Land Use and Food Security

Team

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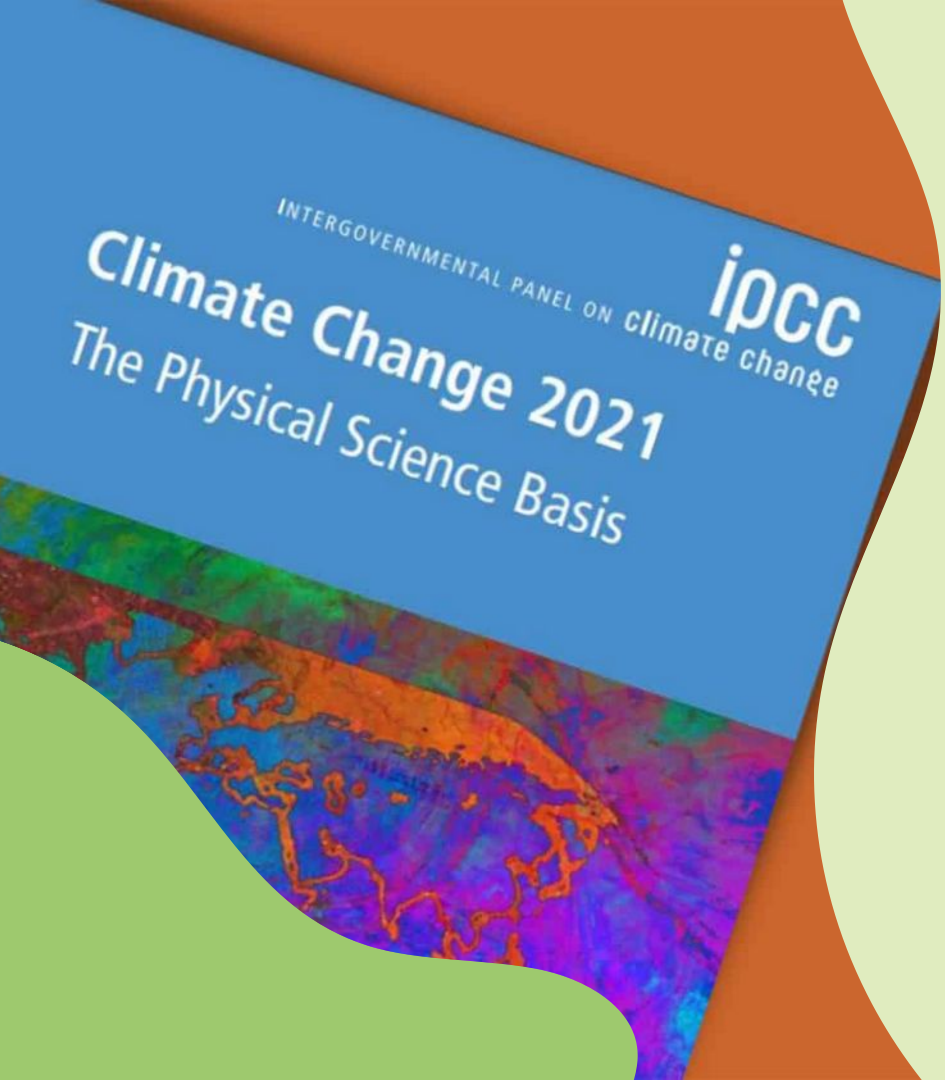


IPCC

- Intergovernmental Panel on Climate Change
- Founded in 1988
- IPCC AR5 and AR6
- IPCC Special Report on Climate Change and Land

Land and Human Needs

Basic

Food, clothing and shelter

Spiritual

Meditation, praying, finding peace, etc.

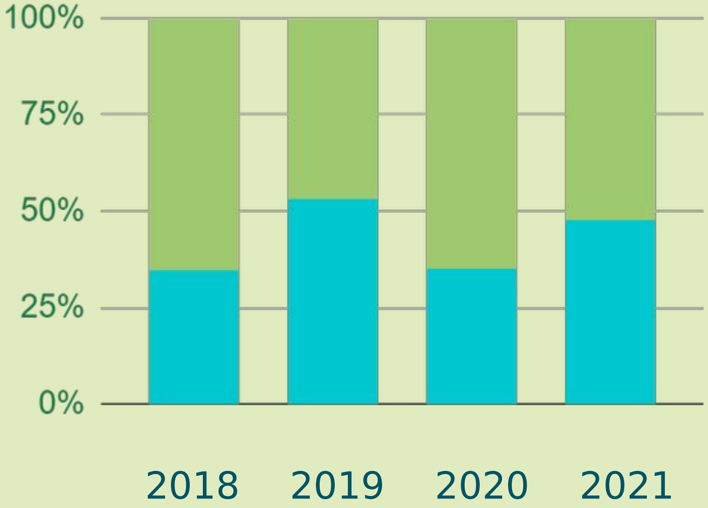
Recreational

Walking, swimming, hiking, etc.

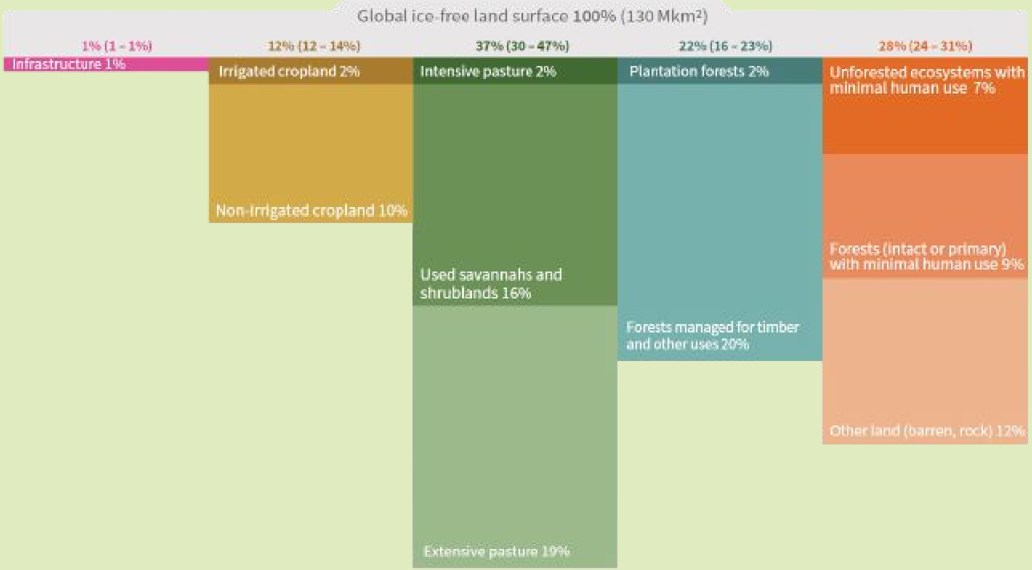
Sense of Belonging

To be accepted as a member of a group.

Apathy?



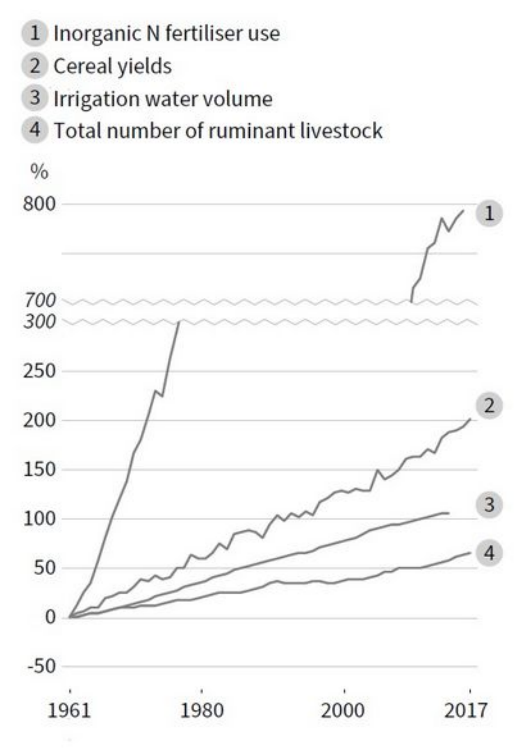
Anthropogenic Impact on Land



- Humans affected **three quarters** of global ice-free land surface in a direct or indirect way.
- Humans appropriate **one quarter to one third** of the global potential net primary production.
- Humans croplands cover **14%** of the global ice-free surface.
- Humans are producing **33%** more food calories per capita if compared to 1961.

Anthropogenic Impact on Land

- Humans used **9x** the amount of inorganic nitrogen fertiliser compared to 1961.
- Humans **doubled** their consumption of irrigation water during the same period.
- Human activities affect **85%** of forests, **90%** of other ecosystems like grasslands and savannahs, and causes around **11-14%** loss of biodiversity.



Key Issues

1

Warming over land

Increase in the average temperature over land is recorded at 1.53°C compared to the year 1900 and in the global mean temperature by 0.66°C.

2

Over-exploitation of land resources

Technological development, continuous population growth and increasing human need for resources per capita are expected to continue happening rapidly in the foreseeable future.

3

Greenhouse Gases Emissions

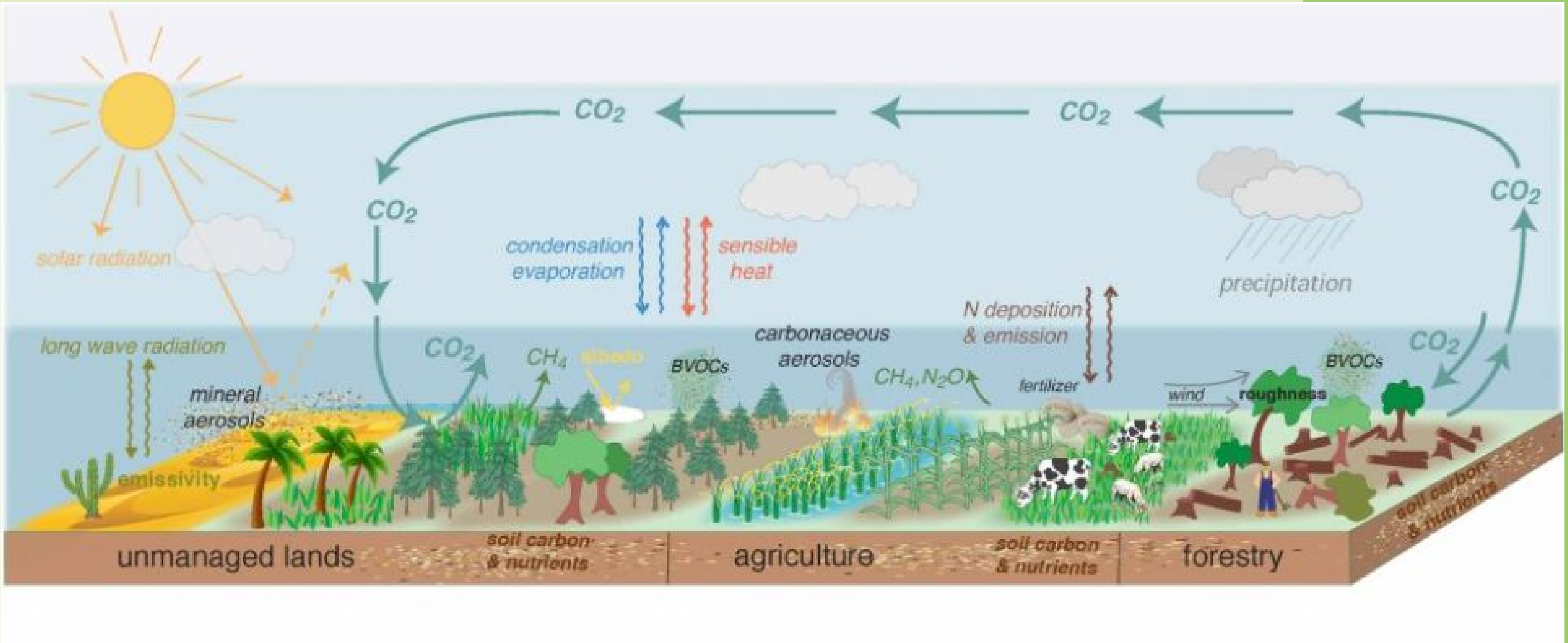
Rapid reductions in the emissions to keep the global temperature increase below 2°C would greatly reduce the impact of climate change on land ecosystems.

