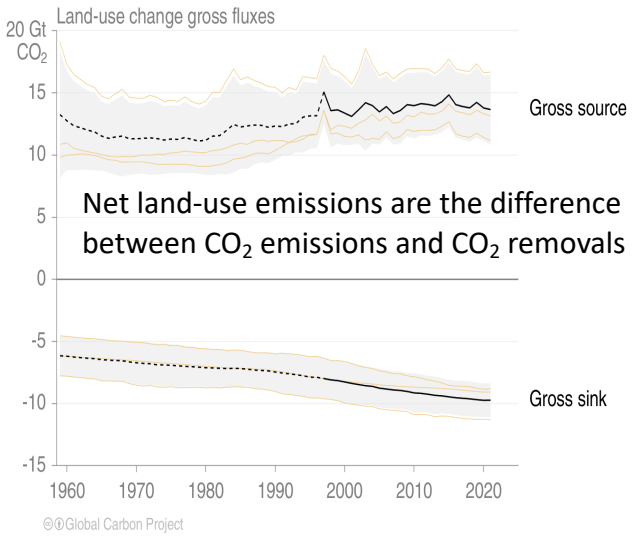
GHGs emission from land use

Global CO_2 sources

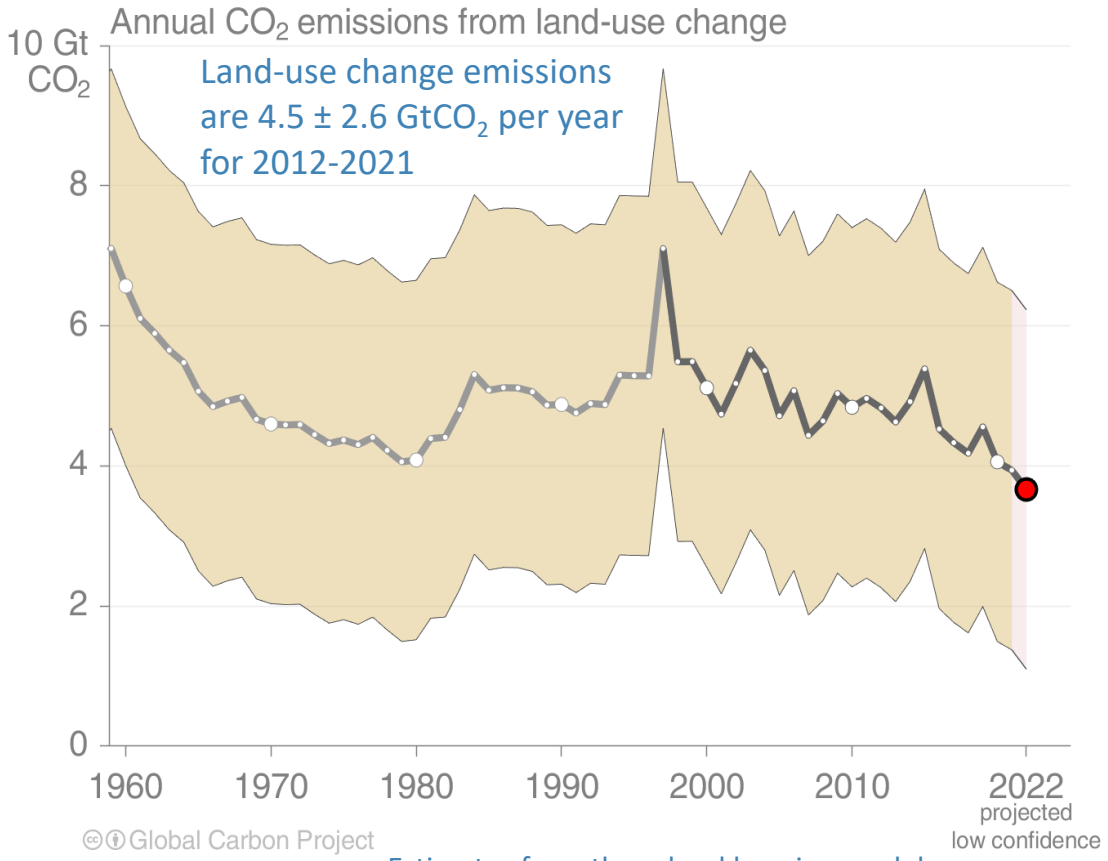
Total global CO_2 emissions: 38.0 ± 3.1 $GtCO_2$ in 2020, 40% over 1990
Percentage land-use change: 42% in 1960, 10% averaged 2011–2020



Land-use change estimates from three bookkeeping models, using fire-based variability from 1997
Source: Friedlingstein et al 2021; Global Carbon Project 2021

