Climate Change and Land

IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems

A. People, land and climate in a warming world.

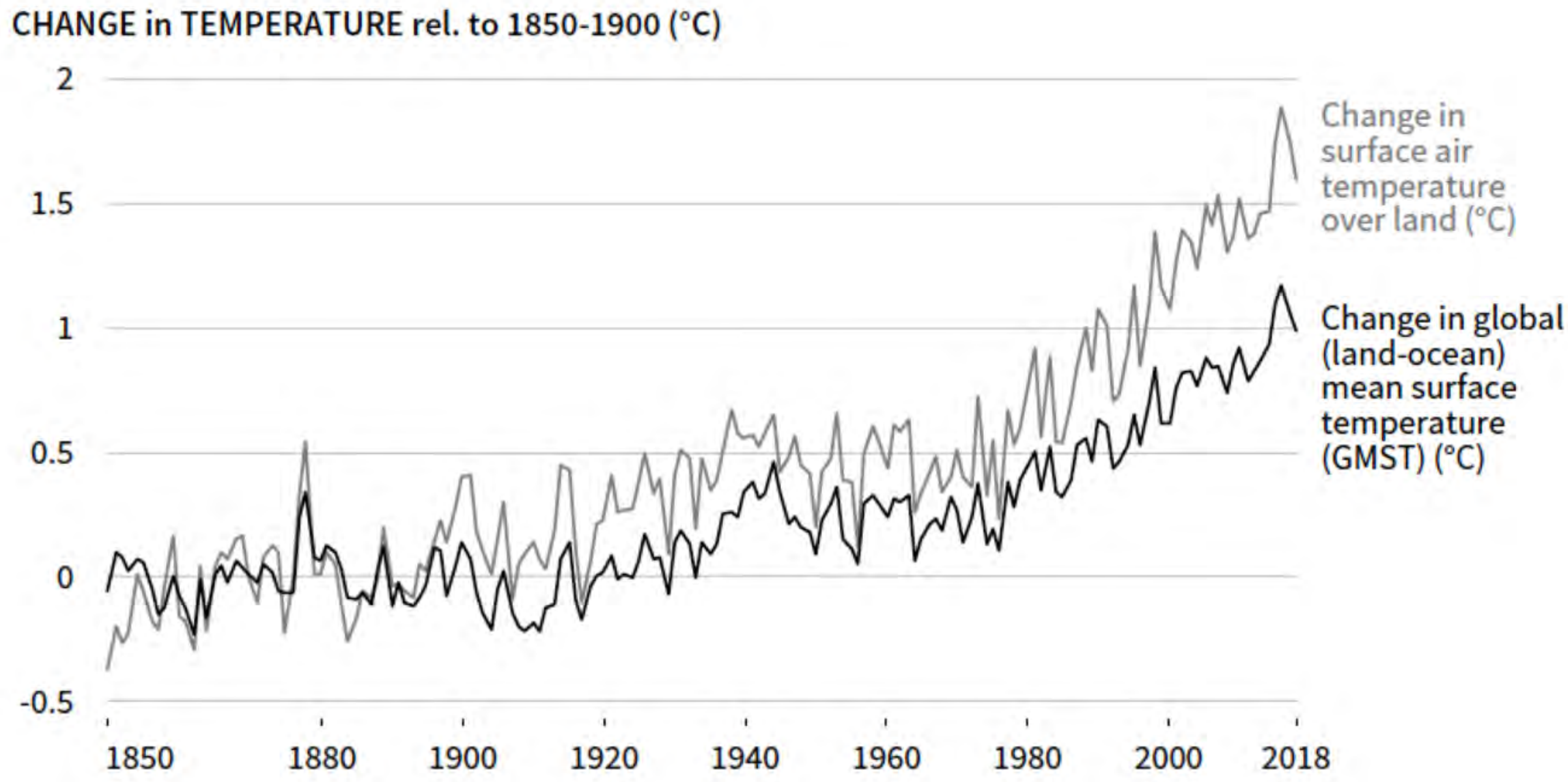
- **A 1. Land provides the principal basis for human livelihoods and well-being including the supply of food, freshwater and multiple other ecosystem services, as well as biodiversity. Human use directly affects more than 70% (*likely* 69-76%) of the global, ice- free land surface (*high confidence*). Land also plays an important role in the climate system.**

A 2. Since the pre-industrial period, the land surface air temperature has risen nearly twice as much as the global average temperature.