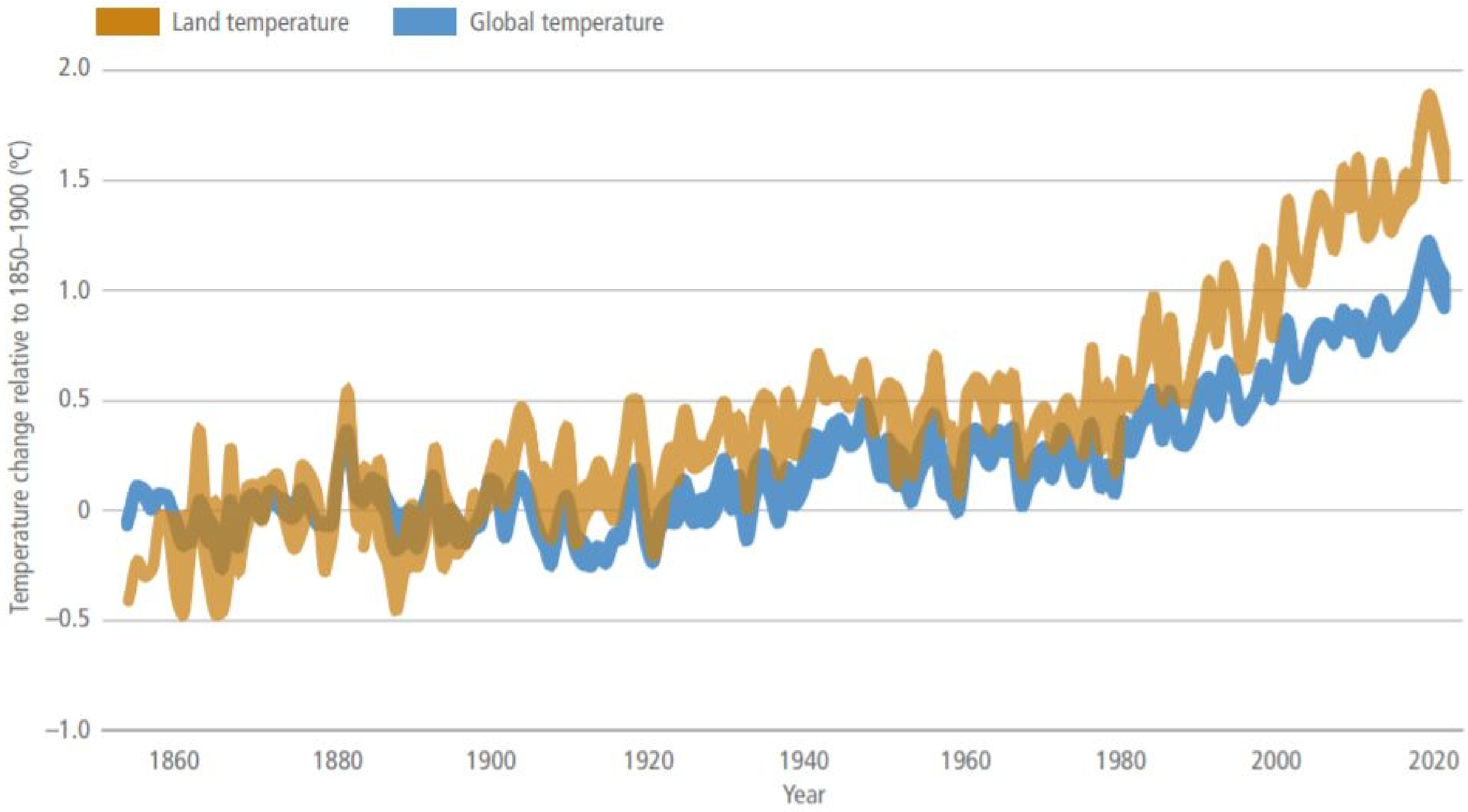
Next

Maria Konovalova

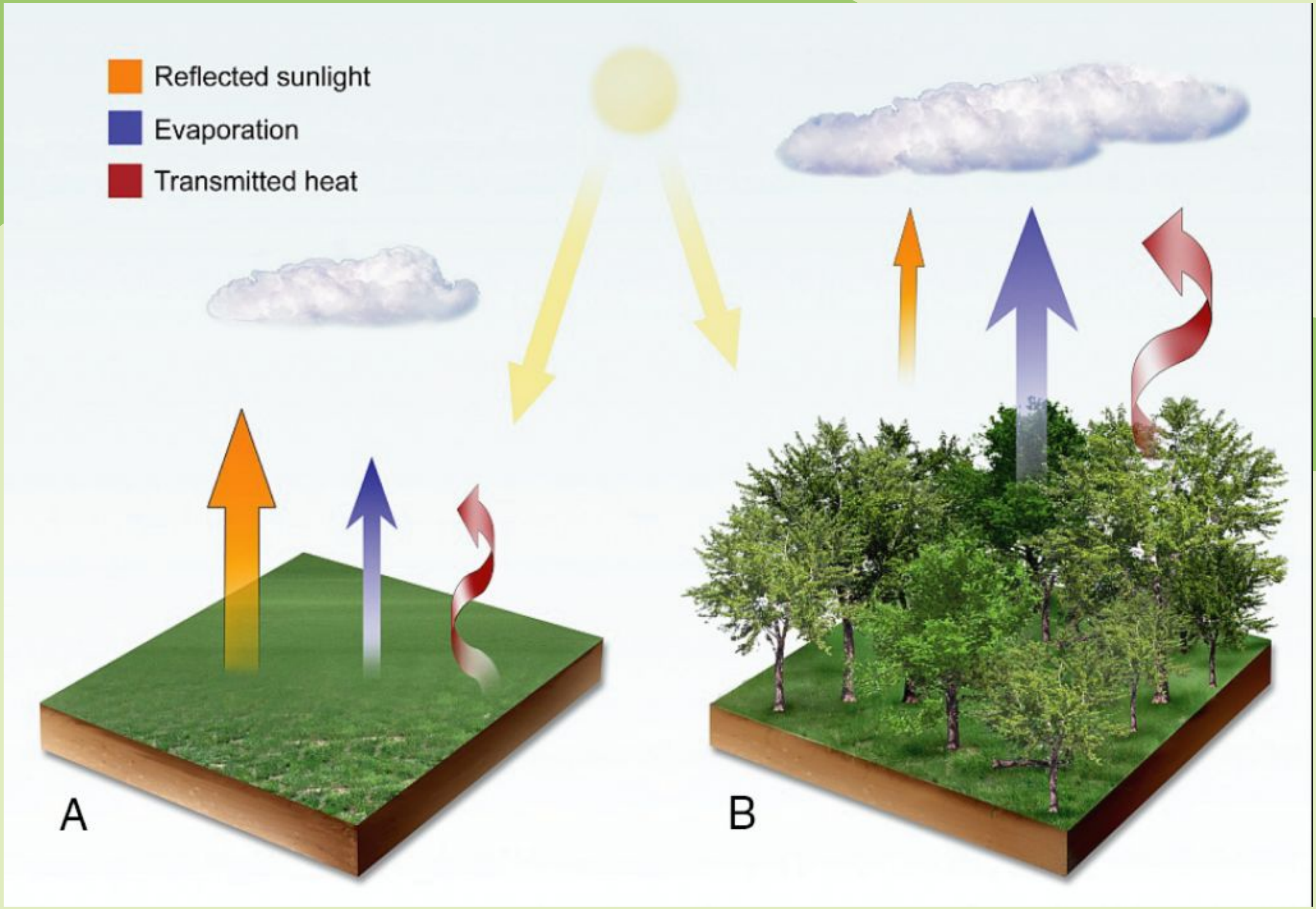
Land Use and Observed Climate Change

Processes underlying land–climate interactions

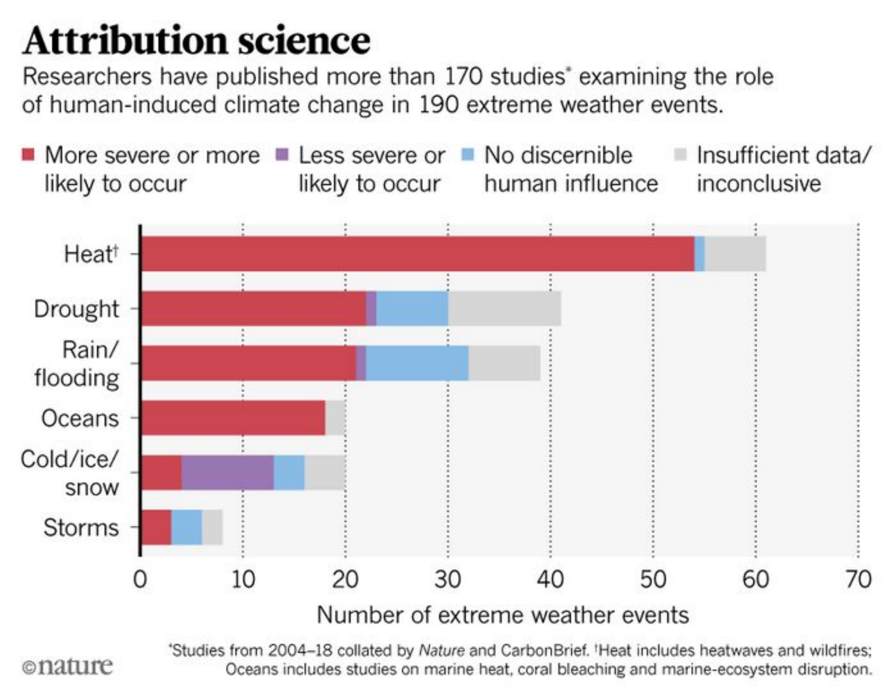


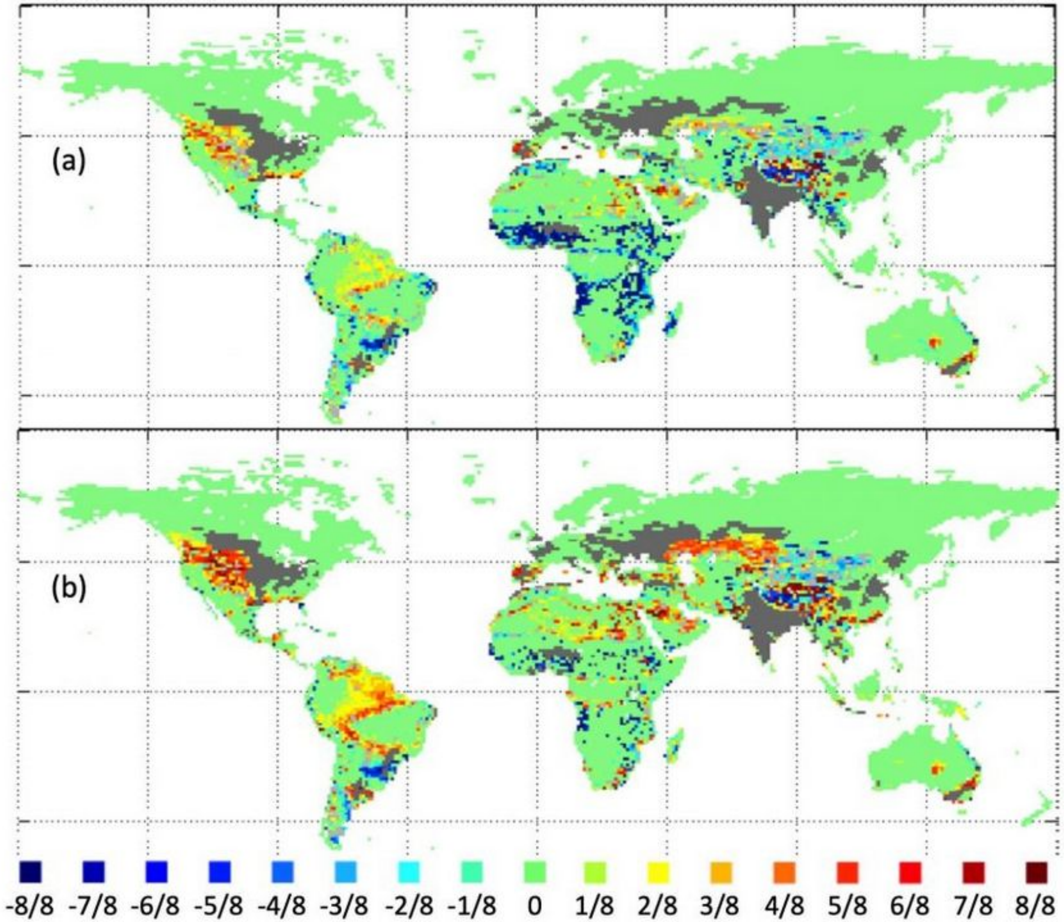


Land temperature
Global temperature
2.0
1.5
1.0
0.5
0
−0.5
−1.0
Temperature change relative to 1850–1900 (°C)
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year


Reflected sunlight
Evaporation
Transmitted heat
A
B

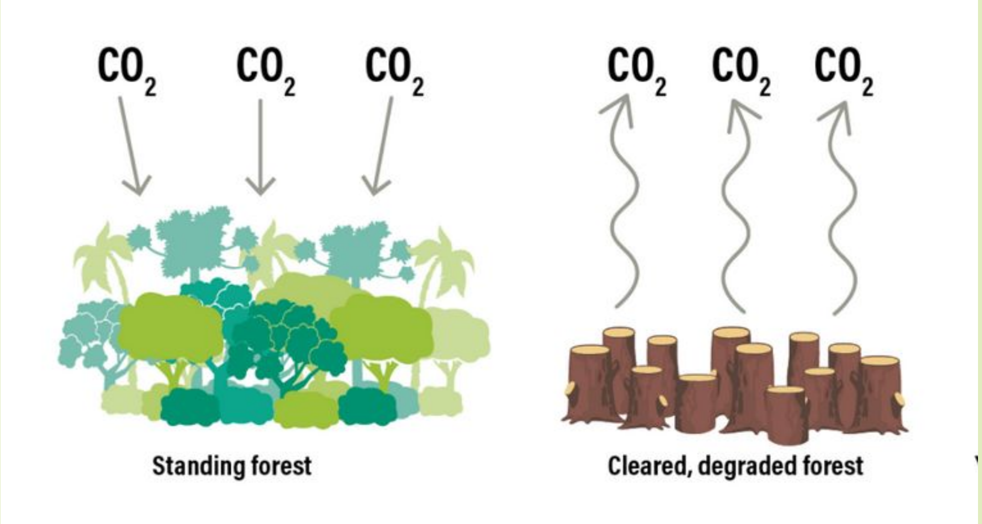
Climate extremes and their impact on land functioning




(a)
(b)
-8/8 -7/8 -6/8 -5/8 -4/8 -3/8 -2/8 -1/8 0 1/8 2/8 3/8 4/8 5/8 6/8 7/8 8/8

Climate change and precipitation

Land use and emissions



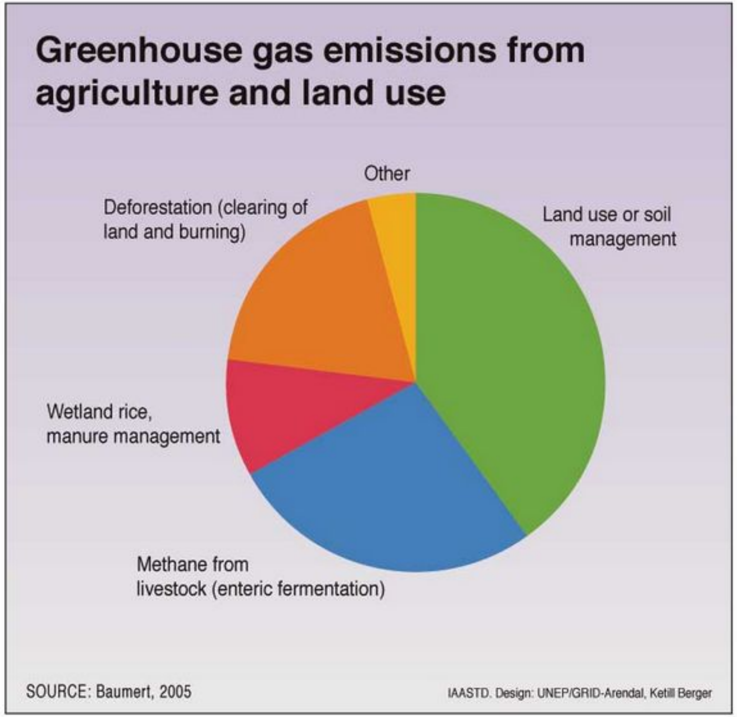
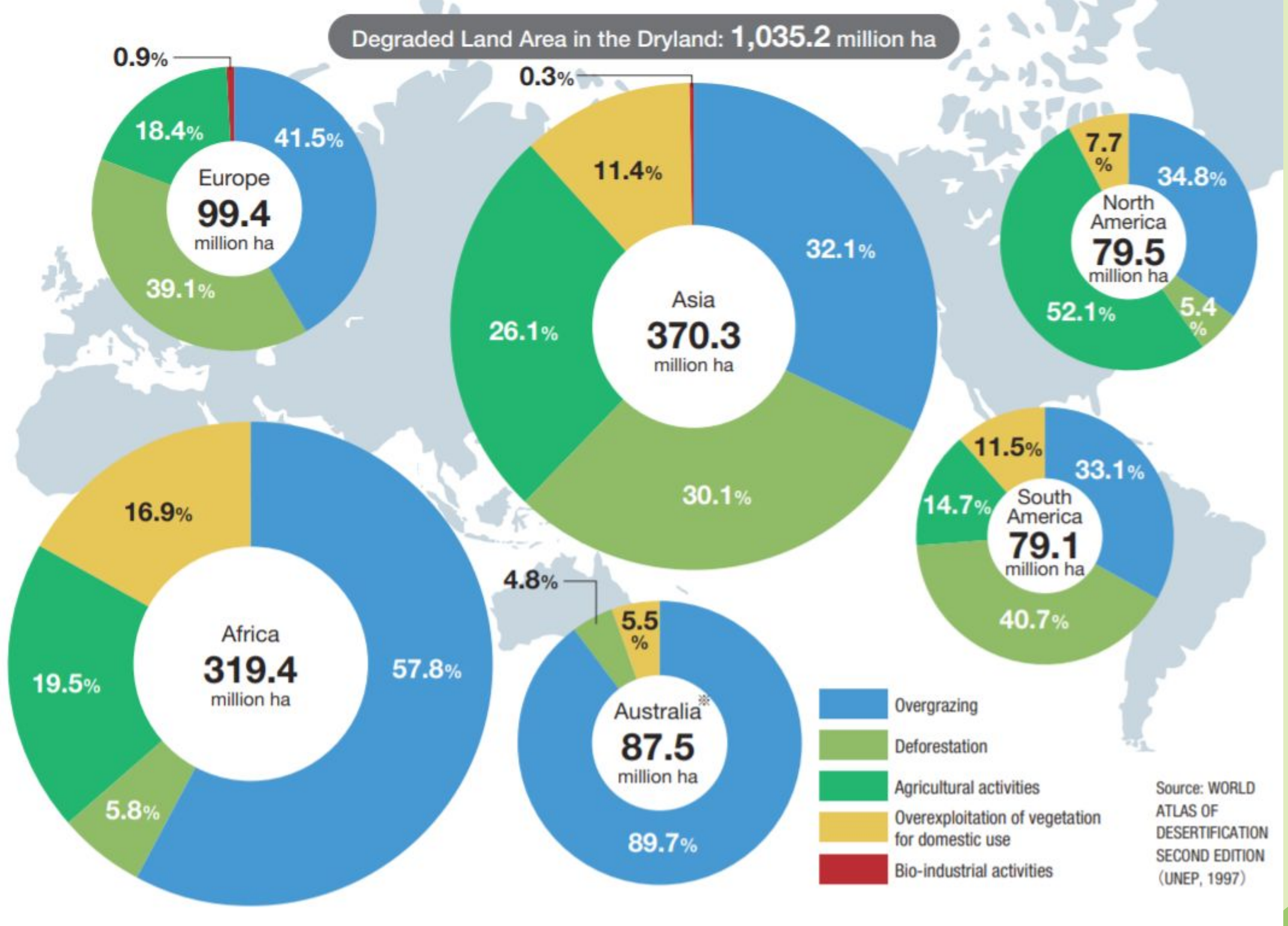


Figure SR-CC1b. GHG emissions from agriculture and land use.