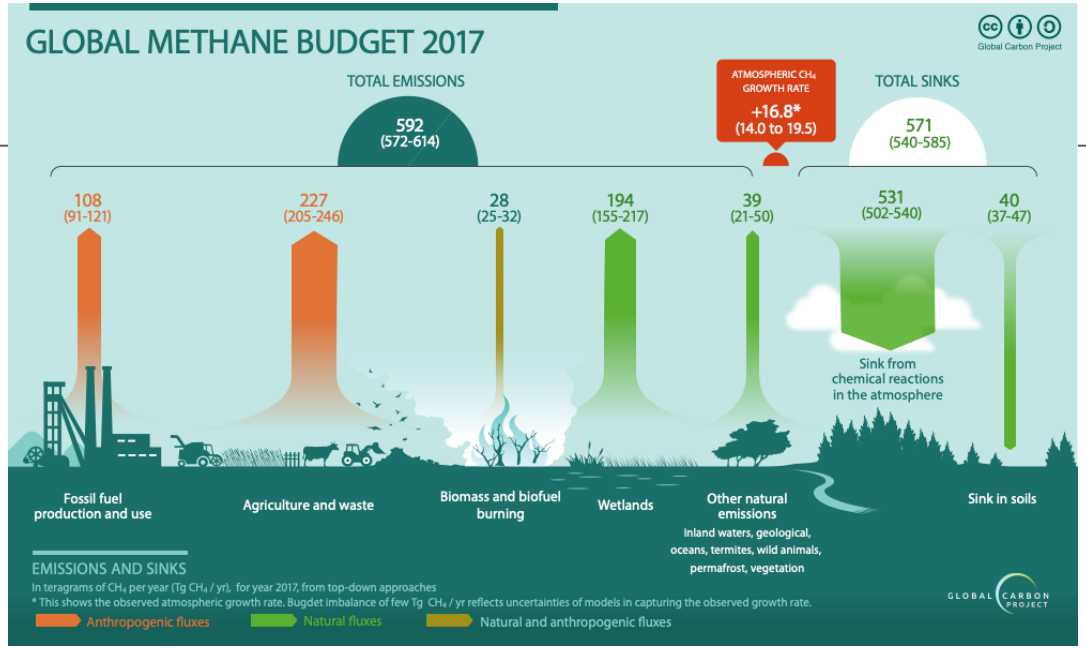


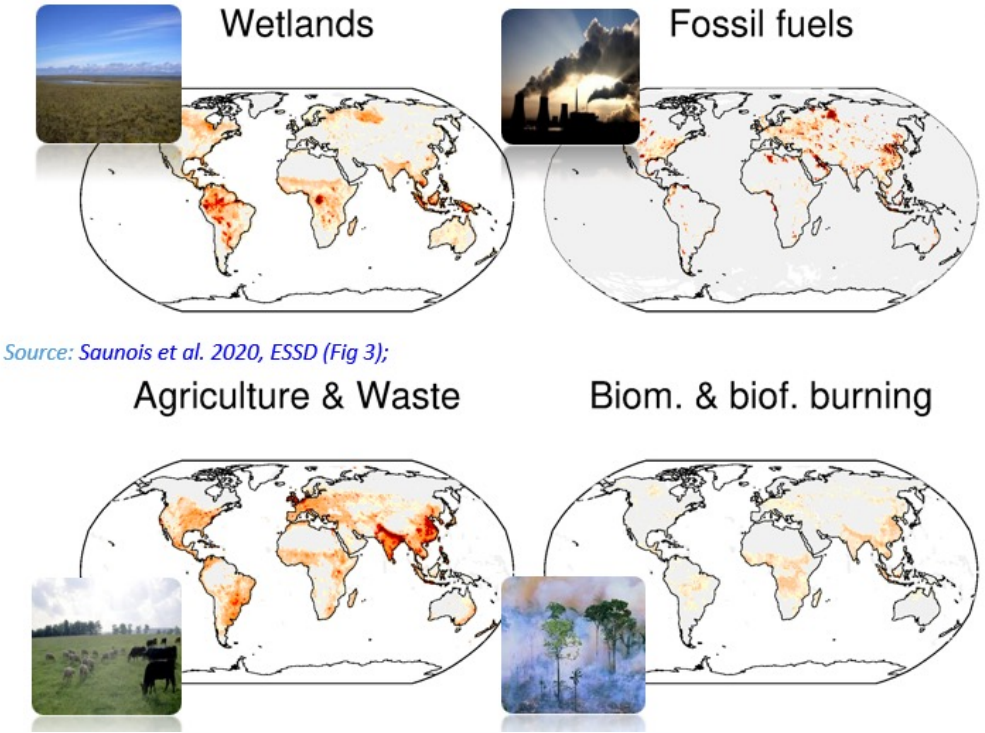
Net land-use emissions are the difference between CO_2 emissions and CO_2 removals



Estimates from three bookkeeping models
Source: Friedlingstein et al 2022; Global Carbon Project 2022

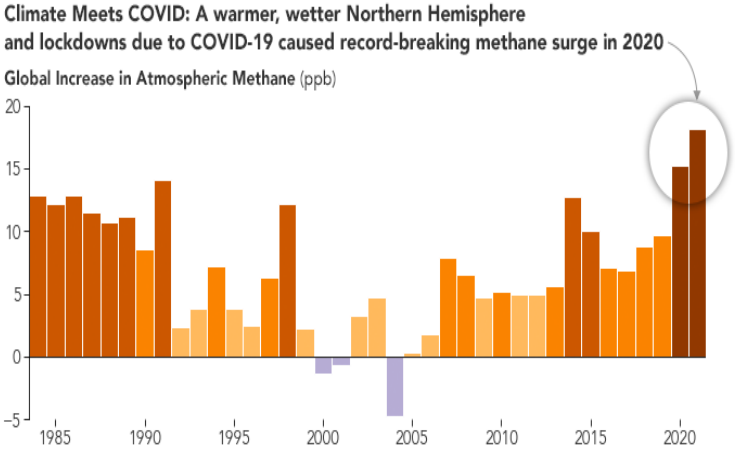
Global Methane sources





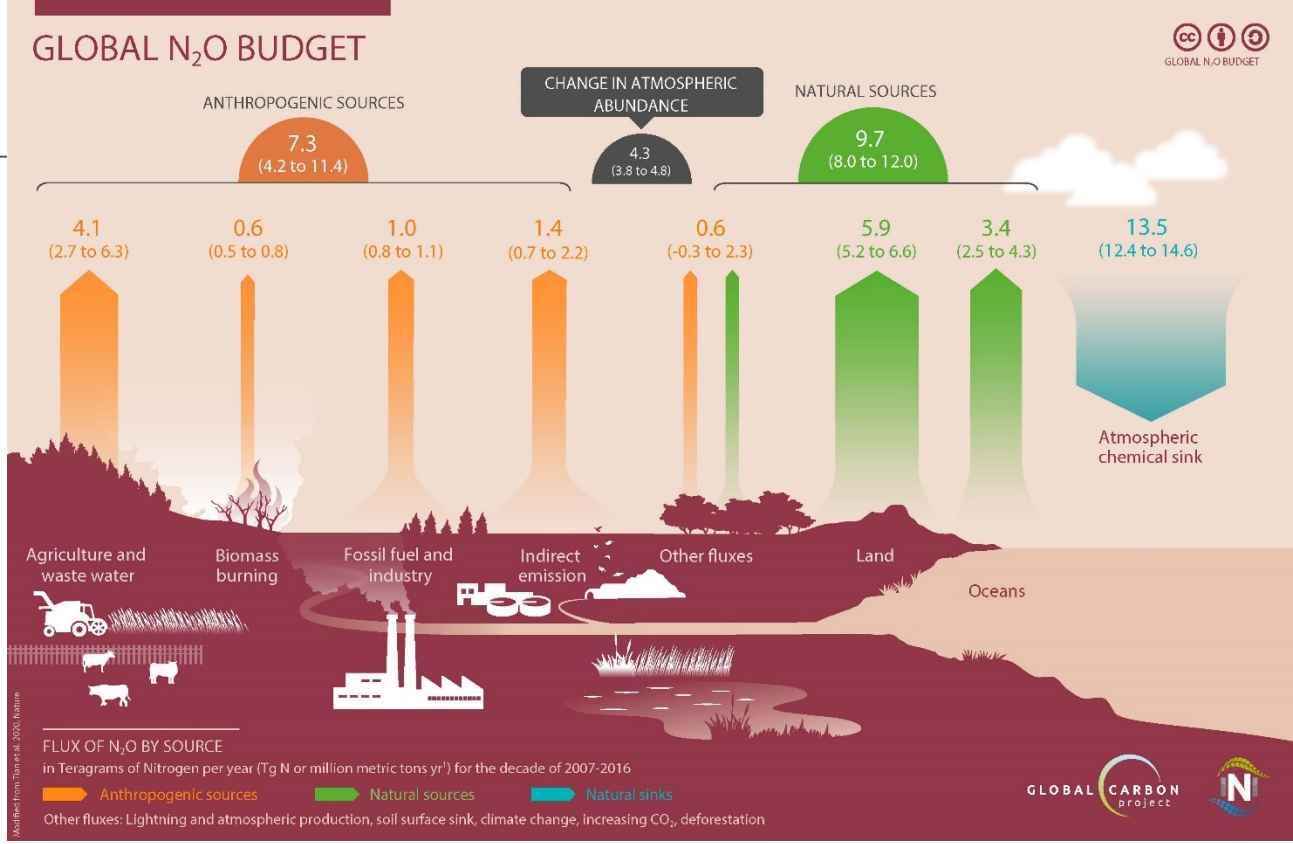
Source: *Saunois et al. 2020, ESSD (Fig 3);*