- **Climate change, including increases in frequency and intensity of extremes, has adversely impacted food security and terrestrial ecosystems as well as contributed to desertification and land degradation in many regions (*high confidence*).**

Observed temperature change relative to 1850-1900.

Since the pre-industrial period (1850-1900) the observed mean land surface air temperature has risen considerably more than the GMST (land and ocean)

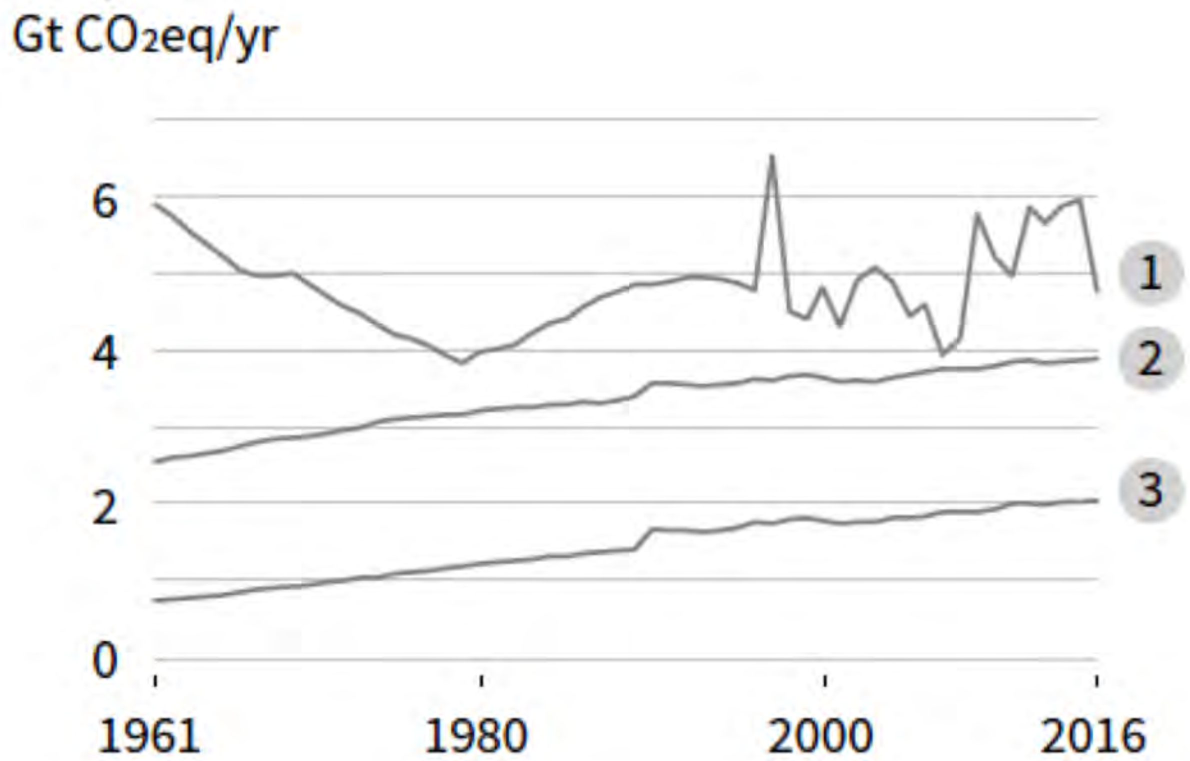


A 3. Agriculture, Forestry and Other Land Use (AFOLU) activities accounted for

- around 13% of CO_2, 44% of methane (CH_4), and 82% of nitrous oxide (N_2O) emissions from human activities globally during 2007-2016, representing 23% (12.0 +/- 3.0 $GtCO_2eq\ yr^{-1}$) of total net anthropogenic emissions of GHGs.