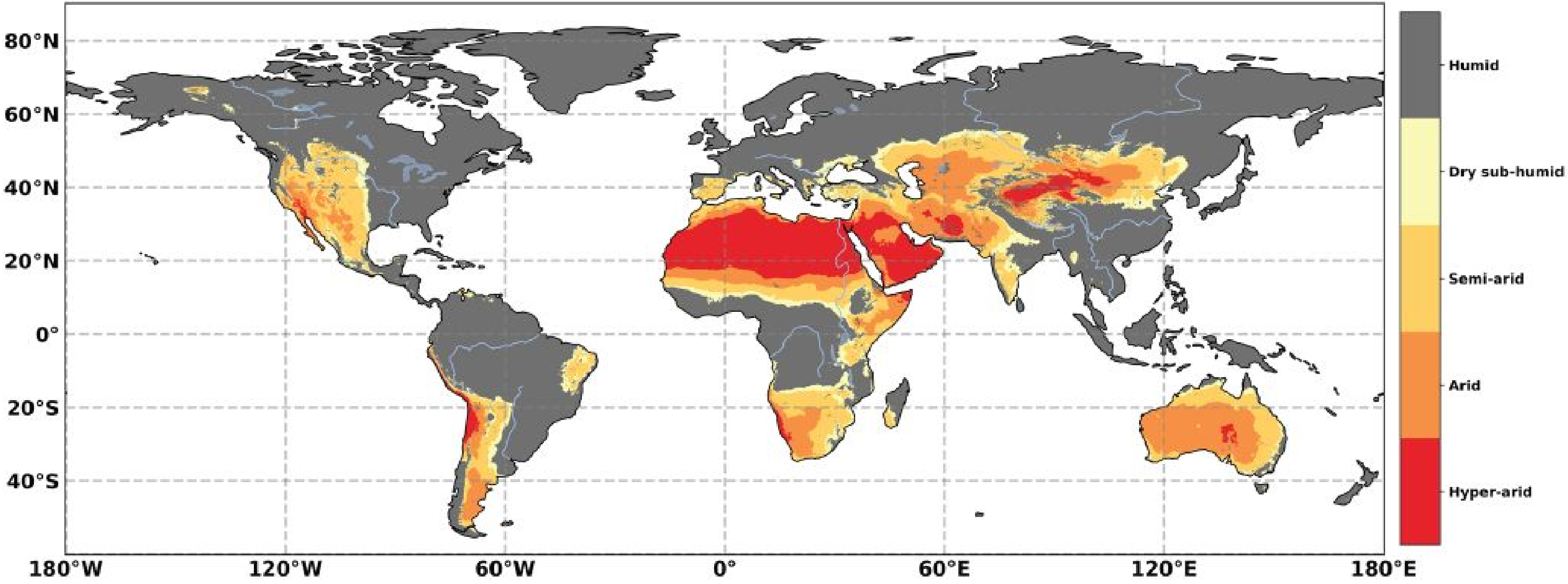
Desertification

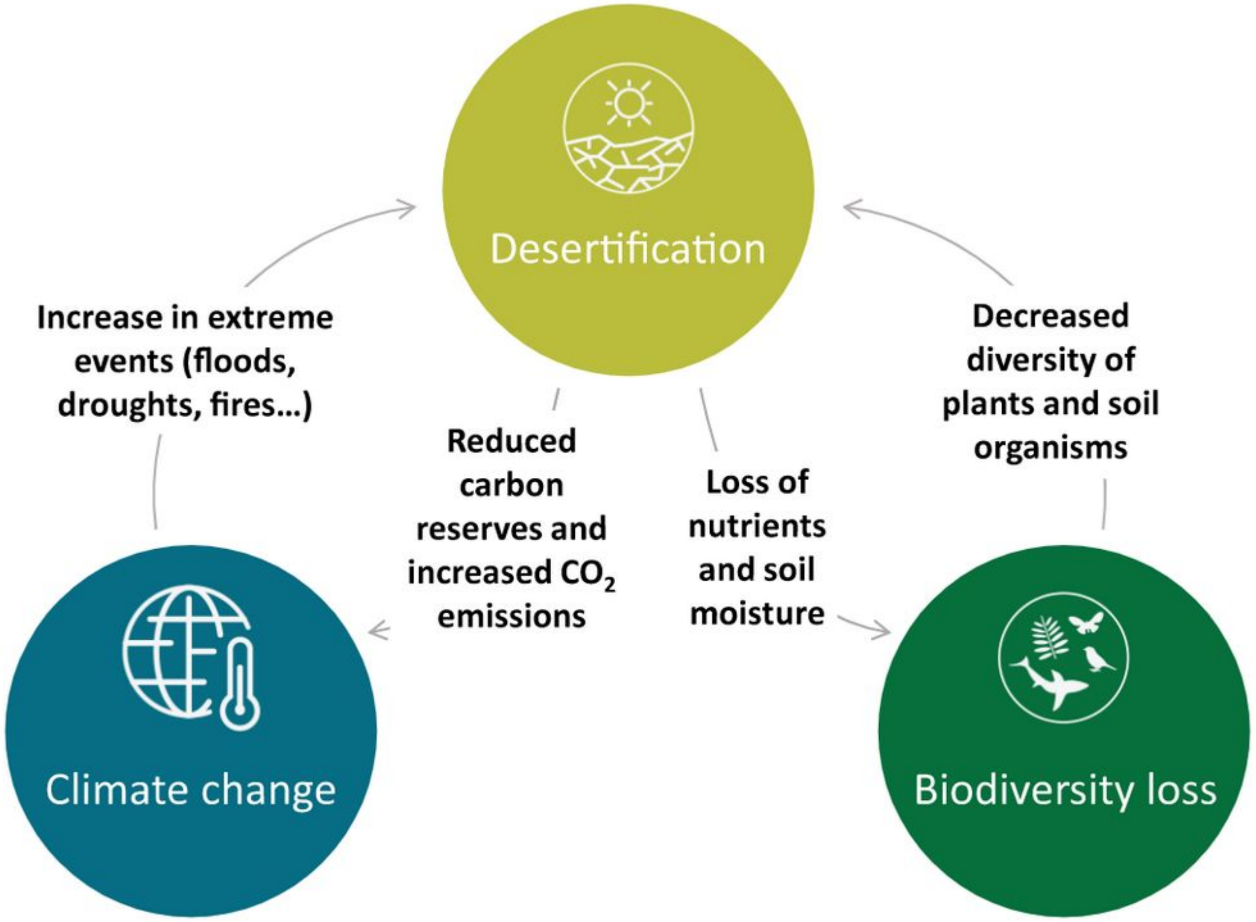
Desertification- land degradation in arid (dry, barren), semi-arid and dry sub-humid areas, collectively known as **drylands**, resulting from many factors, including **human activities and climatic variations** (periodical change of climate).

The difference between **desertification** and **land degradation** is not process-based but geographic. Although land degradation can occur anywhere across the world, when it occurs in drylands, it is considered desertification.

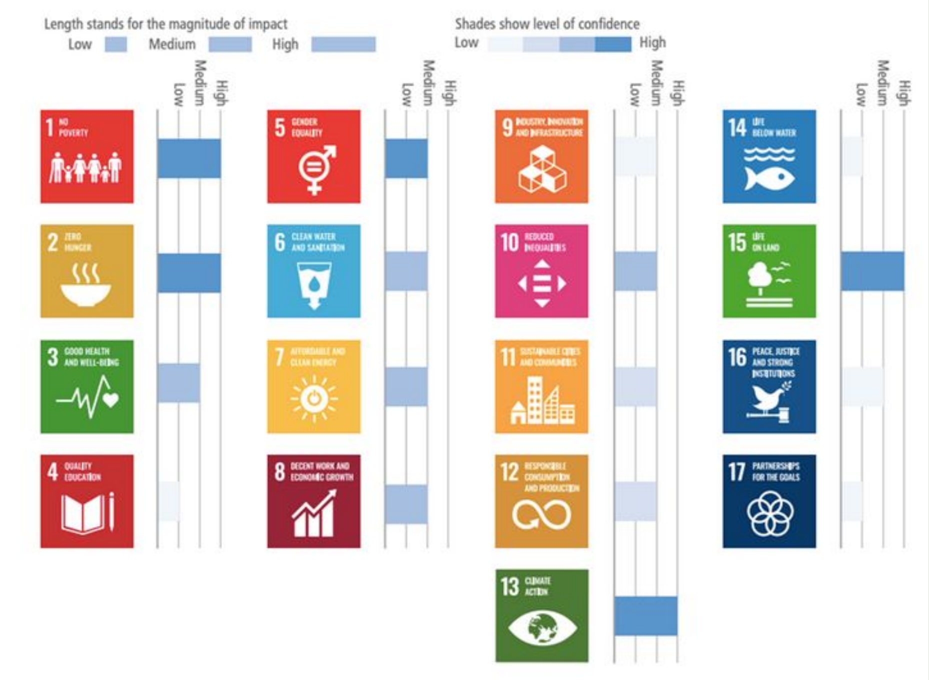


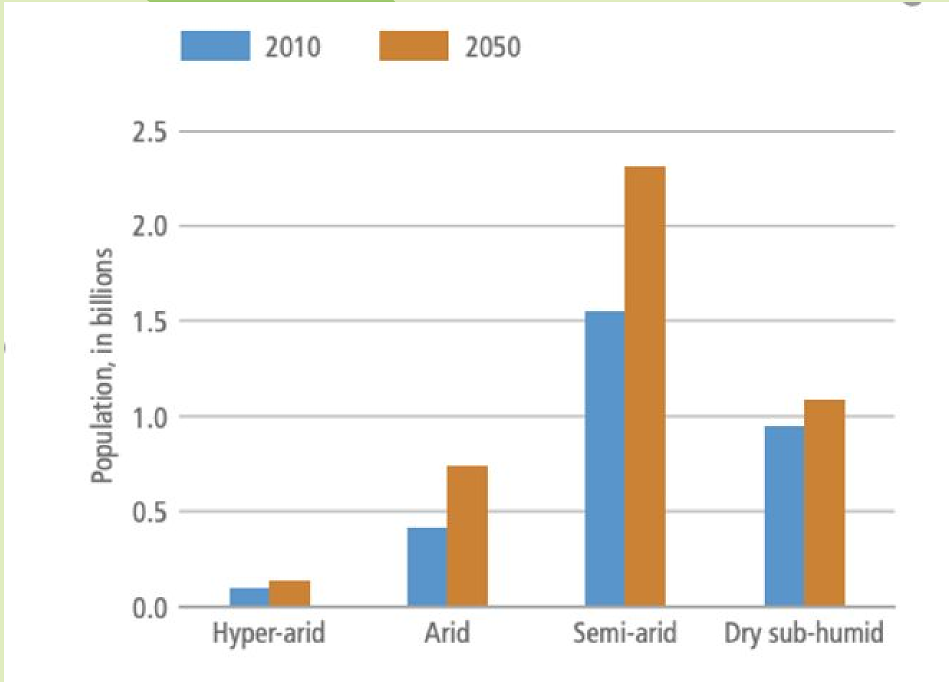
Degraded Land Area in the Dryland: 1,035.2 million ha
Europe
99.4
million ha
41.5%
39.1%
18.4%
0.9%
Asia
370.3
million ha
32.1%
30.1%
26.1%
11.4%
0.3%
North America
79.5
million ha
34.8%
5.4 %
52.1%
7.7 %
South America
79.1
million ha
33.1%
40.7%
14.7%
11.5%
Africa
319.4
million ha
57.8%
5.8%
19.5%
16.9%
Australia※
87.5
million ha
89.7%
4.8%
5.5 %
Overgrazing
Deforestation
Agricultural activities
Overexploitation of vegetation for domestic use
Bio-industrial activities
Source: WORLD ATLAS OF DESERTIFICATION SECOND EDITION (UNEP, 1997)

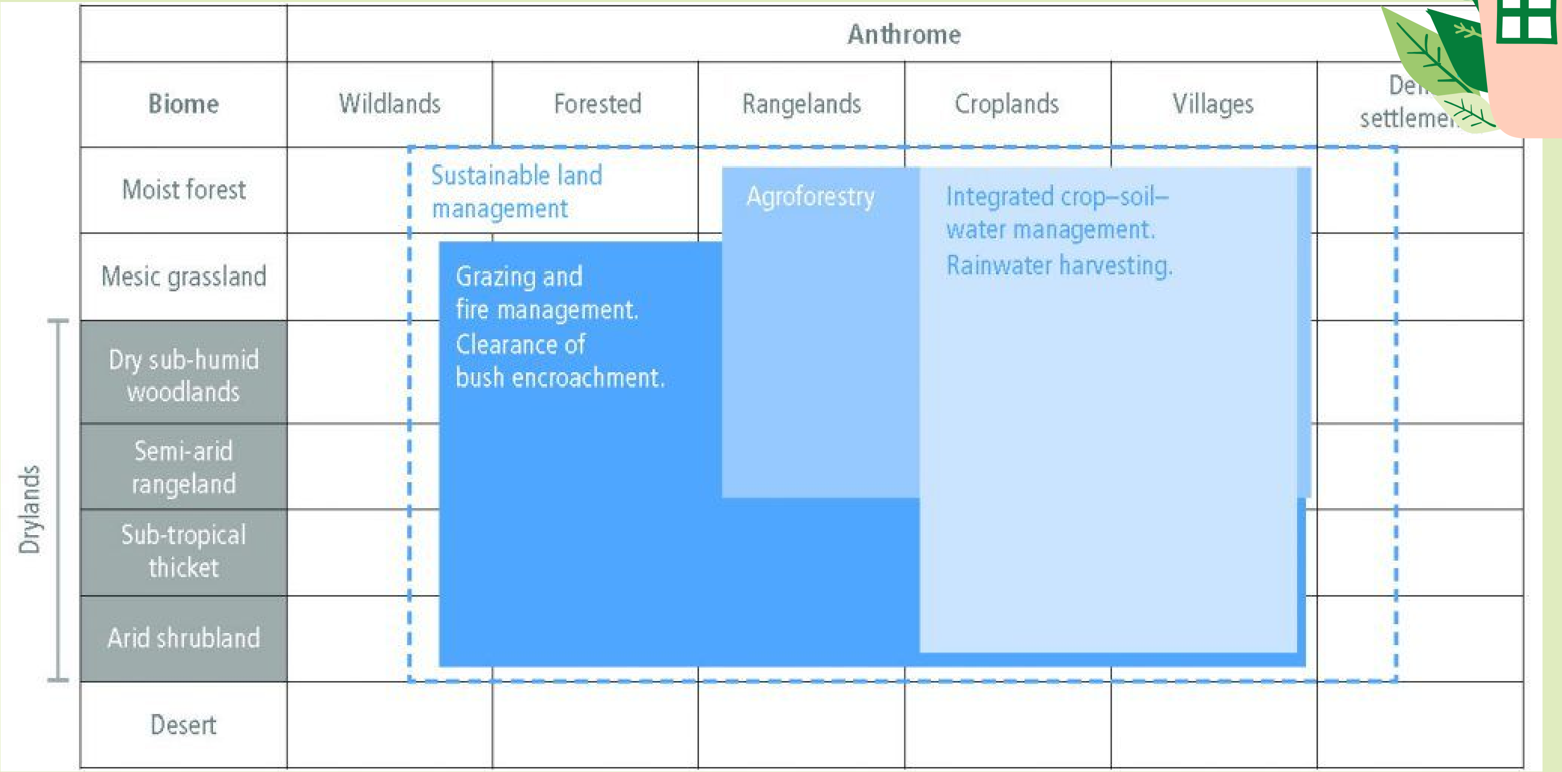

80°N
60°N
40°N
20°N
0°
20°S
40°S
180°W
120°W
60°W
0°
60°E
120°E
180°E
Humid
Dry sub-humid
Semi-arid
Arid
Hyper-arid


Desertification
Increase in extreme events (floods, droughts, fires…)
Decreased diversity of plants and soil organisms
Reduced carbon reserves and increased CO_2 emissions
Loss of nutrients and soil moisture
Climate change
Biodiversity loss

How does desertification affects us?






Anthrome
Biome
Wildlands
Forested
Rangelands
Croplands
Villages
Moist forest
Mesic grassland
Dry sub-humid woodlands
Semi-arid rangeland
Sub-tropical thicket
Arid shrubland
Desert
Drylands
Sustainable land management
Agroforestry
Integrated crop–soil–water management.
Rainwater harvesting.
Grazing and fire management.
Clearance of bush encroachment.