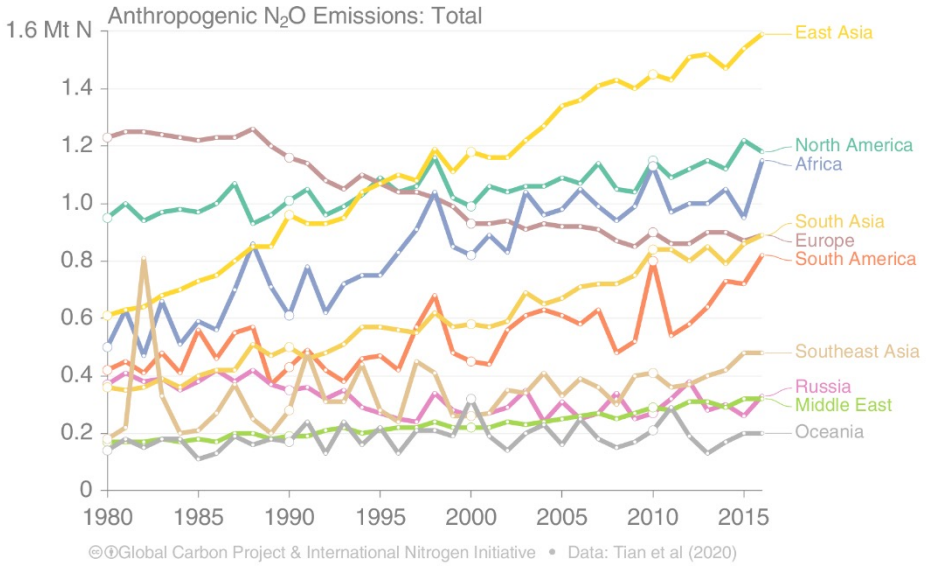
Source: *Jackson et al. 2020, ERL (Fig. 1)*



https://www.nature.com/articles/s41586-022-05447-w

Global N_2O sources





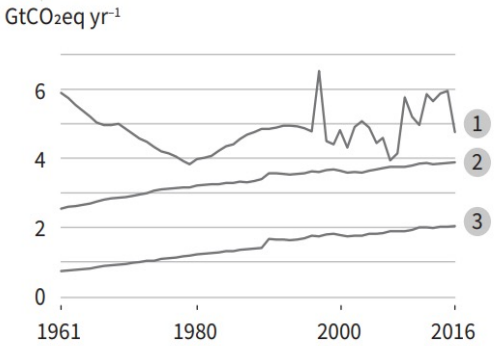
The recent global increase in N_2O emissions is driven by Asia, followed by South America and Africa, while emissions in Europe have decreased since 1990

Net anthropogenic emission

An estimated 23% of total anthropogenic greenhouse gas emissions (2007–2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).

CHANGE in EMISSIONS since 1961

1. Net CO_2 emissions from FOLU ($GtCO_2\ yr^{-1}$)
2. CH_4 emissions from Agriculture ($GtCO_2eq\ yr^{-1}$)
3. N_2O emissions from Agriculture ($GtCO_2eq\ yr^{-1}$)

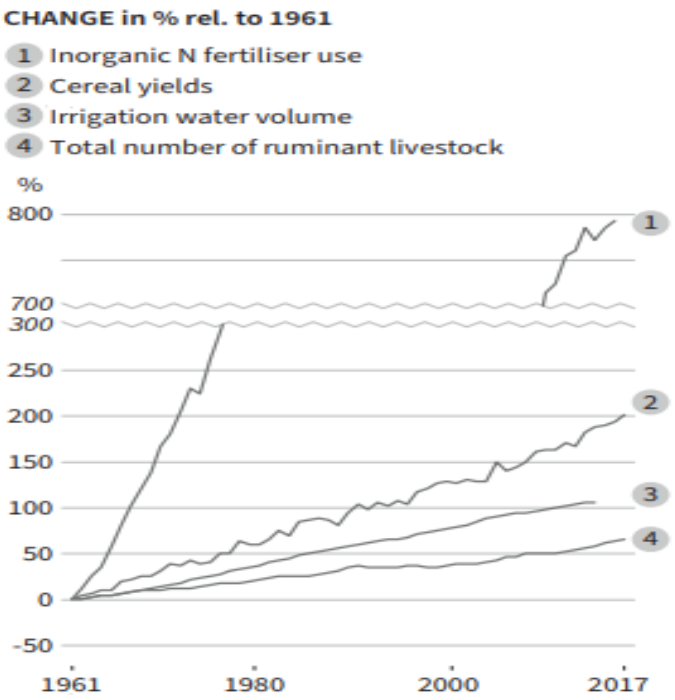


Gas	Units	Direct Anthropogenic: Net anthropogenic emissions due to Agriculture, Forestry, and Other Land Use (AFOLU)			Direct Anthropogenic: Non-AFOLU anthropogenic GHG emissions[6]	Total net anthropogenic emissions (AFOLU + non-AFOLU) by gas	AFOLU as a % of total net anthropogenic emissions, by gas
Panel 1: Contribution of AFOLU							
		FOLU	Agriculture	Total			
		A	B	C = A + B	D	**E = C + D**	F = (C/E) ×100
CO_2[2]	$GtCO_2\ yr^{-1}$	5.2 ± 2.6	No data[11]	5.2 ± 2.6	33.9 ± 1.8	**39.1 ± 3.2**	13%
CH_4[3,8]	$MtCH_4\ yr^{-1}$	19.2 ± 5.8	142 ± 42	161 ± 43	201 ± 101	**362 ± 109**	
	$GtCO_2eq\ yr^{-1}$	0.5 ± 0.2	4.0 ± 1.2	4.5 ± 1.2	5.6 ± 2.8	**10.1 ± 3.1**	44%
N_2O[3,8]	$MtN_2O\ yr^{-1}$	0.3 ± 0.1	8.3 ± 2.5	8.7 ± 2.5	2.0 ± 1.0	**10.6 ± 2.7**	
	$GtCO_2eq\ yr^{-1}$	0.09 ± 0.03	2.2 ± 0.7	2.3 ± 0.7	0.5 ± 0.3	**2.8 ± 0.7**	81%
Total (GHG)	**$GtCO_2eq\ yr^{-1}$**	**5.8 ± 2.6**	**6.2 ± 1.4**	**12.0 ± 2.9**	**40.0 ± 3.4**	**52.0 ± 4.5**	**23%**

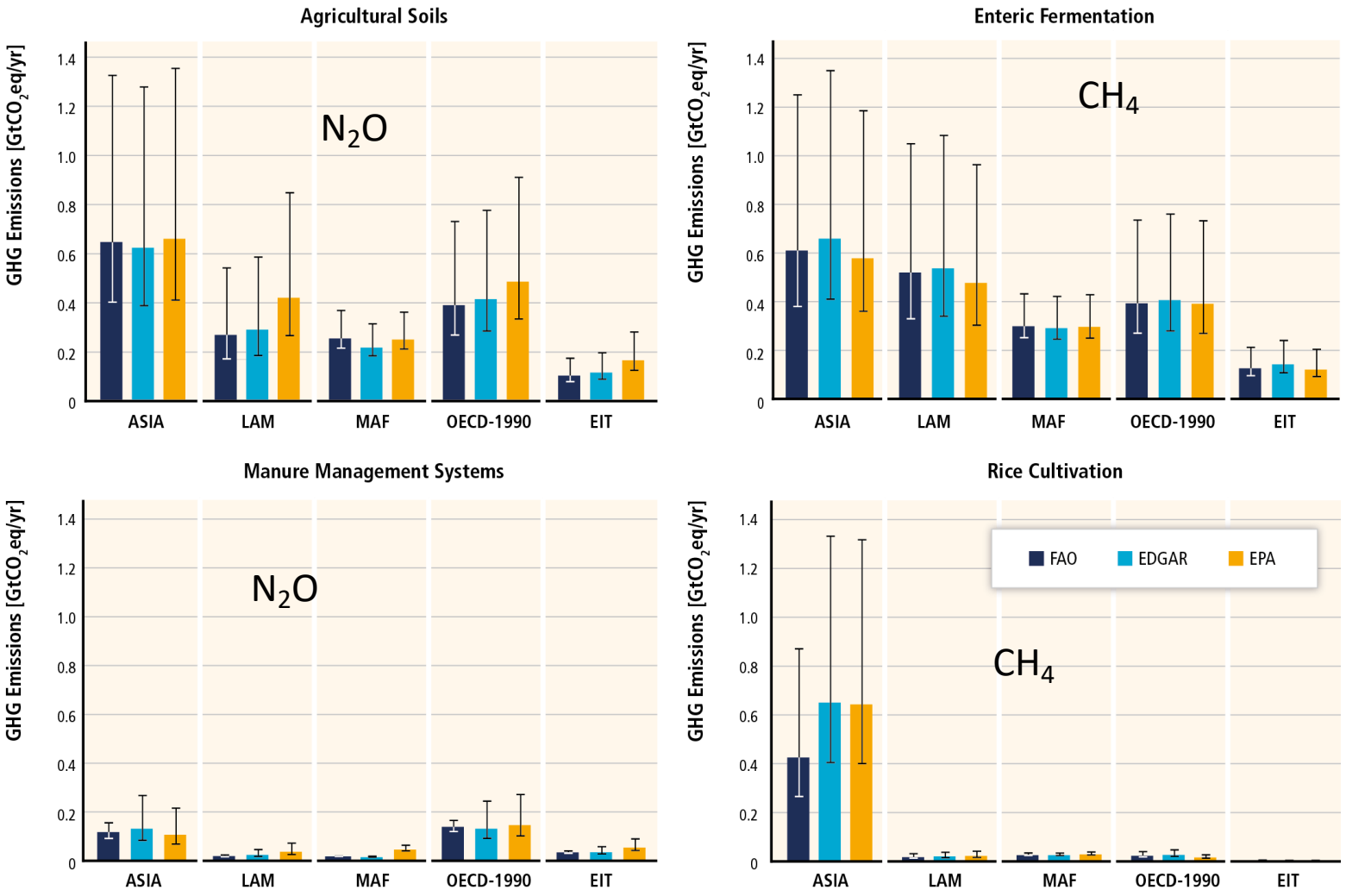
IPCC SR Climate change and land,
https://www.ipcc.ch/site/assets/uploads/sites/4/2022/11/SRCCL_Technical-Summary.pdf