GHG emissions

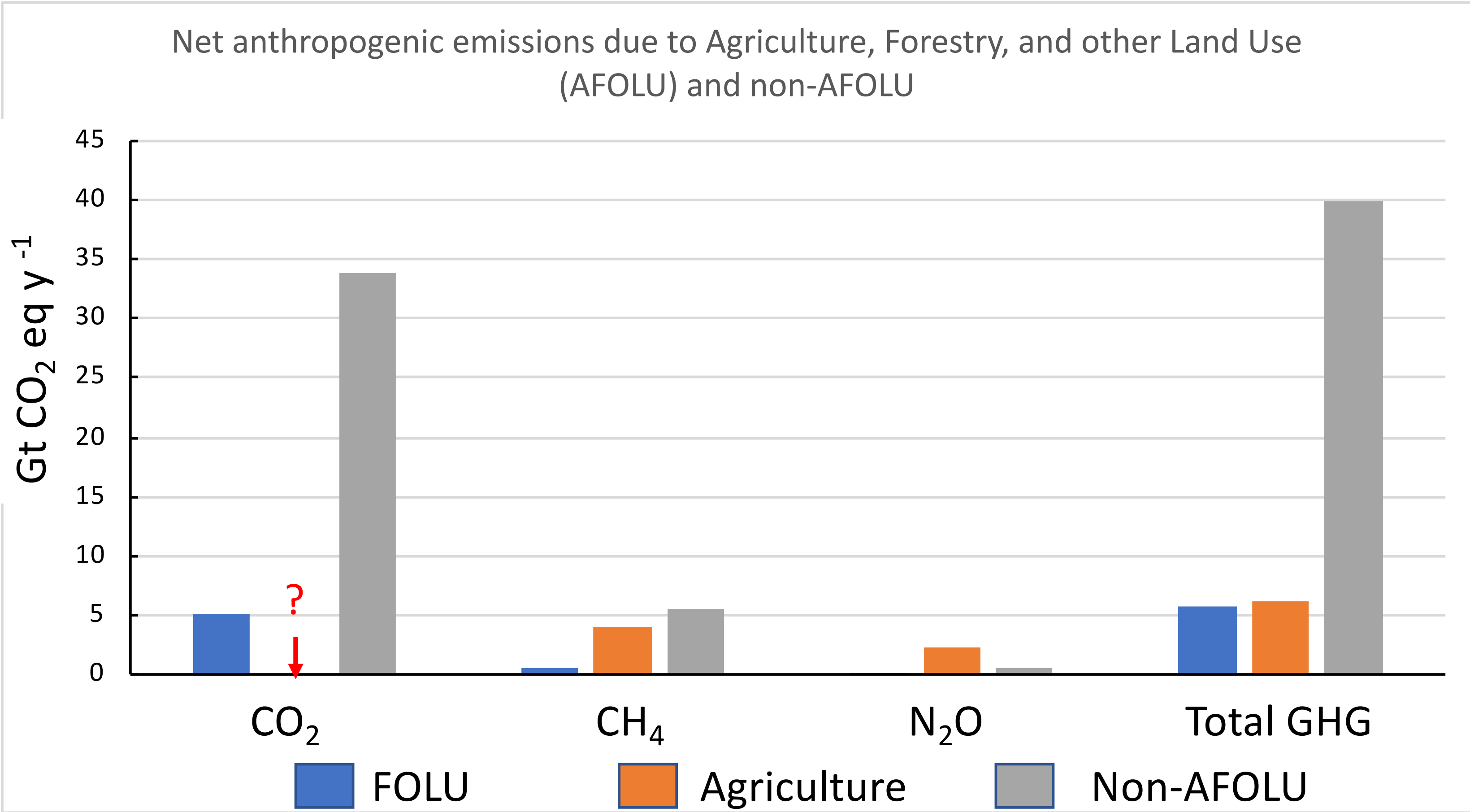
An estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).



Change in emissions relative to 1961.