SUSTAINABLE

Land Degradation and Food Security

Land degradation affects people and ecosystems throughout the planet and is both affected by climate change and contributes to it. In this report, land degradation is defined as a *negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity, or value to humans*. Forest degradation is land degradation that occurs in forest land. Deforestation is the conversion of forest to non-forest land and can result in land degradation. {4.1.3}

Processes	Focal point	Impacts of climate change				Feedbacks on climate change			
		Proximity	Dominance	Climate change pressures	Other pressures	Intensity of chemical effects	Intensity of physical effects	Global extent	Specific impacts
Wind erosion	Soil	high	medium	Altered wind/drought patterns (*high confidence* on effect, *medium-low confidence* on trend) (1). Indirect effect through vegetation type and biomass production shifts	Tillage, leaving low cover, overgrazing, deforestation/ vegetation clearing, large plot sizes, vegetation and fire regime shifts	low	medium	high	Radiative cooling by dust release (*medium confidence*). Ocean and land fertilisation and carbon burial (*medium confidence*). Albedo increase. Dust effect as condensation nuclei (19)
Water erosion	Soil	high	medium	Increasing rainfall intensity (*high confidence* on effect and trend) (2). Indirect effects on fire frequency/ intensity, permafrost thawing, biomass production	Tillage, cultivation leaving low cover, overgrazing, deforestation/ vegetation clearing, vegetation burning, poorly designed roads and paths	medium	medium	high	Net carbon release. Net release is probably less than site-specific loss due to deposition and burial (*high confidence*). Albedo increase (20)
Coastal erosion	Soil/water	high	high	Sea level rise, increasing intensity/ frequency of storm surges (*high confidence* on effects and trends) (3)	Retention of sediments by upstream dams, coastal aquiculture, elimination of mangrove forests, subsidence	high	low	low	Release of old buried carbon pools (*medium confidence*) (21)

Processes	Focal point	Impacts of climate change				Feedbacks on climate change			
		Proximity	Dominance	Climate change pressures	Other pressures	Intensity of chemical effects	Intensity of physical effects	Global extent	Specific impacts
Subsidence	Soil/water	low	low	Indirect through increasing drought leading to higher ground water use. Indirect through enhanced decomposition (e.g., through drainage) in organic soils	Groundwater depletion/ overpumping, peatland drainage	low/high	low	low	Unimportant in the case of groundwater depletion. Very high net carbon release in the case of drained peatlands
Compaction/ hardening	Soil	low	low	Indirect through reduced organic matter content	Land-use conversion, machinery overuse, intensive grazing, poor tillage/grazing management (e.g., under wet or waterlogged conditions)	low	low	medium	Contradictory effects of reduced aeration on N_2O emissions
Nutrient depletion	Soil	low	low	Indirect (e.g., shifts in cropland distribution, BECCS)	Insufficient replenishment of harvested nutrients	low	low	medium	Net carbon release due shrinking SOC pools. Larger reliance on soil liming with associated CO_2 releases
Acidification/ overfertilisa-tion	Soil	low	low	Indirect (e.g., shifts in cropland distribution, BECCS). Sulfidic wetland drying due to increased drought as special direct effect	High nitrogen fertilisation, high cation depletion, acid rain/deposition	medium	low	medium	N_2O release from overfertilised soils, increased by acidification. Inorganic carbon release from acidifying soils (*medium to high confidence*) (22)
Pollution	Soil/biota	low	low	Indirect (e.g., increased pest and weed incidence)	Intensifying chemical control of weed and pests	low	low	medium	Unknown, probably unimportant

Organic matter decline	Soil	high	medium	Warming accelerates soil respiration rates (*medium confidence* on effects and trends) (4). Indirect effects through changing quality of plant litter or fire/waterlogging regimes	Tillage. reduced plant input to soil. Drainage of waterlogged soils. Influenced by most of the other soil degradation processes.	high	low	high	Net carbon release (*high confidence*) (
Metal toxicity	Soil	low	low	Indirect	High cation depletion, fertilisation, mining activities	low	low	low	Unknown, probably unimportant
Salinisation	Soil / water	high	low	Sea level rise (*high confidence* on effects and trends) (5). Water balance shifts (*medium confidence* on effects and trends) (6). Indirect effects through irrigation expansion	Irrigation without good drainage infrastructure. Deforestation and water table-level rises under dryland agriculture	low	medium	medium	Reduced methane emissions with high sulfate load. Albedo increase
Sodification (increased sodium and associated physical degradation in soils)	Soil / water	high	low	Water balance shifts (*medium confidence* on effects and trends) (7). Indirect effects through irrigation expansion	Poor water management	low	medium	low	Net carbon release due to soil structure and organic matter dispersio Albedo increase
Permafrost thawing	Soil / water	high	high	Warming (*very high confidence* on effects and trends) (8), seasonality shifts and accelerated snow melt leading to higher erosivity.		high	low	high	Net carbon release. CH_4 release (*high confidence*) (24)

Processes	Focal point	Impacts of climate change				Feedbacks on climate change			
		Proximity	Dominance	Climate change pressures	Other pressures	Intensity of chemical effects	Intensity of physical effects	Global extent	Specific impacts
Waterlogging of dry systems	Water	high	medium	Water balance shifts (*medium confidence* on effects and trends) (9). Indirect effects through vegetation shifts	Deforestation. Irrigation without good drainage infrastructure	medium	medium	low	CH_4 release. Albedo decrease
Drying of continental waters/ wetland/ lowlands	Water	high	medium	Increasing extent and duration of drought (*high confidence* on effects, *medium confidence* on trends) (10). Indirect effects through vegetation shifts	Upstream surface and groundwater consumption. Intentional drainage. Trampling/overgrazing	medium	medium	medium	Net carbon release. N_2O release. Albedo increase
Flooding	Water	high	medium	Sea level rise, increasing intensity/ frequency of storm surges, increasing rainfall intensity causing flash floods (*high confidence* on effects and trends) (11)	Land clearing. Increasing impervious surface. Transport infrastructure	medium	medium	low	CH_4 and N_2O release. Albedo decrease
Eutrophica-tion of continental waters	Water/biota	low	low	Indirect through warming effects on nitrogen losses from the land or climate change effects on erosion rates. Interactive effects of warming and nutrient loads on algal blooms	Excess fertilisation. Erosion. Poor management of livestock/ human sewage	medium	low	low	CH_4 and N_20 release
Woody encroachment	Biota	high	medium	Rainfall shifts (*medium confidence* on effects and trends), CO_2 rise (*medium confidence* on effects, *very high confidence* on trends) (12)	Overgrazing. Altered fire regimes, fire suppression. Invasive alien species	high	high	high	Net carbon storage. Albedo decrease

Woody encroachment	Biota	high	medium	Rainfall shifts (*medium confidence* on effects and trends), CO_2 rise (*medium confidence* on effects, *very high confidence* on trends) (12)	Overgrazing. Altered fire regimes, fire suppression. Invasive alien species	high	high	high	Net carbon storage. Albedo decrease
Species loss, compositional shifts	Biota	high	medium	Habitat loss as a result of climate shifts (*medium confidence* on effects and trends) (13)	Selective grazing and logging causing plant species loss, Pesticides causing soil microbial and soil faunal losses, large animal extinctions, interruption of disturbance regimes	low	low	medium	Unknown
Soil microbial and mesofaunal shifts	Biota	high	low	Habitat loss as a result of climate shifts (*medium confidence* on effects and trends) (14)	Altered fire regimes, nitrogen deposition, pesticide pollution, vegetation shifts, disturbance regime shifts	low	low	medium	Unknown
Biological soil crust destruction	Biota/soil	high	medium	Warming. Changing rainfall regimes. (*medium confidence* on effects, high confidence and trends). Indirect through fire regime shifts and/or invasions (15)	Overgrazing and trampling. Land-use conversion	low	high	high	Radiative cooling through albedo rise and dust release (*high confidence*) (25)
Invasions	Biota	high	medium	Habitat gain as a result of climate shifts (*medium confidence* on effects and trends) (16)	Intentional and unintentional species introductions	low	low	medium	Unknown
Pest outbreaks	Biota	high	medium	Habitat gain and accelerated reproduction as a result of climate shifts (*medium confidence* on effects and trends) (17)	Large-scale monocultures. Poor pest management practices	medium	low	medium	Net carbon release

Processes	Focal point	Impacts of climate change				Feedbacks on climate change			
		Proximity	Dominance	Climate change pressures	Other pressures	Intensity of chemical effects	Intensity of physical effects	Global extent	Specific impacts
Increased burning	Soil/biota	high	high	Warming, drought, shifting precipitation regimes, also wet spells rising fuel load (*high confidence* on effects and trends) (18)	Fire suppression policies increasing wildfire intensity. Increasing use of fire for rangeland management. Agriculture introducing fires in humid climates without previous fire history. Invasions	high	medium	medium	Net carbon release. CO, CH_4, N_2O release. Albedo increase (*high confidence*). Long-term decline of NPP in non-adapted ecosystems (26)

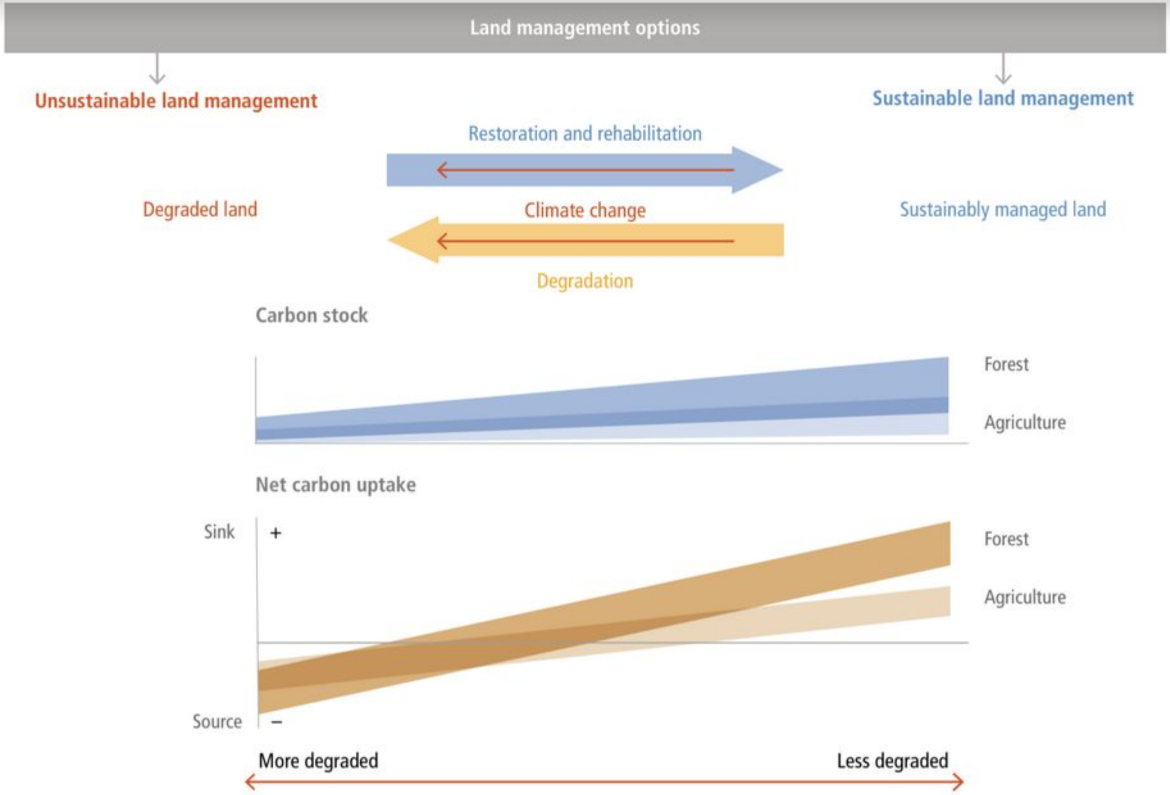
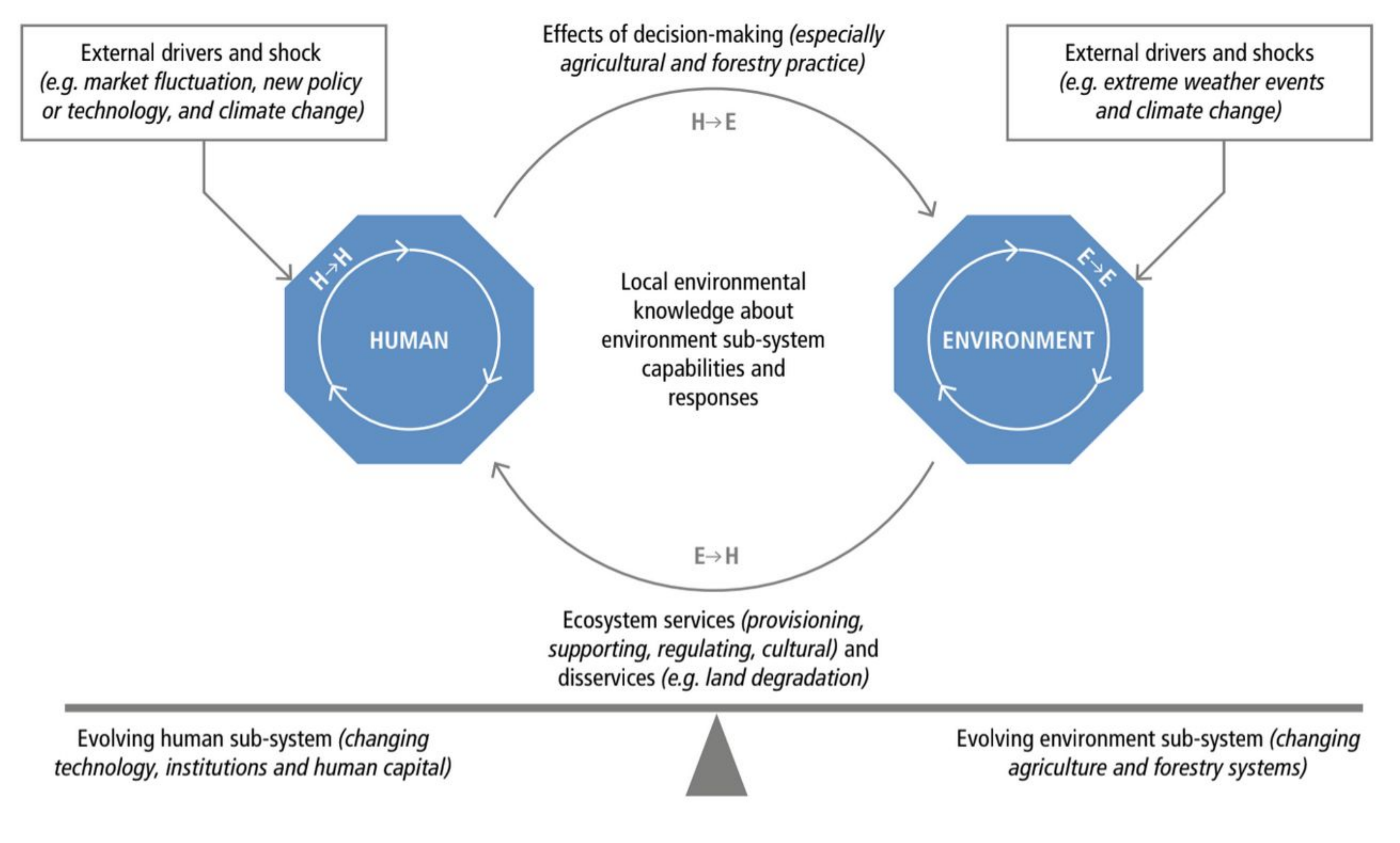


Figure 4.1 | Conceptual figure illustrating that climate change impacts interact with land management to determine sustainable or degraded outcome. Climate change can exacerbate many degradation processes (Table 4.1) and introduce novel ones (e.g., permafrost thawing or biome shifts), hence management needs to respond to climate impacts in order to avoid, reduce or reverse degradation. The types and intensity of human land-use and climate change impacts on lands affect their carbon stocks and their ability to operate as carbon sinks. In managed agricultural lands, degradation typically results in reductions of soil organic carbon stocks, which also adversely affects land productivity and carbon sinks. In forest land, reduction in biomass carbon stocks alone is not necessarily an indication of a reduction in carbon sinks. Sustainably managed forest landscapes can have a lower biomass carbon density but the younger forests can have a higher growth rate, and therefore contribute stronger carbon sinks, than older forests. Ranges of carbon sinks in forest and agricultural lands are overlapping. In some cases, climate change impacts may result in increased productivity and carbon stocks, at least in the short term.