Agricultural practices

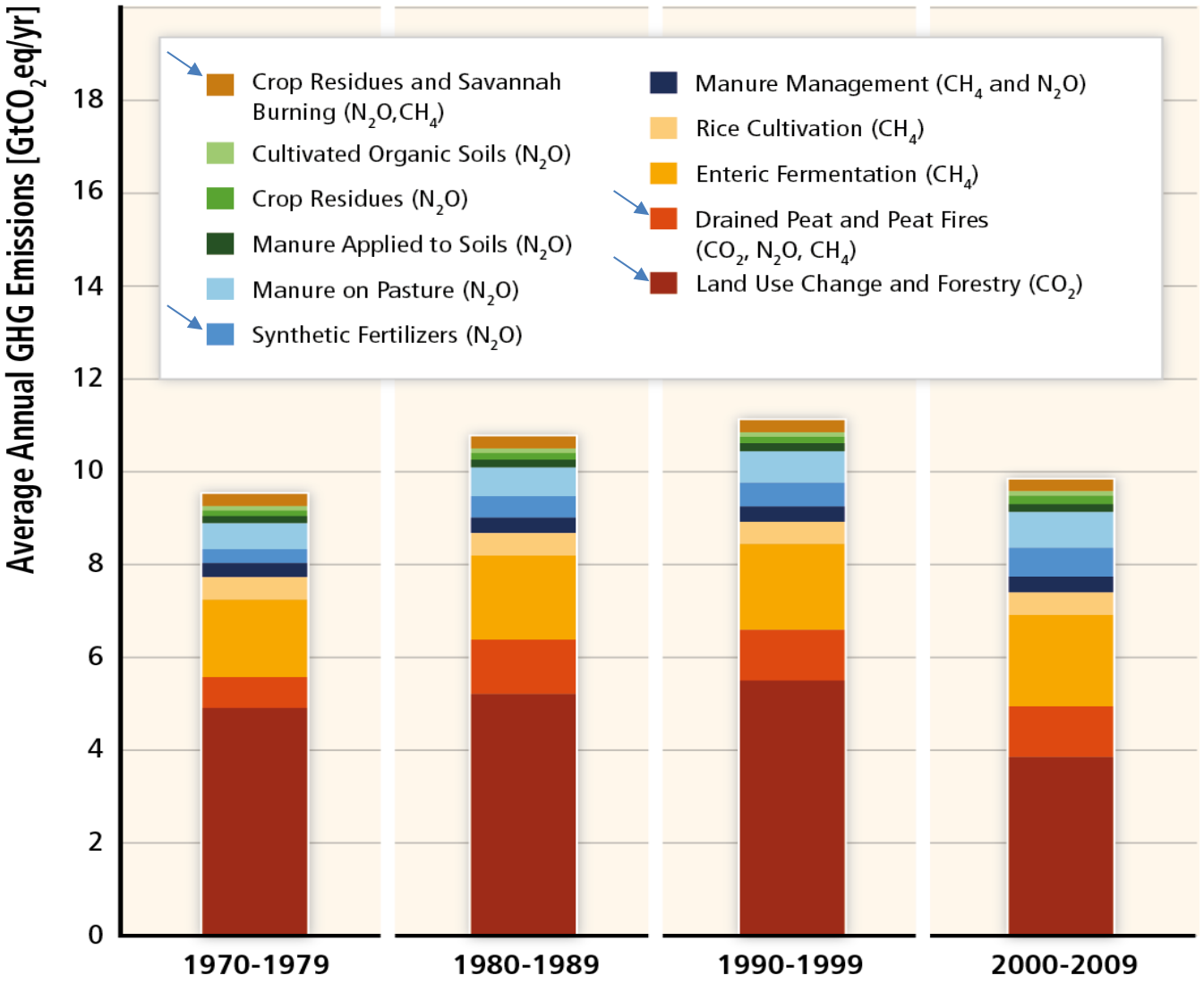
Land use change and rapid land use intensification have supported the increasing production of food, feed and fibre. Since 1961, the total production of food (cereal crops) has increased by 240% (until 2017) because of land area expansion and increasing yields. Fibre production (cotton) increased by 162% (until 2013).