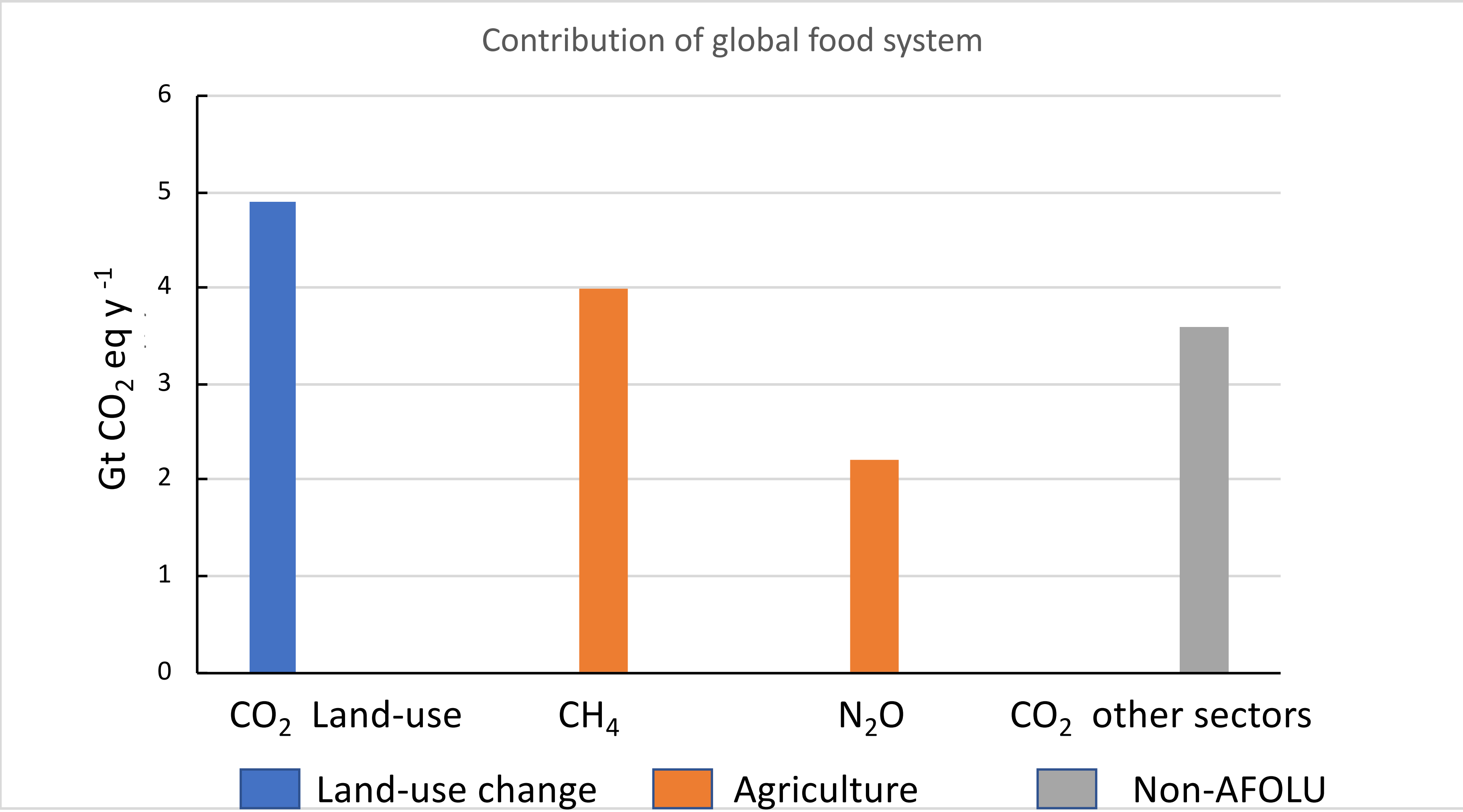
1. Net CO_2 emissions from FOLU (Agriculture is not included.)
2. CH_4 emissions from Agriculture
3. N_2O emissions from Agriculture

Net anthropogenic emissions due to Agriculture, Forestry and other Land Use and non-AFOLU



No global data are available for agricultural CO_2 emissions.

Various sources of CO_2 equivalent emissions in global food system.



A 4. Changes in land conditions, either from land-use or climate change, affect global and regional climate.

- At the regional scale, changing land conditions can reduce or accentuate warming and affect the intensity, frequency and duration of extreme events. The magnitude and direction of these changes vary with location and season.