External drivers and shock
(e.g. market fluctuation, new policy or technology, and climate change)
Effects of decision-making (especially agricultural and forestry practice)
External drivers and shocks
(e.g. extreme weather events and climate change)
H→E
H→H
HUMAN
Local environmental knowledge about environment sub-system capabilities and responses
E→E
ENVIRONMENT
E→H
Ecosystem services (provisioning, supporting, regulating, cultural) and disservices (e.g. land degradation)
Evolving human sub-system (changing technology, institutions and human capital)
Evolving environment sub-system (changing agriculture and forestry systems)

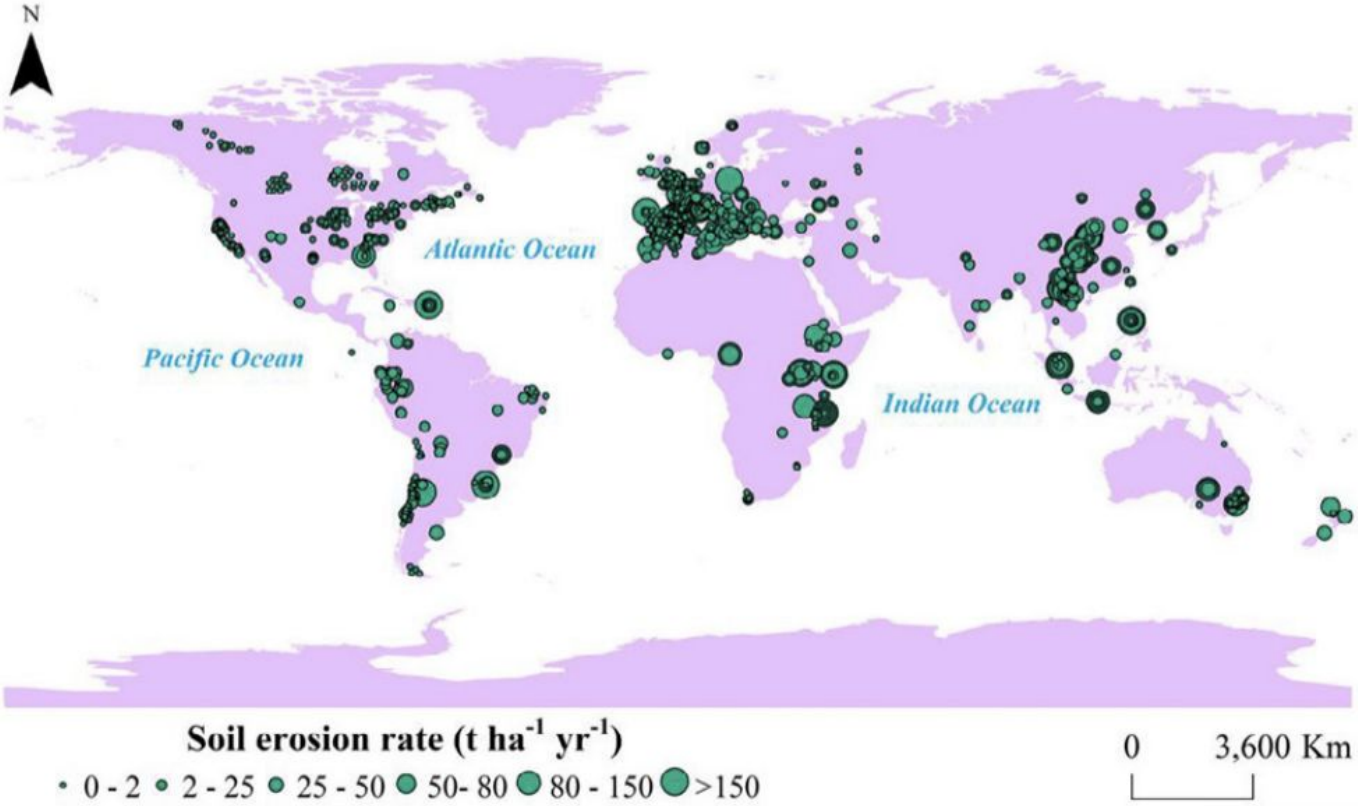


Figure 4.3. | Map of observed soil erosion rates in database of 4,377 entries by García-Ruiz et al. (2015). The map was published by Li and Fang (2016).

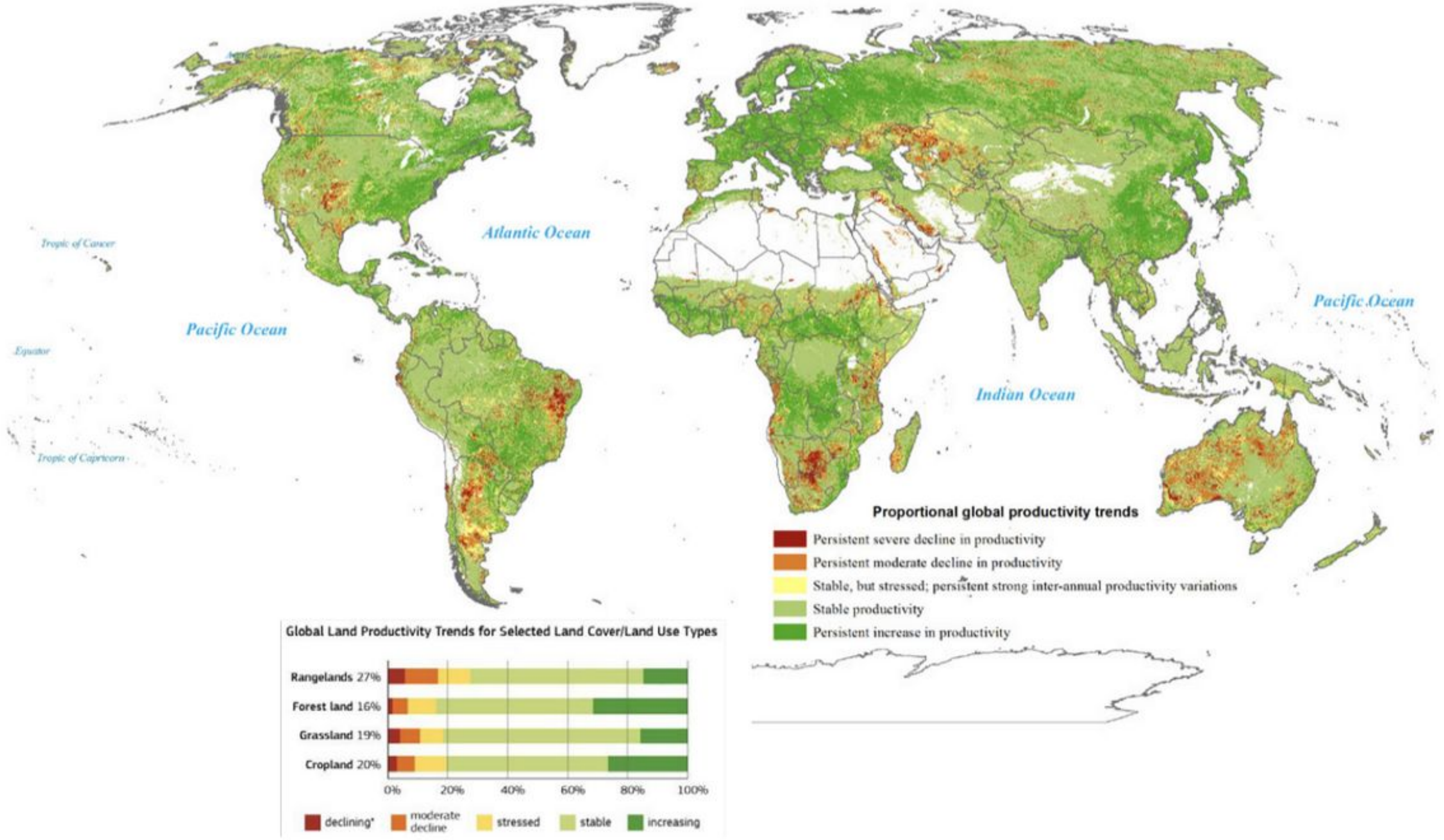


Figure 4.4 | Proportional global land productivity trends by land-cover/land-use class. (Cropland includes arable land, permanent crops and mixed classes with over 50% crops; grassland includes natural grassland and managed pasture land; rangelands include shrubland, herbaceous and sparsely vegetated areas; forest land includes all forest categories and mixed classes with tree cover greater than 40%.) Data source: Copernicus Global Land SPOT VGT, 1999–2013, adapted from (Cherlet et al. 2018).

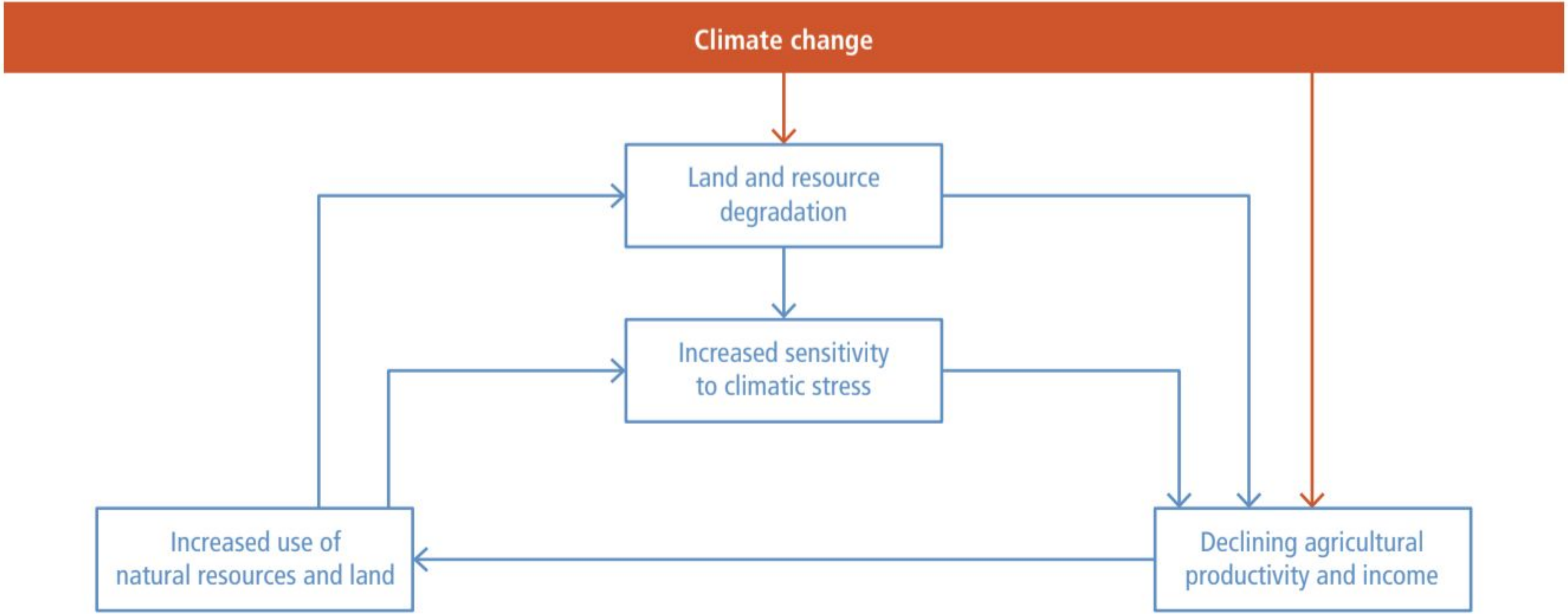


Figure 4.6 | **Schematic representation of links between climate change, land management and socio-economic conditions.**

Table 4.2 | Interaction of human and climate drivers can exacerbate desertification and land degradation. Climate change exacerbates the rate and magnitude of several ongoing land degradation and desertification processes. Human drivers of land degradation and desertification include expanding agriculture, agricultural practices and forest management. In turn, land degradation and desertification are also drivers of climate change through GHG emissions, reduced rates of carbon uptake, and reduced capacity of ecosystems to act as carbon sinks into the future. Impacts on climate change are either warming (in red) or cooling (in blue).

Issue/ syndrome	Impact on climate change	Human driver	Climate driver	Land management options	References
Erosion of agricultural soils	Emission: CO_2, N_2O	Agriculture practice, Expansion of agriculture	Warming trend, Drying trend, Extreme rainfall, Shifting rains	Increase soil organic matter, no-till, perennial crops, erosion control, agroforestry, dietary change	3.1.4, 3.4.1, 3.5.2, 3.7.1, 4.8.1, 4.8.5, 4.9.2, 4.9.5
Deforestation	Emission of CO_2	Forest clearing, Expansion of agriculture		Forest protection, sustainable forest management and dietary change	4.1.5, 4.5, 4.8.3, 4.8.4, 4.9.3
Forest degradation	Emission of CO_2 Reduced carbon sink	Forest clearing		Forest protection, sustainable forest management	4.1.5, 4.5, 4.8.3, 4.8.4, 4.9.3
Overgrazing	Emission: CO_2, CH_4 Increasing albedo	Grazing pressure	Warming trend, Drying trend	Controlled grazing, rangeland management	3.1.4.2, 3.4.1, 3.6.1, 3.7.1, 4.8.1.4
Firewood and charcoal production	Emission: CO_2, CH_4 Increasing albedo	Wood fuel		Clean cooking (health co-benefits, particularly for women and children)	3.6.3, 4.5.4, 4.8.3, 4.8.4
Increasing fire frequency and intensity	Emission: CO_2, CH_4, N_2O Emission: aerosols, increasing albedo		Warming trend, Extreme temperature, Drying trend	Fuel management, fire management	3.1.4, 3.6.1, 4.1.5, 4.8.3, Cross-Chapter Box 3 in Chp 2
Degradation of tropical peat soils	Emission: CO_2, CH_4	Agriculture practice, Expansion of agriculture	Drying trend	Peatland restoration, erosion control, regulating the use of peat soils	4.9.4
Thawing of permafrost	Emission: CO_2, CH_4		Warming trend, Extreme temperature	Relocation of settlement and infrastructure	4.8.5.1
Coastal erosion	Emission: CO_2, CH_4		Intensifying cyclones, Sea level rise, Extreme rainfall	Wetland and coastal restoration, mangrove conservation, long-term land-use planning	4 .9.6, 4.9. 7, 4.9.8
Sand and dust storms, wind erosion	Emission: aerosols	Grazing pressure, Agriculture practice, Expansion of agriculture, Wood fuel	Drying trend, Shifting rains	Vegetation management, afforestation, windbreaks	3.3.1, 3.4.1, 3.6.1, 3.7.1, 3.7.2
Bush encroachment	Capturing: CO_2, Decreasing albedo	Grazing pressure, Wood fuel	Shifting rains	Grazing land management, fire management	3.6.1.3, 3.7.3.2

Human driver	Climate driver
Grazing pressure	Warming trend
Agriculture practice	Extreme temperature
Expansion of agriculture	Drying trend
Forest clearing	Extreme rainfall
Wood fuel	Shifting rains
	Intensifying cyclones
	Sea level rise

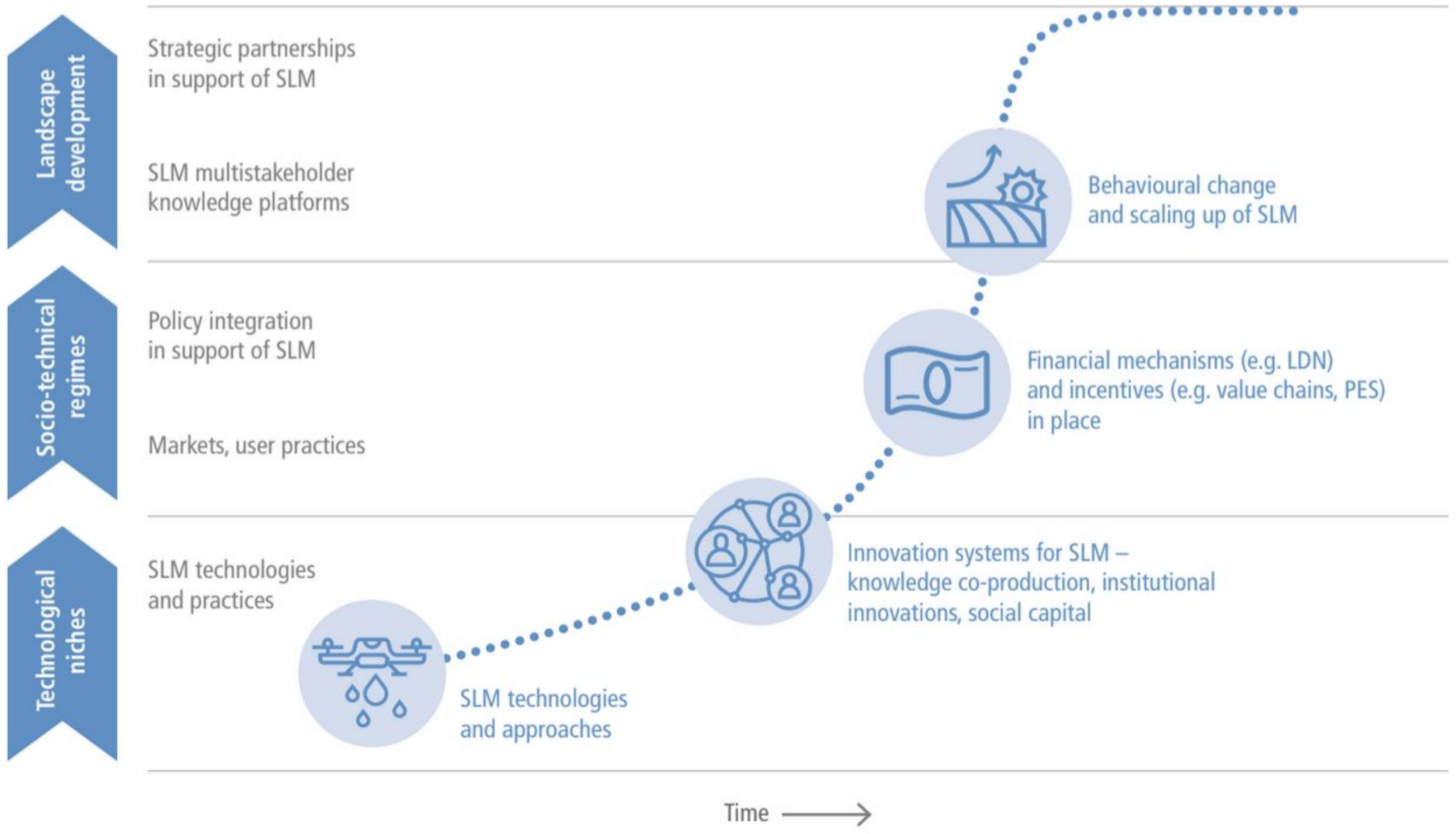


Figure 4.7 | The transition from SLM niche adoption to regime shift and landscape development. Figure draws inspiration from Geels (2002), adapted from Tengberg and Valencia (2018).