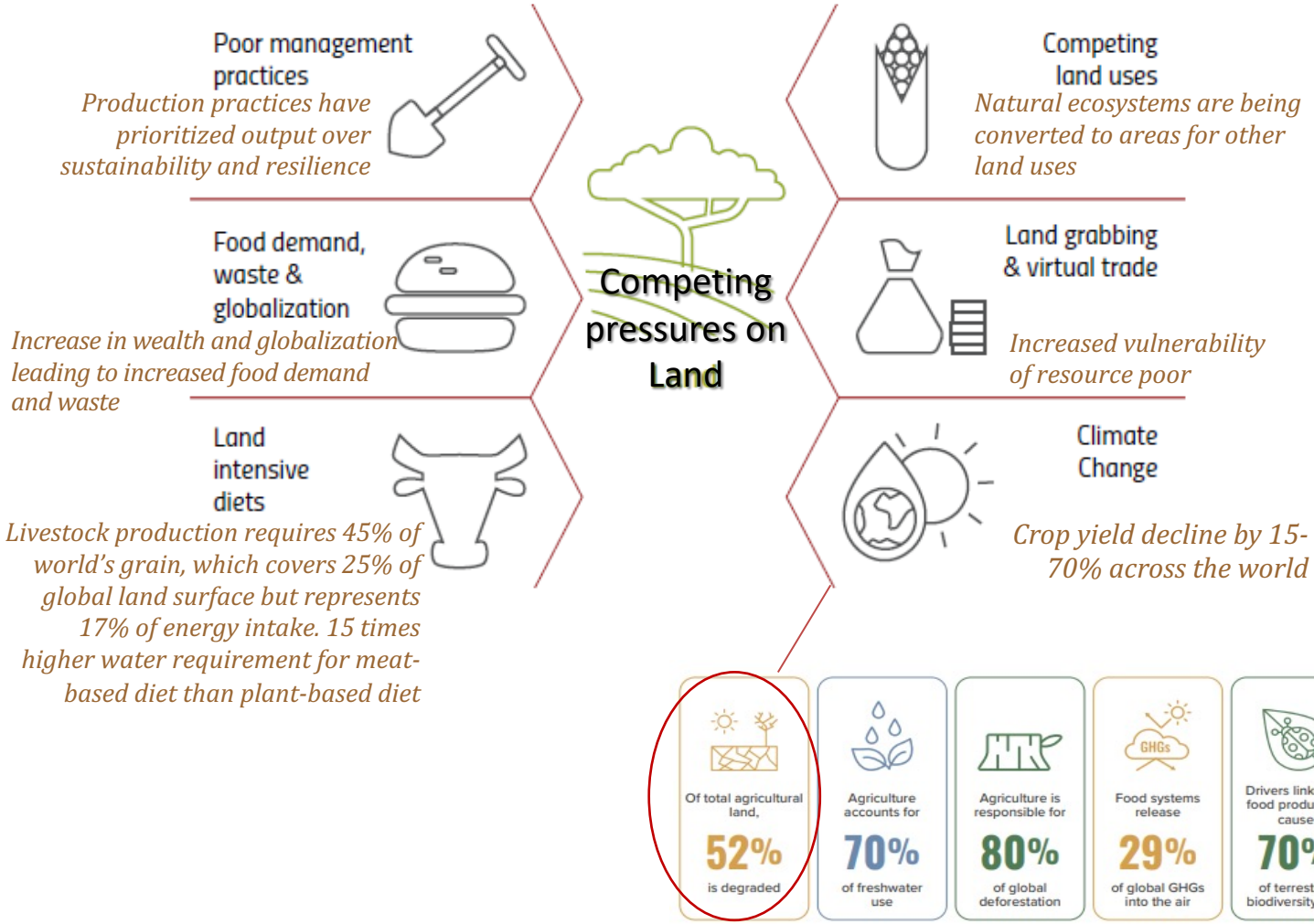
Emissions by Agricultural practices



Emissions by Agricultural practices



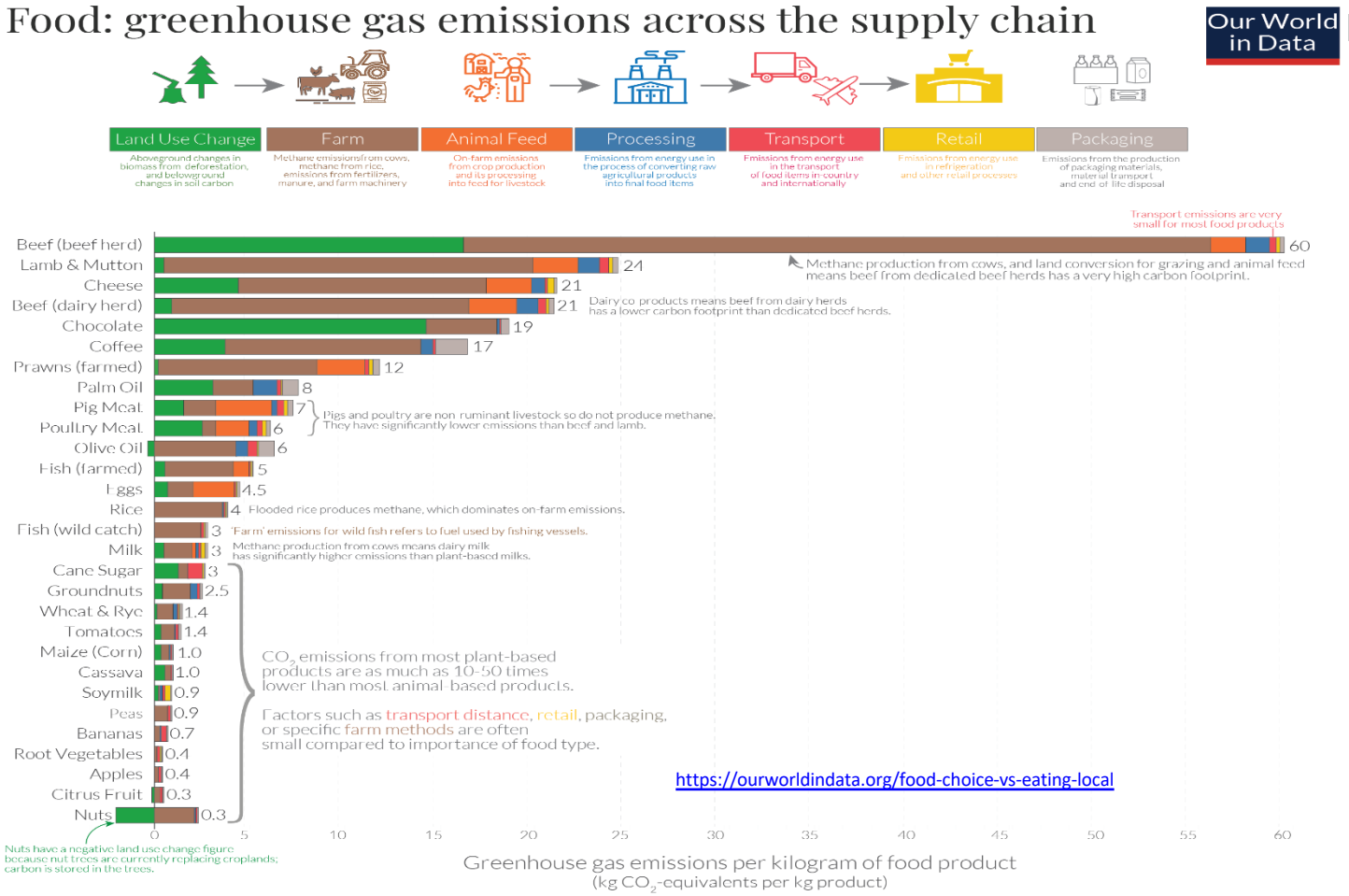
The Big Picture



Impacts of land use

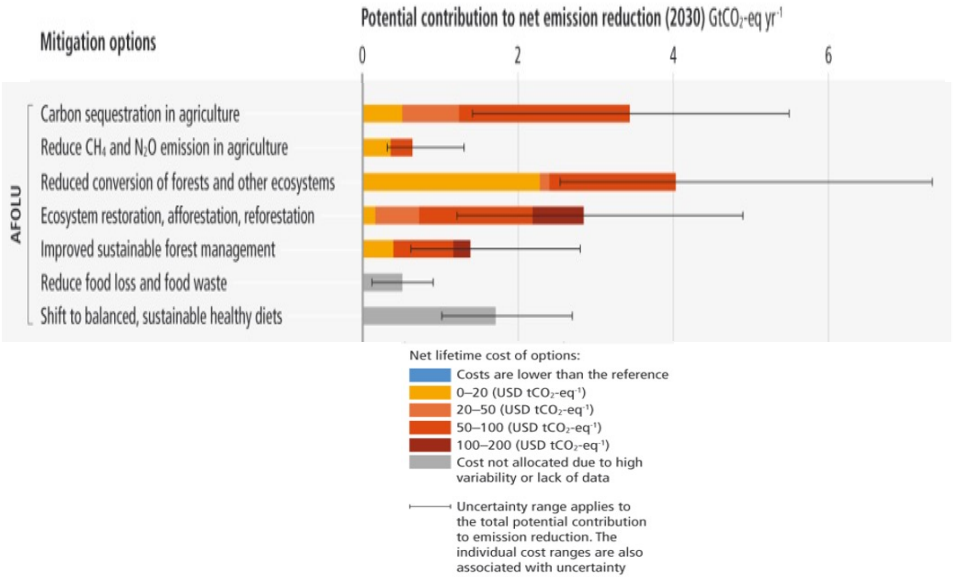
https://www.unccd.int/sites/default/files/2022-04/UNCCD_GLO2_low-res_2.pdf

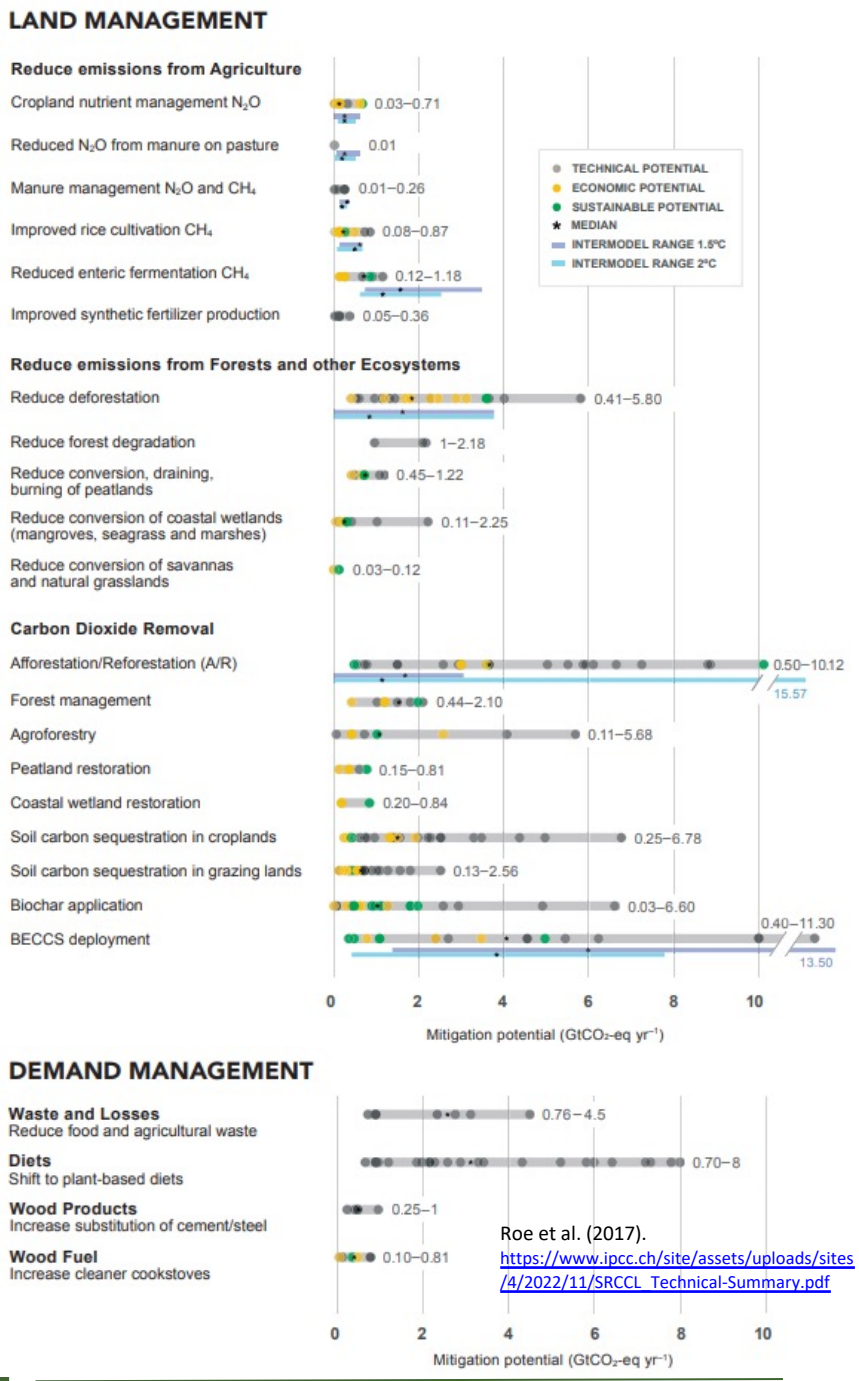
GHG footprint of food



Mitigation potential

of response options in 2020–2050, measured in GtCO2-eq yr–1





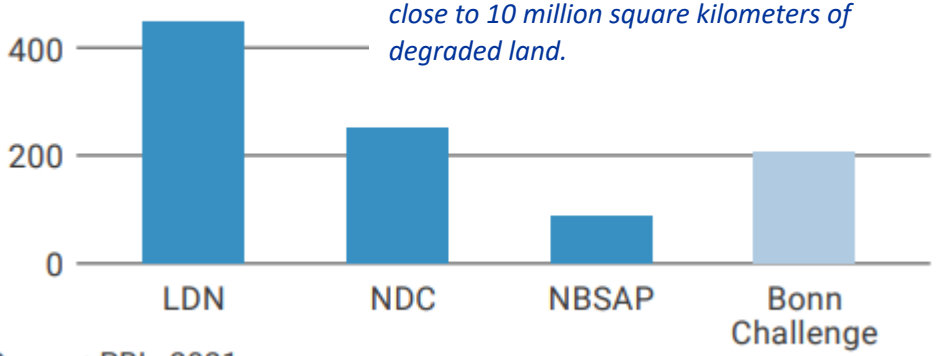
Roe et al. (2017). https://www.ipcc.ch/site/assets/uploads/sites/4/2022/11/SRCCL_Technical-Summary.pdf

Global restoration commitments

Degradation Processes

- Landscape modification
- Soil erosion by water and wind
- Soil surface sealing, compaction
- Soil salinisation & alkalisation
- Soil acidification
- Soil fertility decline
- Soil contamination
- Soil extraction
- Aridification
- Decline in vegetation cover
- Decline in vegetation community functioning
- Decline in biomass
- Decline in biodiversity
- Depletion of seed bank
- Increase in weeds
- Increase in invasive species
- Habitat loss
- Hydrological modification
- Change in groundwater level / quality

Million ha



115 countries have committed to restore close to 10 million square kilometers of degraded land.

Source: PBL, 2021.

https://www.pbl.nl/sites/default/files/downloads/pbl-2022-the-global-potential-for-land-restoration-glo2-4816_0.pdf

Land Degradation Neutrality

- to combat desertification and land degradation
- Adopted on 17 June 1994 and entered into force in Dec 1996 (197 parties)

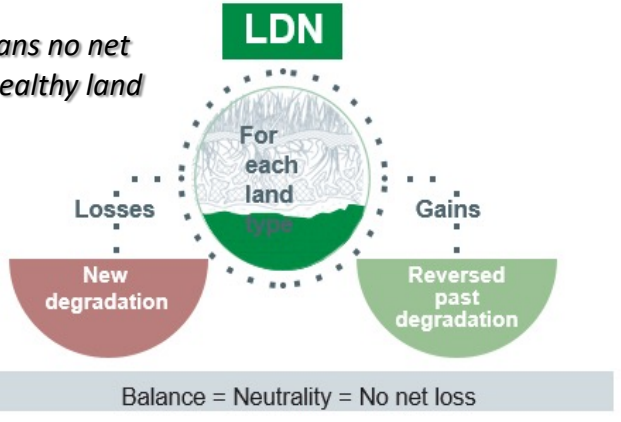
The total economic value (TEV) cost of land degradation in the zones of the world
(Mirzabaev, 2014)