Table 4.3 | Synthesis of how the case studies interact with climate change and a broader set of co-benefits.

Case studies (4.9)	Mitigation benefits and potential	Adaptation benefits	Co-benefits
Urban green infrastructure (4.9.1) An increasing majority of the world population live in cities and land degradation is an urgent matter for urban areas	↓	[reduced flood risk] [reduced heat stress]	human health, recreation
Perennial grains (4.9.2) After 40 years of breeding, perennial grains now seem to have the potential of reducing climate impacts of agriculture while increasing its overall sustainability	↓ ↑	[drought resistance] [reduced flood risk]	reduced use of herbicides, reduced soil erosion and nutrient leakage
Reforestation (4.9.3) Two cases of successful reforestation serve as illustrations of the potential of sustained efforts into reforestation	↓	[reduced flood risk]	economic return from sustainable forestry, reduced flood risk downstream
Management of peat soils (4.9.4) Degradation of peat soils in tropical and Arctic regions is a major source of greenhouse gases, hence an urgent mitigation option	↑		improved air quality in tropical regions
Biochar (4.9.5) Biochar is a land-management technique of high potential, but controversial	↓ ↑	[drought resistance]	improved soil fertility
Protection against hurricane damages (4.9.6) More severe tropical cyclones increase the risk of land degradation in some areas, hence the need for increased adaptation		[reduced flood risk] [storm protection]	reduced losses (human lives, livelihoods, and assets)
Responses to saltwater intrusion (4.9.7) The combined effect of climate-induced sea level rise and land-use change in coastal regions increases the risk of saltwater intrusion in many coastal regions		[protection against sea level rise] [storm protection]	improved food and water security
Avoiding coastal maladaptation (4.9.8) Low-lying coastal areas are in urgent need of adaptation, but examples have resulted in maladaptation		[protection against sea level rise] [storm protection]	reduced losses (human lives, livelihoods, and assets)

Legend	
↓	carbon sink
↑	reduced emission
[reduced flood risk]	reduced flood risk
[reduced heat stress]	reduced heat stress
[drought resistance]	drought resistance
[storm protection]	storm protection
[protection against sea level rise]	protection against sea level rise

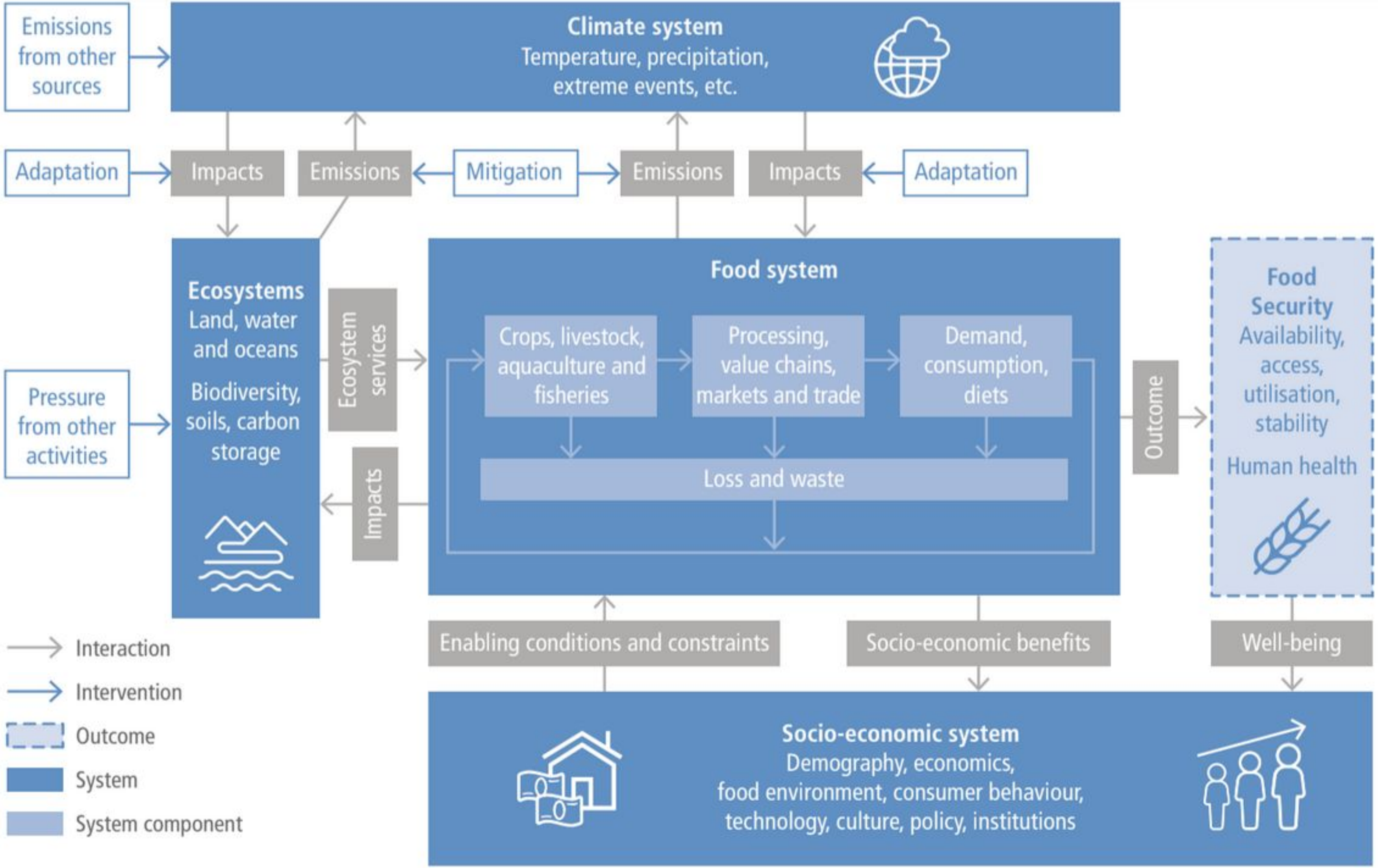


Figure 5.1 | Interlinkages between the climate system, food system, ecosystems (land, water and oceans) and socio-economic system. These systems operate at multiple scales, both global and regional. Food security is an outcome of the food system leading to human well-being, which is also indirectly linked with climate and ecosystems through the socio-economic system. Adaptation measures can help to reduce negative impacts of climate change on the food system and ecosystems. Mitigation measures can reduce GHG emissions coming from the food system and ecosystems.

Table 5.1 | Relationships between food security, the food system, and climate change, and guide to chapter.

Food security pillar	Examples of observed and projected climate change impacts	Sections	Examples of adaptation and mitigation	Section
Availability *Production of food and its readiness for use through storage, processing, distribution, sale and/or exchange*	Reduced yields in crop and livestock systems	5.2.2.1, 5.2.2.2	Development of adaptation practices	5.3
	Reduced yields from lack of pollinators; pests and diseases	5.2.2.3, 5.2.2.4	Adoption of new technologies, new and neglected varieties	5.3.2.3, 5.3.3.1,
	Reduced food quality affecting availability (e.g., food spoilage and loss from mycotoxins)	5.2.4.1, 5.5.2.5	Enhanced resilience by integrated practices, better food storage	5.3.2.3, 5.3.3.4, 5.6.4
	Disruptions to food storage and transport networks from change in climate, including extremes	5.2.5.1, 5.3.3.4, 5.8.1, Box 5.5	Reduction of food demand by reducing waste, modifying diets	5.3.4, 5.5.2, 5.7
			Closing of crop yield and livestock productivity gaps	5.6.4.4, 5.7
			Risk management, including marketing mechanisms, financial insurance	5.3.2, 5.7
Access *Ability to obtain food, including effects of price*	Yield reductions, changes in farmer livelihoods, limitations on ability to purchase food	5.2.2.1, 5.2.2.2	Integrated agricultural practices to build resilient livelihoods	5.6.4
	Price rise and spike effects on low-income consumers, in particular women and children, due to lack of resources to purchase food	5.1.3, 5.2.3.1, 5.2.5.1, Box 5.1	Increased supply chain efficiency (e.g., reducing loss and waste)	5.3.3, 5.3.4
	Effects of increased extreme events on food supplies, disruption of agricultural trade and transportation infrastructure	5.8.1	More climate-resilient food systems, shortened supply chains, dietary change, market change	5.7
Utilisation *Achievement of food potential through nutrition, cooking, health*	Impacts on food safety due to increased prevalence of microorganisms and toxins	5.2.4.1	Improved storage and cold chains	5.3.3, 5.3.4
	Decline in nutritional quality resulting from increasing atmospheric CO_2	5.2.4.2	Adaptive crop and livestock varieties, healthy diets, better sanitation	5.3.4, 5.5.2, 5.7
	Increased exposure to diarrheal and other infectious diseases due to increased risk of flooding	5.2.4.1		
Stability *Continuous availability and access to food without disruption*	Greater instability of supply due to increased frequency and severity of extreme events; food price rises and spikes; instability of agricultural incomes	5.2.5, 5.8.1	Resilience via integrated systems and practices, diversified local agriculture, infrastructure investments, modifying markets and trade, reducing food loss and waste	5.6.4, 5.7, 5.8.1
	Widespread crop failure contributing to migration and conflict	5.8.2	Crop insurance for farmers to cope with extreme events	5.3.2.2, 5.7
			Capacity building to develop resilient systems	5.3.6, 5.7.4
Combined Systemic *impacts from interactions of all four pillars*	Increasing undernourishment as food system is impacted by climate change	5.1	Increased food system productivity and efficiency (e.g., supply side mitigation, reducing waste, dietary change)	5.5.1, 5.7
	Increasing obesity and ill health through narrow focus on adapting limited number of commodity crops	5.1	Increased production of healthy food and reduced consumption of energy-intensive products	5.5.2, 5.7
	Increasing environmental degradation and GHG emissions	Cross-Chapter Box 6	Development of climate smart food systems by reducing GHG emissions, building resilience, adapting to climate change	5.3.3, 5.7
	Increasing food insecurity due to competition for land and natural resources (e.g., for land-based mitigation)	5.6.1	Governance and institutional responses (including food aid) that take into consideration gender and equity.	5.2.5, 5.7

Table 5.2 | Global prevalence of various forms of malnutrition.

	HLPE 2017 (UN)	SOFI 2017 (FAO)	GNR 2017	SOFI 2018 (FAO)	GNR2018
Overweight but not obese[a]	1.3 billion		1.29 billion		1.34 billion (38,9%)[c]
Overweight under five	41 million	41 million	41 million	38 million	38 million
Obesity[b]	600 million	600 million (13%)	641 million	672 million	678 million (13,1%)[c]
Undernourishment	800 million	815 million	815 million	821 million	
Stunting under five	155 million	155 million	155 million[d]	151 million	151 million[d] (22%)
Wasting under five	52 million	52 million (8%)	52 million[d]	50 million	51 million[d] (7%)
MND (iron)	19.2% of pregnant women[e]	33% women of reproductive age	613 million women and girls aged 15 to 49[f]	613 million (32.8%) women and girls aged 15 to 49[f]	613 million (32.8%) women and girls aged 15 to 49[f]

HLPE: High Level Panel of Experts on Food Security and Nutrition; SOFI: The State of Food Security and Nutrition in the World; GNR: Global Nutrition Report; MND: Micro nutrient deficiency (iron deficiency for year 2016, uses anaemia as a proxy (percentage of pregnant women whose haemoglobin level is less than 110 grams per litre at sea level and percentage of non-pregnant women whose haemoglobin level is less than 120 grams per litre at sea level).

[a] Body mass index between 25 kg m^{-2} and 29.9 kg m^{-2}.

[b] Body mass index greater than 30 kg m^{-2}.

[c] Prevalence of overweight/obesity among adults (age ≥18) in year 2016. Data from NCD Risc data source.

[d] UNICEF WHO Joint Malnutrition.

[e] In 2011.

[f] Anaemia prevalence in girls and women aged 15 to 49.

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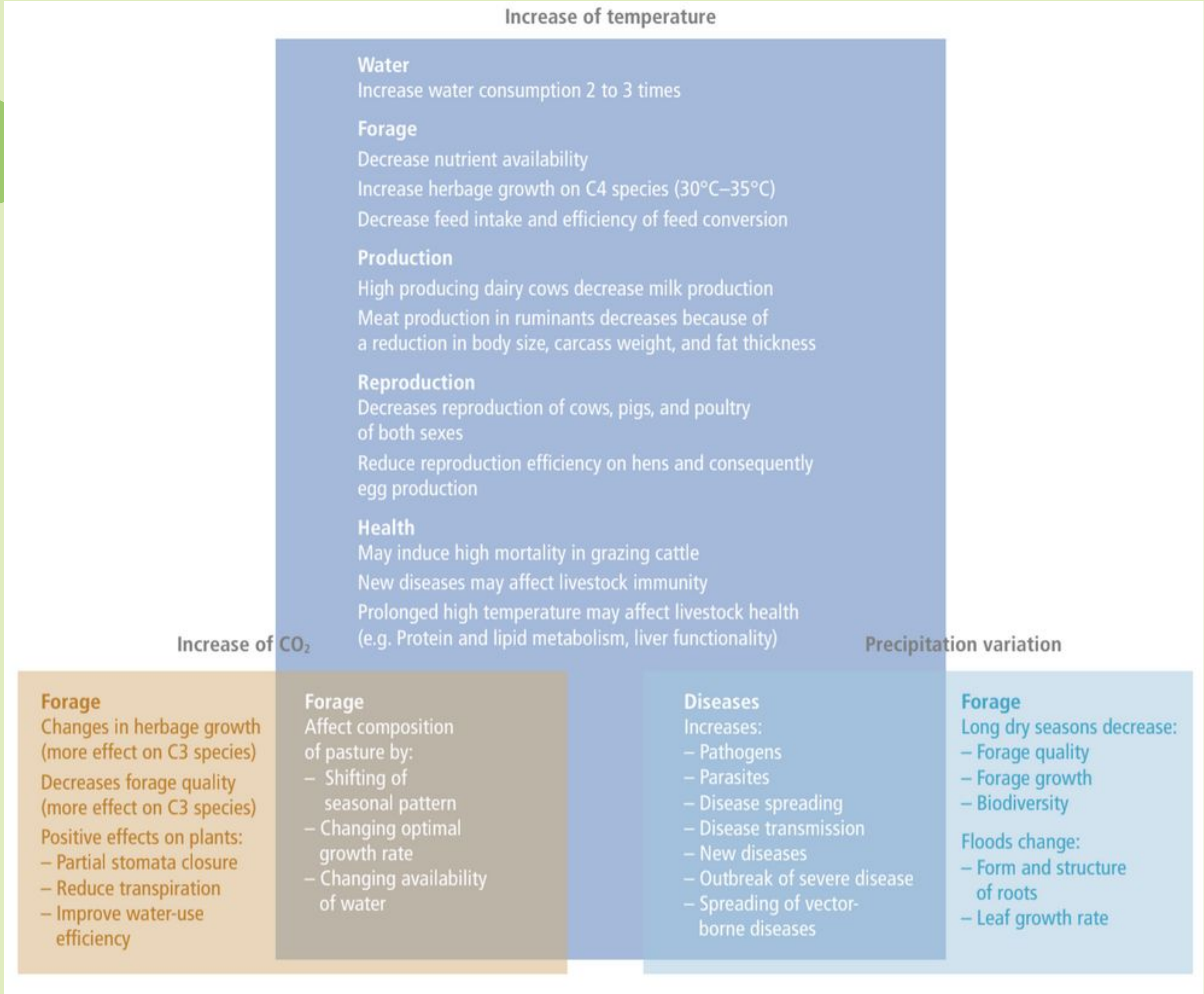
1 Does not take into account terrestrial production of feed.



Increase of temperature
Water
Increase water consumption 2 to 3 times
Forage
Decrease nutrient availability
Increase herbage growth on C4 species (30°C–35°C)
Decrease feed intake and efficiency of feed conversion
Production
High producing dairy cows decrease milk production
Meat production in ruminants decreases because of a reduction in body size, carcass weight, and fat thickness
Reproduction
Decreases reproduction of cows, pigs, and poultry of both sexes
Reduce reproduction efficiency on hens and consequently egg production
Health
May induce high mortality in grazing cattle
New diseases may affect livestock immunity
Prolonged high temperature may affect livestock health (e.g. Protein and lipid metabolism, liver functionality)
Increase of CO_2
Forage
Changes in herbage growth (more effect on C3 species)
Decreases forage quality (more effect on C3 species)
Positive effects on plants:
– Partial stomata closure
– Reduce transpiration
– Improve water-use efficiency
Forage
Affect composition of pasture by:
– Shifting of seasonal pattern
– Changing optimal growth rate
– Changing availability of water
Precipitation variation
Diseases
Increases:
– Pathogens
– Parasites
– Disease spreading
– Disease transmission
– New diseases
– Outbreak of severe disease
– Spreading of vector-borne diseases
Forage
Long dry seasons decrease:
– Forage quality
– Forage growth
– Biodiversity
Floods change:
– Form and structure of roots
– Leaf growth rate

Table 5.3 | Synthesis of food security related adaptation options to address climate risks (IPCC 2014b; Vermeulen et al. 2013, 2018; Burnham and Ma 2016; Bhatta and Aggarwal 2016).

Key climate drivers and risks	Incremental adaptation	Transformational adaptation	Enabling conditions
– Extreme events and short-term climate variability – Stress on water resources, drought stress, dry spells, heat extremes, flooding, shorter rainy seasons, pests	– Change in variety, water management, water harvesting, supplemental irrigation during dry spells – Planting dates, pest control, feed banks – Transhumance, other sources of revenue (e.g., charcoal, wild fruits, wood, temporary work) – Soil management, composting	– Early Warning Systems – Planning for and prediction of seasonal to intra-seasonal climate risks to transition to safer food conditions – Abandonment of monoculture, diversification – Crop and livestock insurance – Alternate cropping, intercropping – Erosion control	– Establishment of climate services – Integrated water management policies, integrated land and water governance – Seed banks, seed sovereignty and seed distribution policies – Capacity building and extension programmes
– Warming trend, drying trend – Reduced crop productivity due to persistent heat, long drought cycles, deforestation and land degradation with strong adverse effects on food production and nutrition quality, increased pest and disease damage	– Strategies to reduce effects of recurring food challenges – Sustainable intensification, agroforestry, conservation agriculture, SLM – Adoption of existing drought-tolerant crop and livestock species – Counter season crop production – Livestock fattening – New ecosystem-based adaptation (e.g., bee keeping, woodlots) – Farmers management of natural resources – Labour redistribution (e.g., mining, development projects, urban migration) – Adjustments to markets and trade pathways already in place	– Climate services for new agricultural programmes (e.g., sustainable irrigation districts) – New technology (e.g., new farming systems, new crops and livestock breeds) – Switches between cropping and transhumant livelihoods, replacement of pasture or forest to irrigated/rainfed crops – Shifting to small ruminants or drought resistant livestock or fish farming – Food storage infrastructures, food transformation – Changes in cropping area, land rehabilitation (enclosures, afforestation) perennial farming – New markets and trade pathways	– Climate information in local development policies – Stallholders' access to credit and production resources – National food security programme based on increased productivity, diversification, transformation and trade – Strengthening (budget, capacities, expertise) of local and national institutions to support agriculture and livestock breeding – Devolution to local communities, women's empowerment, market opportunities – Incentives for establishing new markets and trade pathways

Table 5.4 | GHG emissions ($GtCO_2$-eq yr^{-1}) from the food system and their contribution (%) to total anthropogenic emissions. Mean of 2007–2016 period.

Food system component	Emissions (Gt CO_2eq yr^{-1})	Share in mean total emissions (%)
Agriculture	6.2 ± 1.4[a,b]	10–14%
Land use	4.9 ± 2.5 [a]	5–14%
Beyond farm gate	2.6[c] – 5.2[d]	5–10% [e]
Food system (total)	10.8 – 19.1	21–37%

Notes: Food system emissions are estimated from a) FAOSTAT (2018), b) US EPA (2012), c) Poore and Nemecek (2018) and d) Fischedick et al. (2014) (using square root of sum of squares of standard deviations when adding uncertainty ranges; see also Chapter 2); e) rounded to nearest fifth percentile due to assessed uncertainty in estimates. Percentage shares were computed by using a total emissions value for the period 2007–2016 of nearly 52 $GtCO_2$-eq yr^{-1} (Chapter 2), using GWP values of the IPCC AR5 with no climate feedback (GWP-CH_4=28; GWP-N_2O=265).

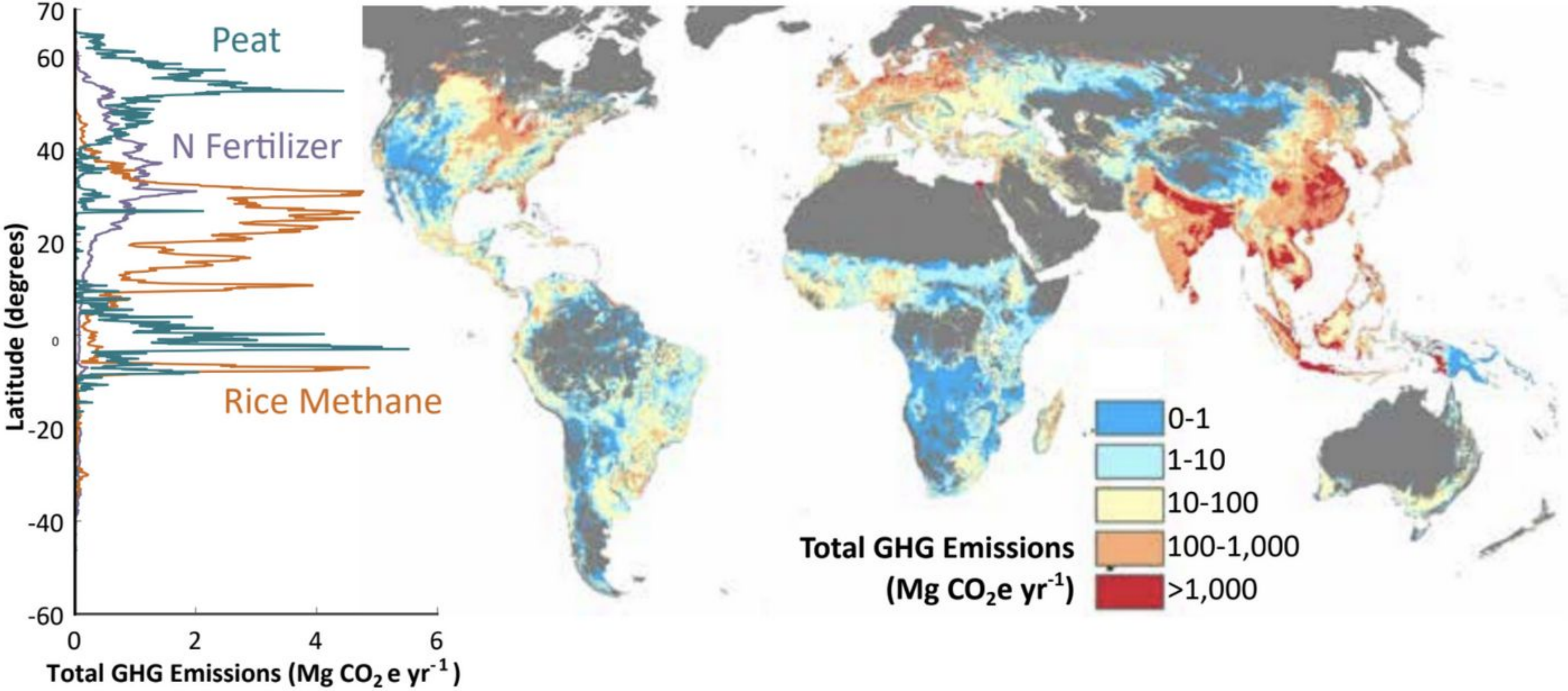


Figure 5.9 | Cropland GHGs consist of CH_4 from rice cultivation, CO_2, N_2O, and CH_4 from peatland draining, and N_2O from N fertiliser application. Total emissions from each grid cell are concentrated in Asia, and are distinct from patterns of production intensity (Carlson et al. 2017).

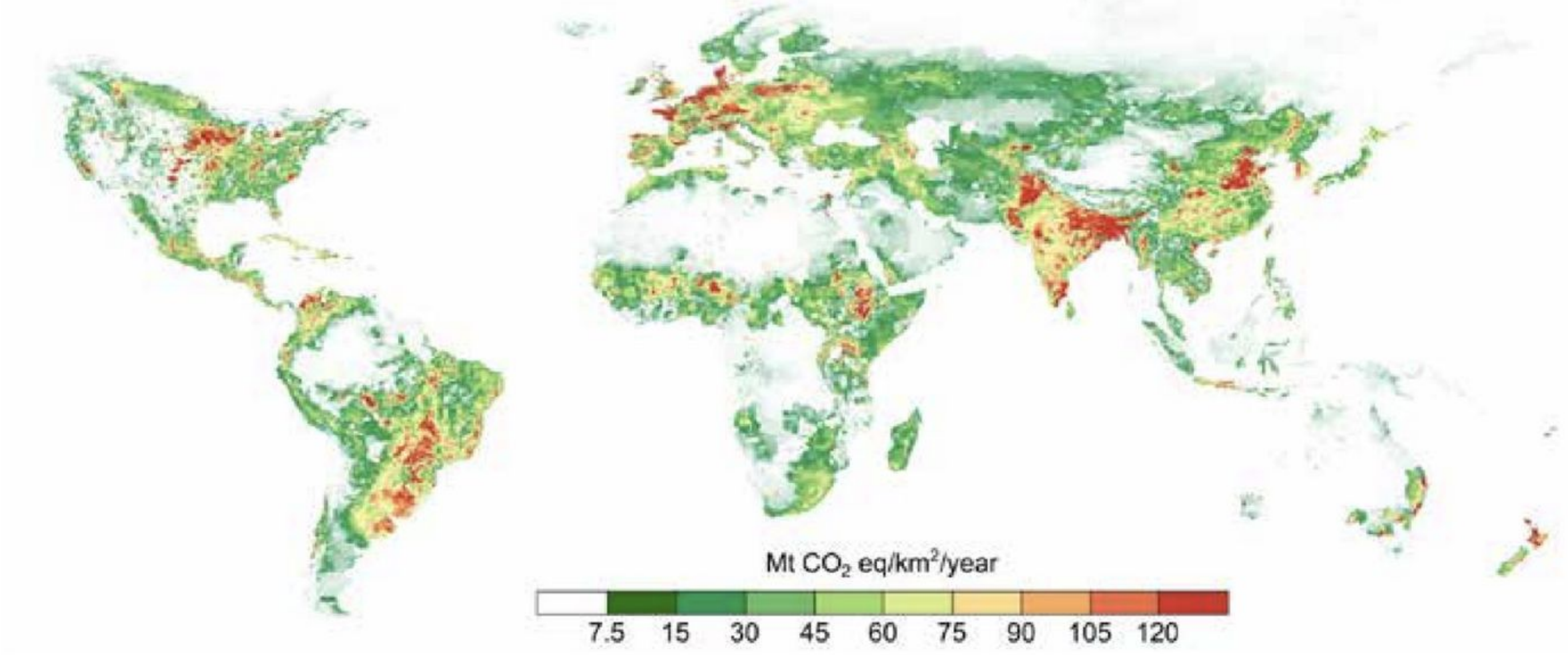
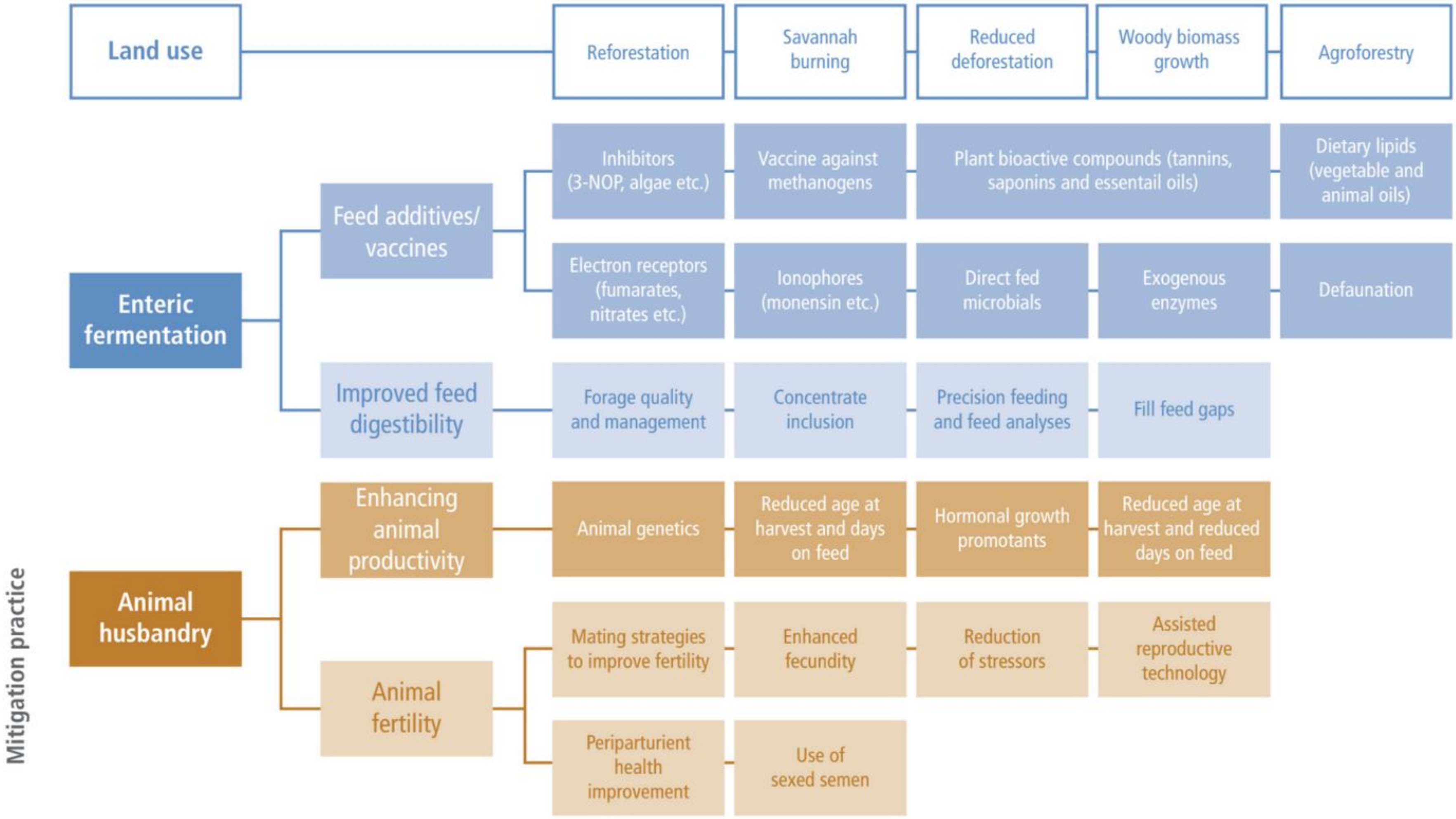
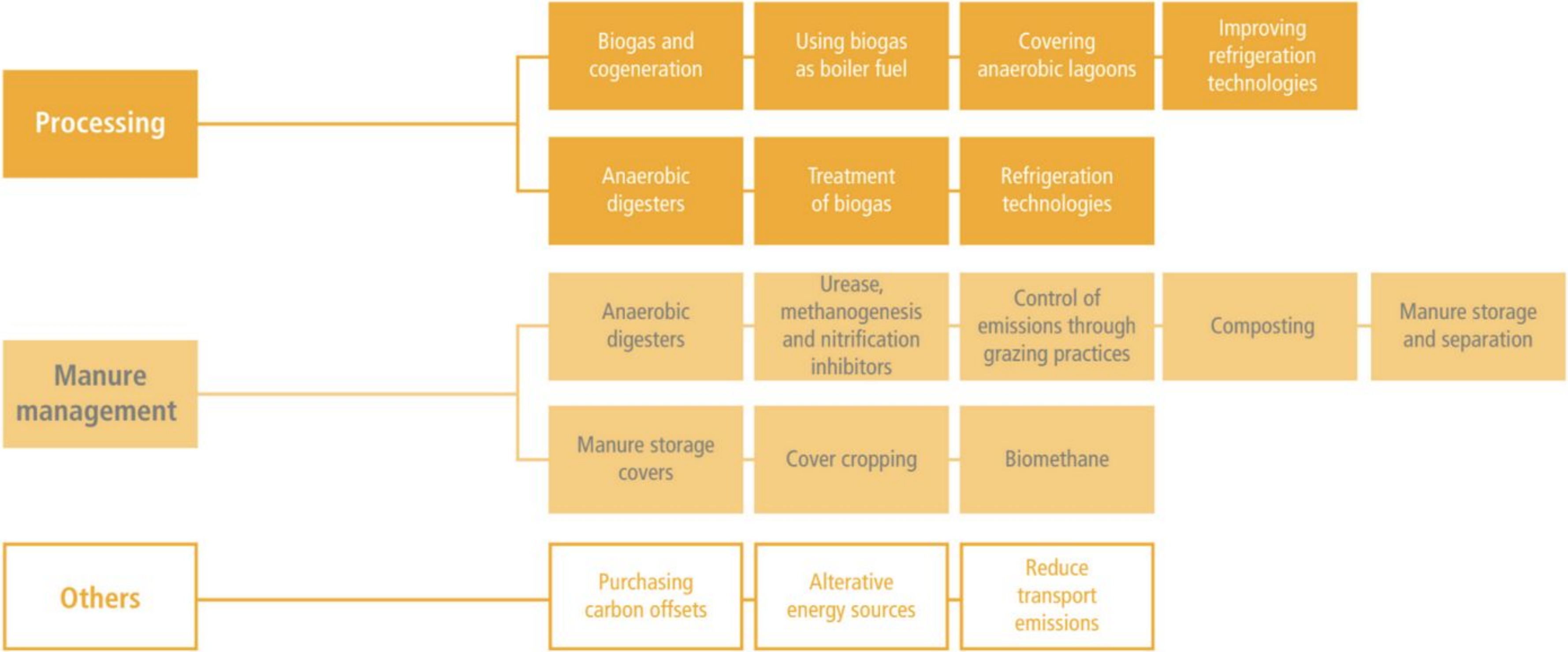