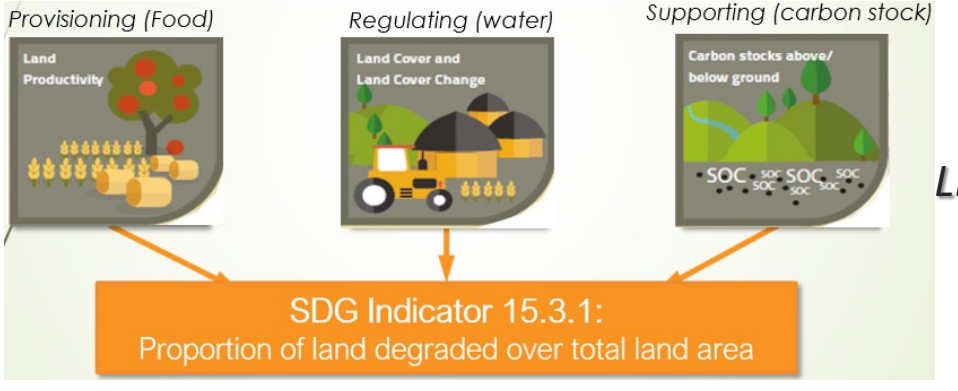
Zone	Cost of land degradation (2001 – 2009), USD billions	Cost of action (30 years) USD billions	Cost of inaction (30 years) USD billions	Ratio
Central Asia	216	53	277	5
East Asia	164	508	2,594	5
East Europe	52	777	4,813	6
Latin America and the Caribbean (LAC)	473	754	2,977	4
North America (NAM)	238	751	4,545	6
Near East and North Africa (NENA)	94	80	504	6
Oceania	125	407	2,442	6
South Asia	87	210	646	3
Southeast Asia	52	135	400	3
Sub-Saharan Africa (SSA)	543	797	3,343	4
West Europe	47	181	926	5
Global	**2,091**	**4,653**	**23,465**	**5**

Tilahun, M., Singh, A., Kumar, P., Apindi, E., Schauer, M., Libera, J., Lund H.G. (2018). The Economics of Land Degradation Neutrality in Asia: Empirical Analyses and Policy Implications for the Sustainable Development Goals. Available from www.eld-initiative.org

LDN is a state whereby the amount and quality of land resources necessary to support ecosystem functions and services to enhance food security remain stable, or increase, within specified temporal and spatial scales and ecosystems."

LDN means no net loss of healthy land



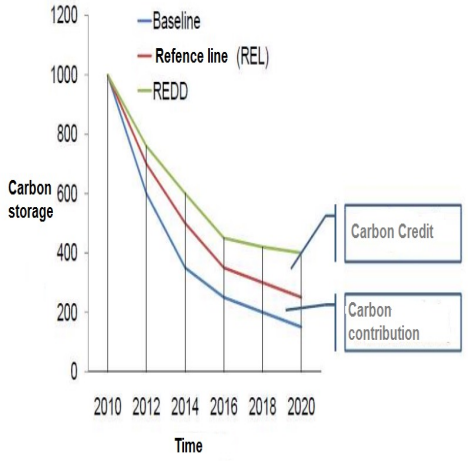


LDN indicators

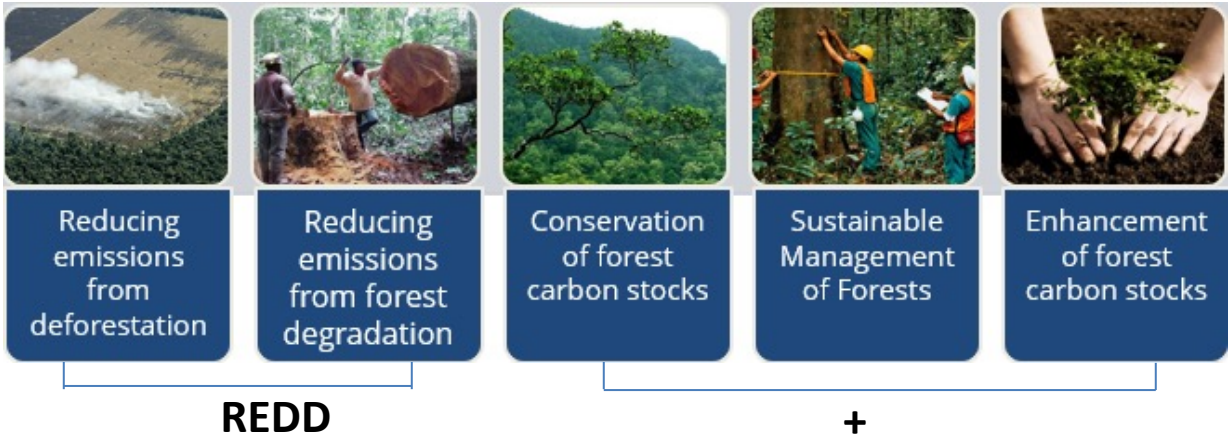
Reducing Emissions from Deforestation and Forest Degradation (REDD+)

Aim

- to encourage developing countries to contribute to climate change mitigation efforts by:
  - reducing greenhouse gas emissions (GHG) by slowing, halting and reversing forest loss and degradation; and
  - increasing removal of GHGs from the earth's atmosphere through the conservation, management and expansion of forests.



Activities



Timeline

2005 **COP11 Montreal RED** discussions started. Papua New Guinea and Costa Rica asked for new agenda item: "Reducing emissions from deforestation in developing countries: Approaches to stimulate action."

2007 **COP13 Bali** Bali Action Plan was provided, in which the RED concept was broadened to REDD+.

2009 **COP15 Copenhagen** Methodological guidance for REDD+ activities was developed.

2010 **COP16 Cancun** was a formal agreements (Dec.1/CP16) were established, including policy approaches and positive incentives on issues relating to REDD+ in developing countries and role of *conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries"*.

2013 **COP19 Warsaw** REDD+ package was developed, including modalities and guidance for establishing national forest-monitoring systems; measuring, reporting, and verification (MRV); and forest reference (emission) levels and addressing safeguards and drivers.