Figure 5.10 | Global GHG emissions from livestock for 1995–2005 (adapted from Herrero et al. 2016a).


Land use
Reforestation
Savannah burning
Reduced deforestation
Woody biomass growth
Agroforestry
Enteric fermentation
Feed additives/ vaccines
Inhibitors (3-NOP, algae etc.)
Vaccine against methanogens
Plant bioactive compounds (tannins, saponins and essentail oils)
Dietary lipids (vegetable and animal oils)
Electron receptors (fumarates, nitrates etc.)
Ionophores (monensin etc.)
Direct fed microbials
Exogenous enzymes
Defaunation
Improved feed digestibility
Forage quality and management
Concentrate inclusion
Precision feeding and feed analyses
Fill feed gaps
Animal husbandry
Enhancing animal productivity
Animal genetics
Reduced age at harvest and days on feed
Hormonal growth promotants
Reduced age at harvest and reduced days on feed
Animal fertility
Mating strategies to improve fertility
Enhanced fecundity
Reduction of stressors
Assisted reproductive technology
Periparturient health improvement
Use of sexed semen
Mitigation practice



igure 5.11 | Technical supply-side mitigation practices in the livestock sector (adapted from Hristov et al. 2013b; Herrero et al. 2016b and Smith et al. 2014).

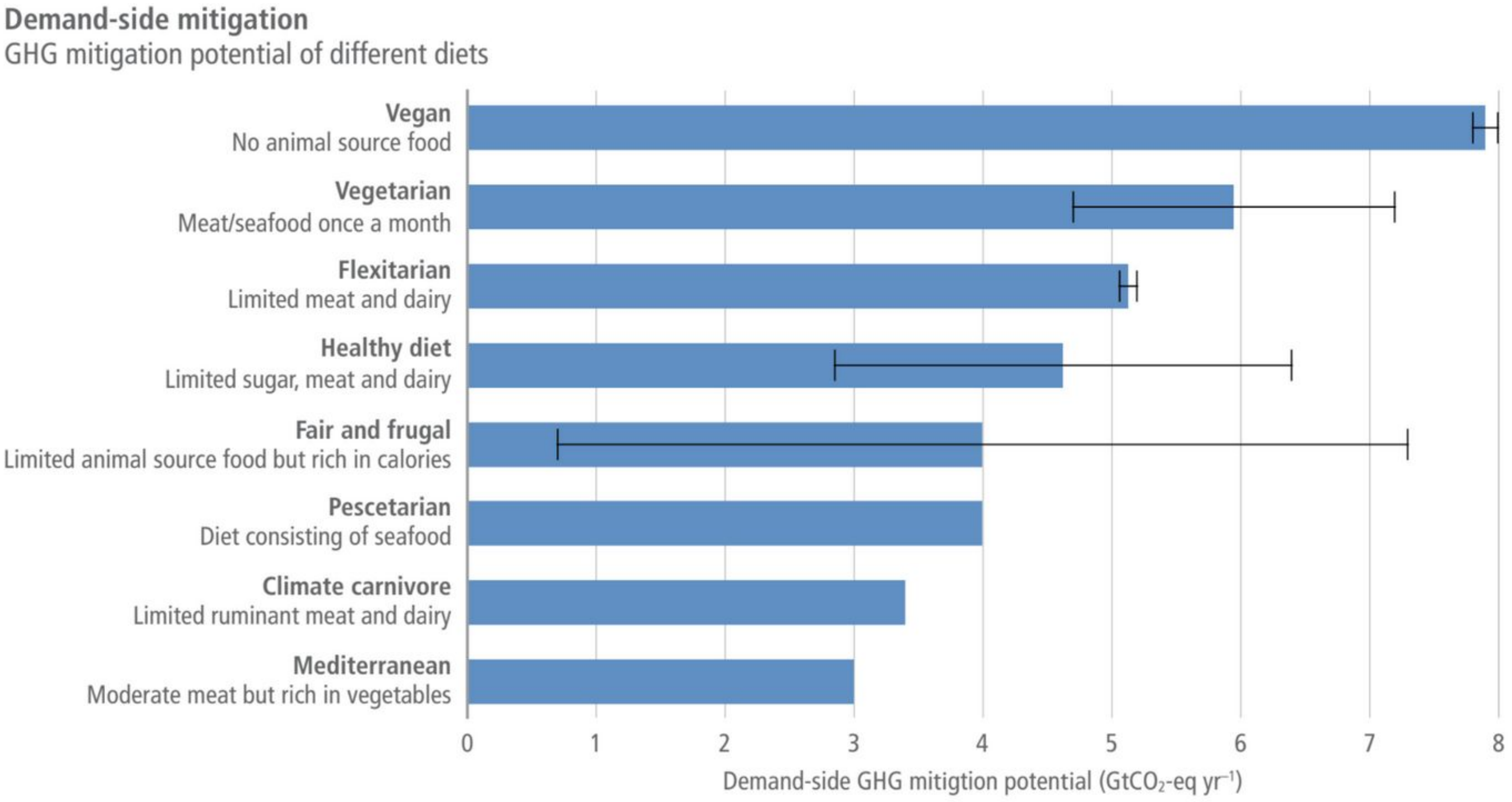
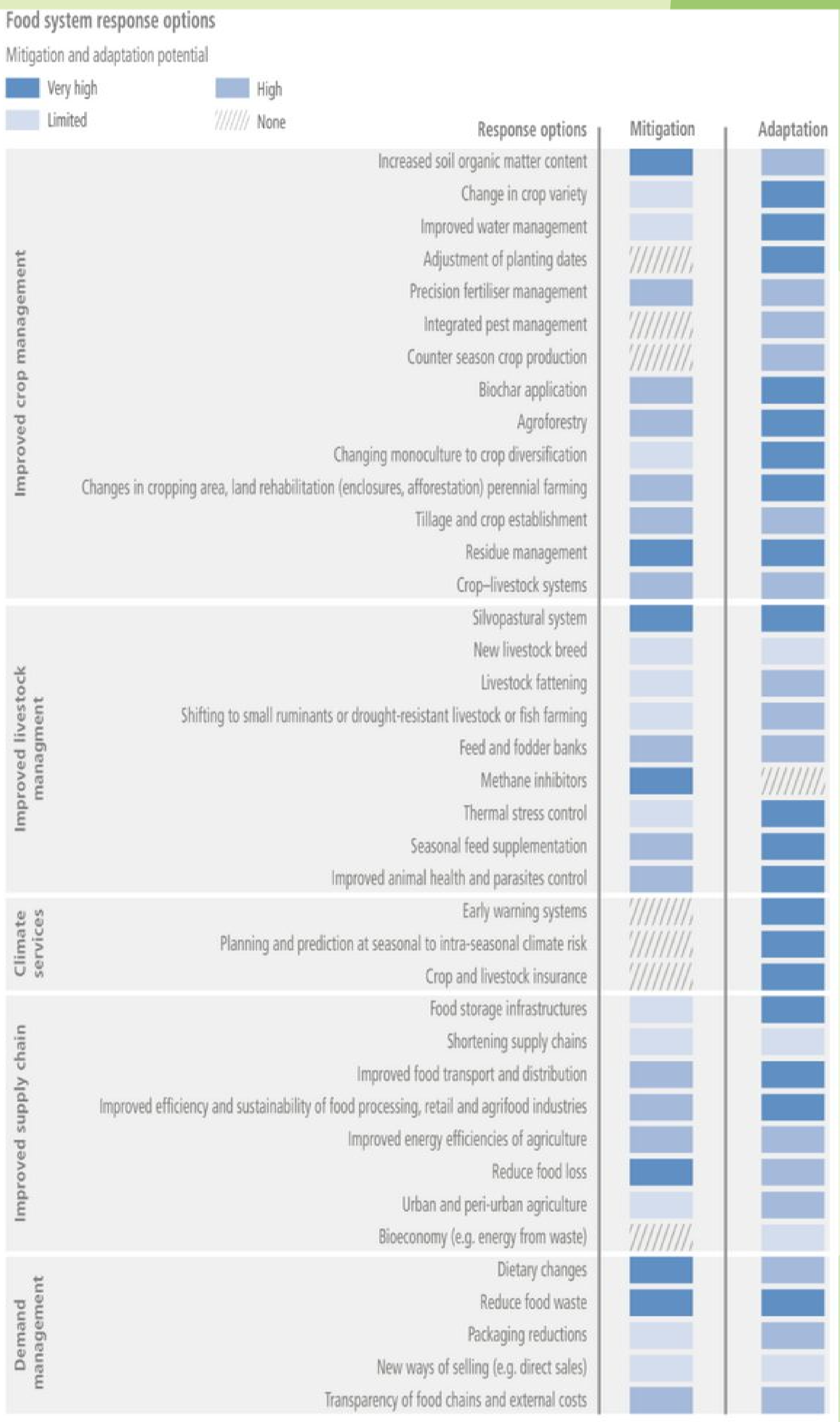


Figure 5.12 | Technical mitigation potential of changing diets by 2050 according to a range of scenarios examined in the literature. Estimates indicate technical potential only and include additional effects of carbon sequestration from land-sparing. Data without error bars are from one study only.



igure 5.13 | **Response options related to food system and their potential impacts on mitigation and adaptation.** Many response options offer significant

Relation of climate shocks to food price spikes

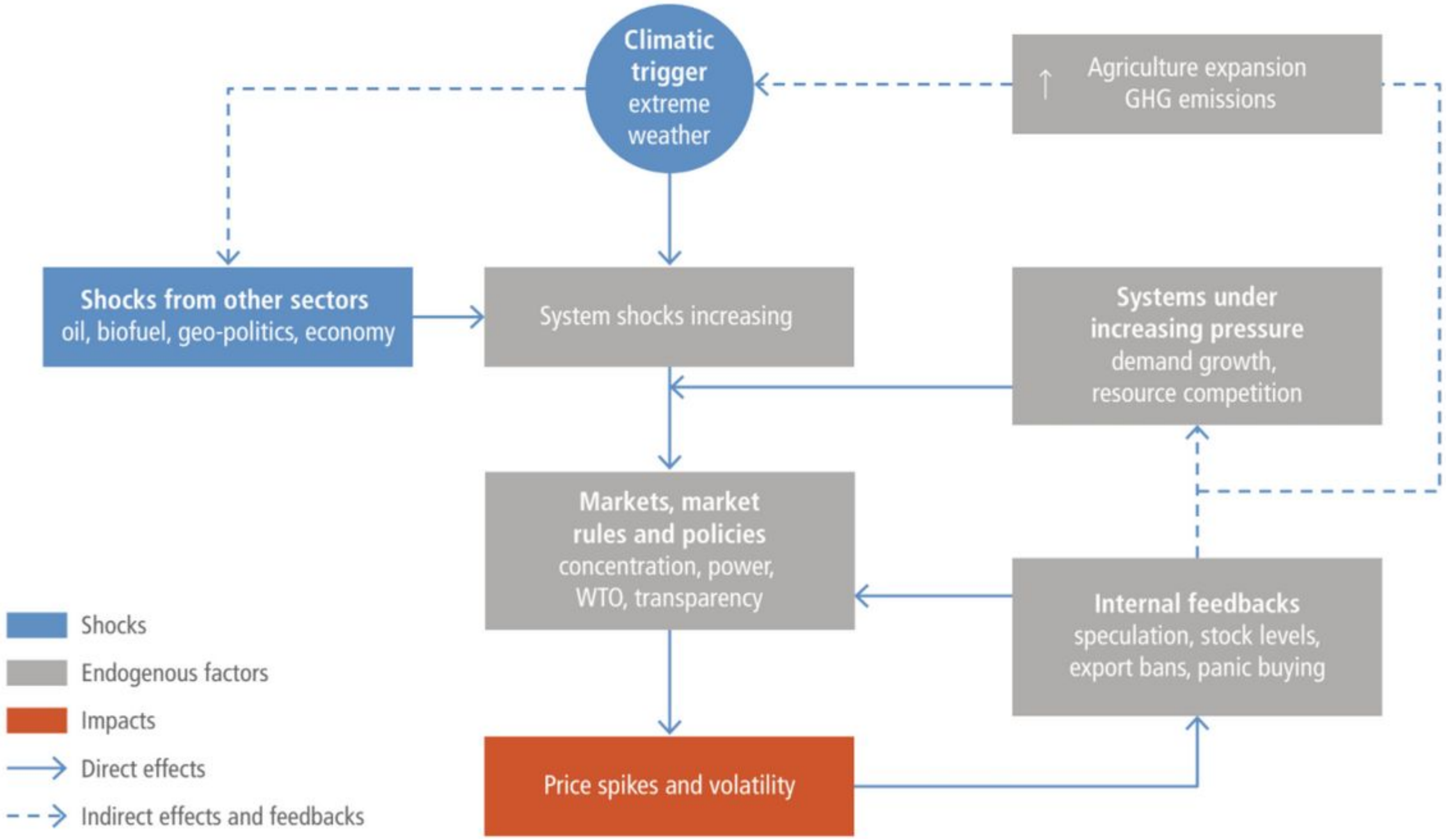


Figure 5.17 | Underlying processes that affect the development of a food price spike in agricultural commodity markets (Challinor et al. 2018).