2016 Green Climate Fund, and REDD+ results- based payments

Aviva announces £38m investment to help restore Britain's lost rainforests

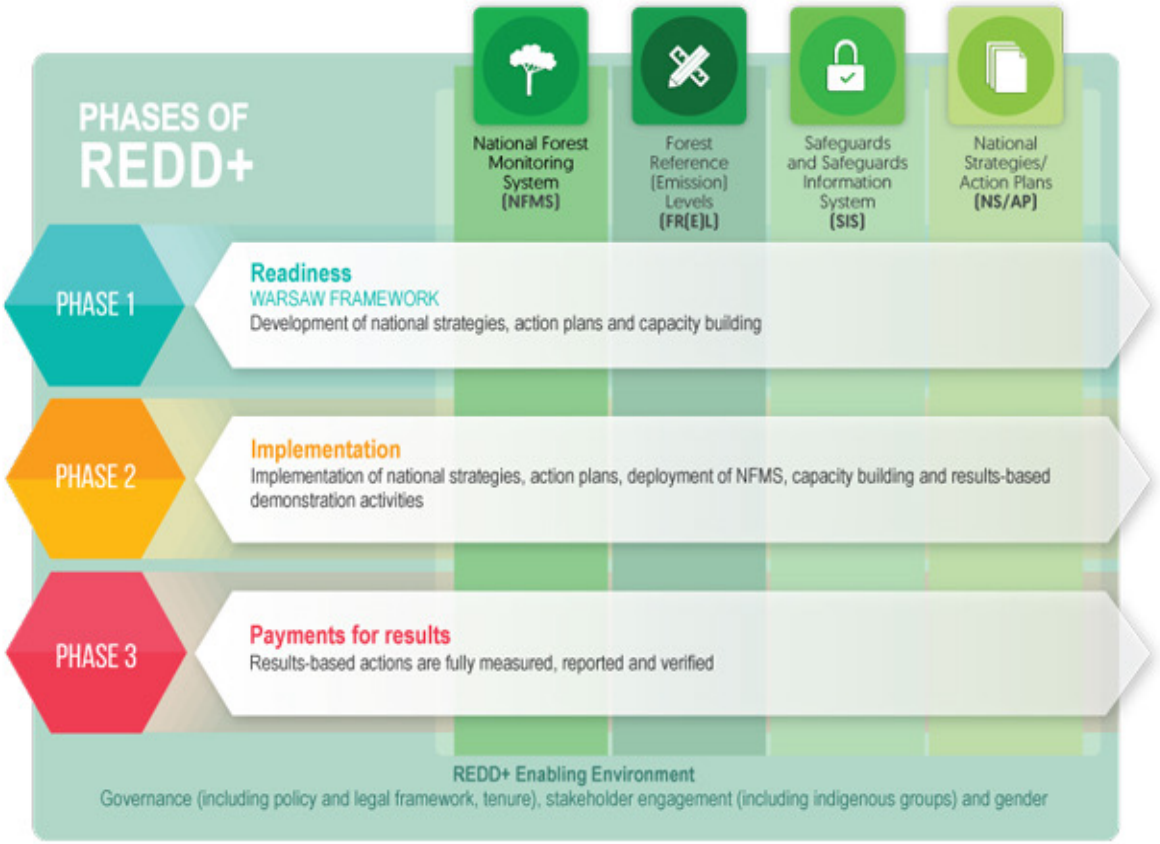
Aviva has announced a £38 million donation to restore Britain's lost temperate rainforests in the UK.

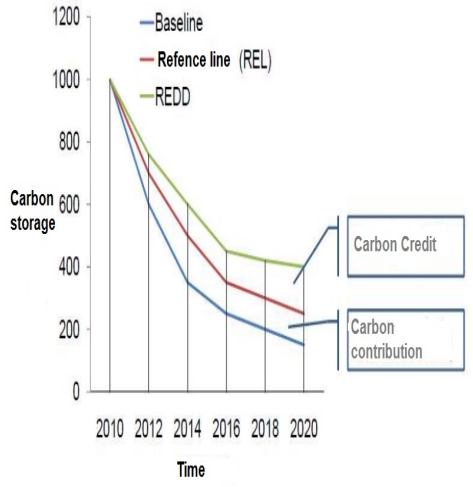
03 February 2023 | Press Release

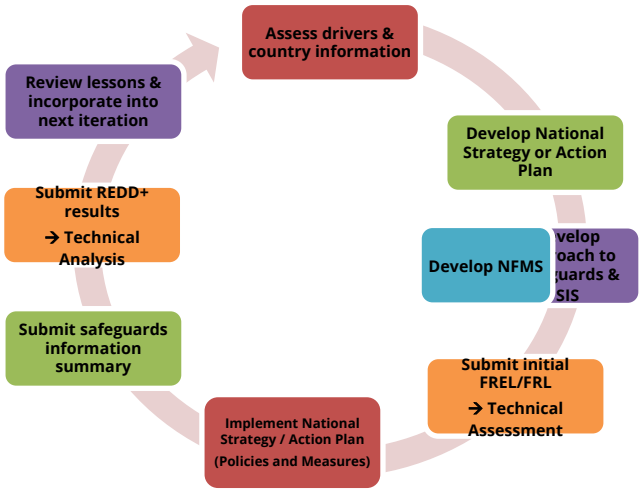
- Temperate rain forest plantation in 5200 acres.
- The restored temperate rainforest will remove an estimated 800,000 tonnes of carbon dioxide from the atmosphere over the next 100 years.
- Carbon removal by forest begins in 2024 and will be at its fastest around 2060 when the forests are expected to be removing about 24,000 tonnes CO2 each year. The carbon removal will continue at a slower rate well beyond 2130.

https://www.climateaction.org/news/aviva-announces-38m-investment-to-help-restore-britains-lost-rainforests?utm_source=ActiveCampaign&utm_medium=email&utm_content=UN+Chief%3A+Fossil+fuel+producers+without+credible+net+zero+targets+should+not+be+in+business+-+Climate+Action+News&utm_campaign=CA+%7C+2023+%7C+7+February+%7C+Newsletter&vgo_ee=3p5sdKGjpJSpL1eNcFPNCKWJq1XY8PK3xsXE1%2FzAmUw%3D

REDD+ phased approach



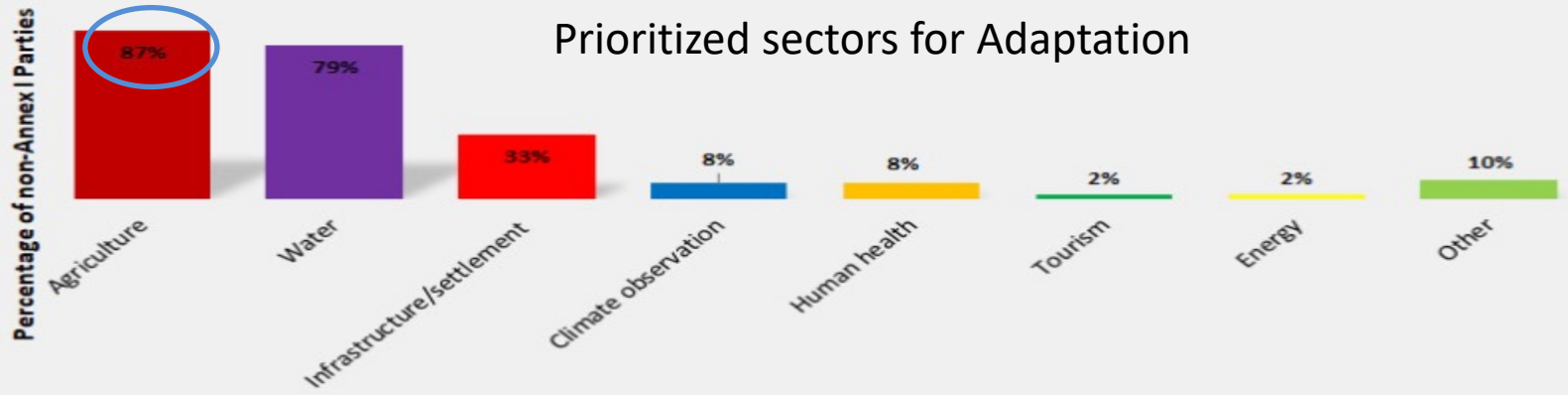




Adaptation in Land sector

39	26	90	1000	2001
Number of developing countries currently undertaking a TNA	Number of developing countries that referred to TNAs in their nationally determined contribution	Number of developing countries that have completed a TNA	Number of TAPs and project ideas seeking support	The year the TNA process started

Climate Technology Needs Assessment (TNA)



Takeaways

- Deforestation, agriculture and food production are major drivers of Climate change
- Deforestation needs to be reduced and increased forest management but rather slow progress due to challenges in measuring the progress in reducing emissions and enhancing removals.
- Land use (AFOLU) is major source for sink but also emitter (13% of CO_2, 44% of CH_4, 81% of N_2O), hence halting land degradation and restoring land can have multiple advantages of sustainable food production and contribution to climate change mitigation and adaptation
- Demand-side responses and adaptation responses in AFOLU, and mitigation responses in other sector are required to realize overall mitigation benefits

References

- IPCC SR Climate change and land https://www.ipcc.ch/srccl/
- REDD+ https://www.euredd.efi.int/what-is-redd
- UN REDD https://www.un-redd.org/