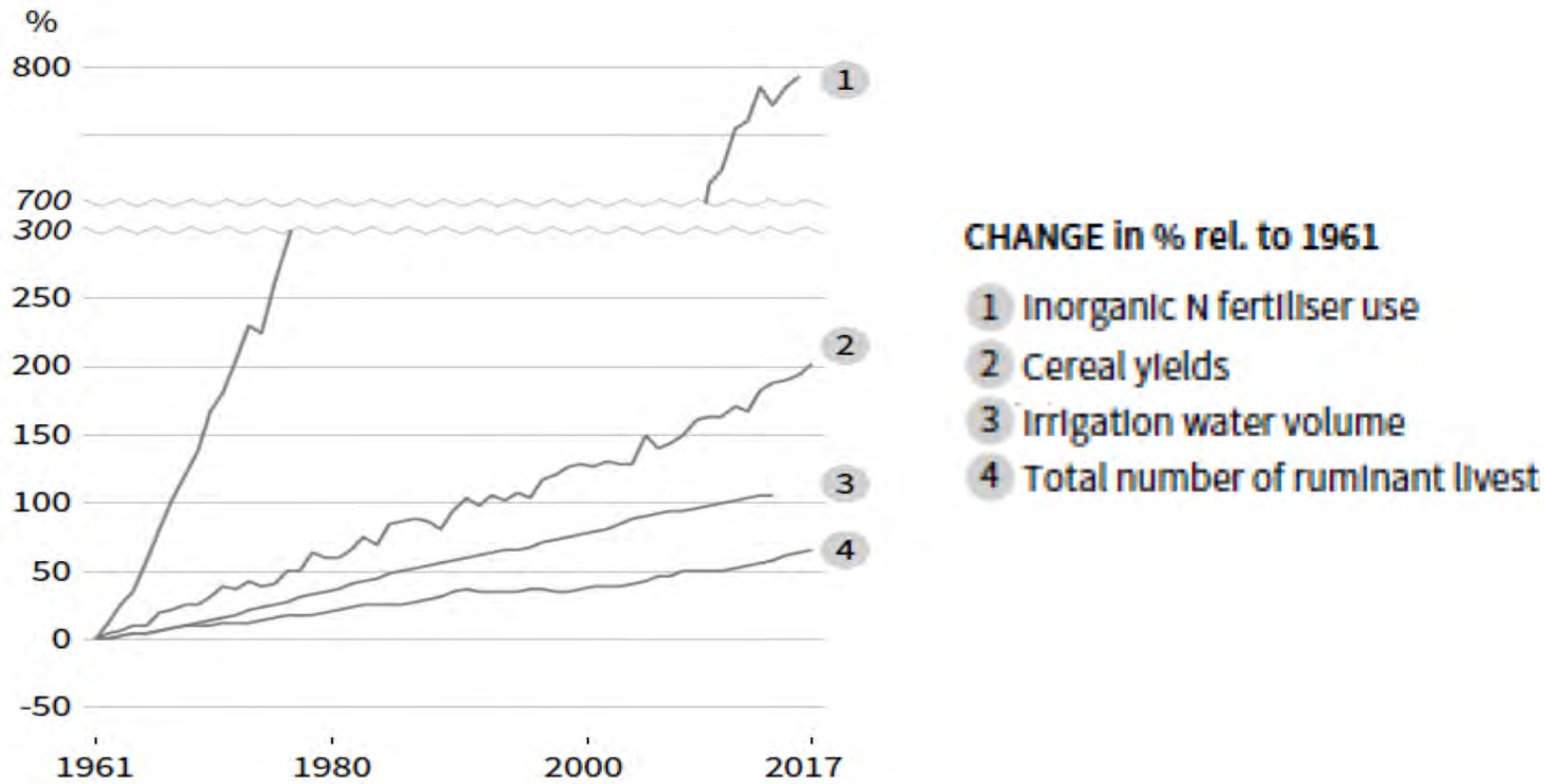
Global land use in circa 2015

Infrastructure 1%	Cropland 12% (12 – 14%)	Grassland 37% (30 – 47%)	Artificial Forest 22% (16 – 23%)	Unused Land 28% (24 – 31%)
Urban, Resident, Road 1%	Irrigated cropland 2%	Intensive pasture 2%	Plantation forests 2%	Unforested ecosystems 7%
	Non-irrigated 10%	Used savannahs and shrublands 16%	Forests managed for timber and others 20%	Intact or primary forests 9%
		粗放的な牧草地 19%		Others (barren, rock) 12%

This table depicts shares of different uses of the global, ice-free land area (130 Mkm^2). Columns are ordered along a gradient of decreasing land-use intensity from left to right.

Agricultural production

Land use change and rapid land use intensification have supported the increasing production of food, feed and fiber.

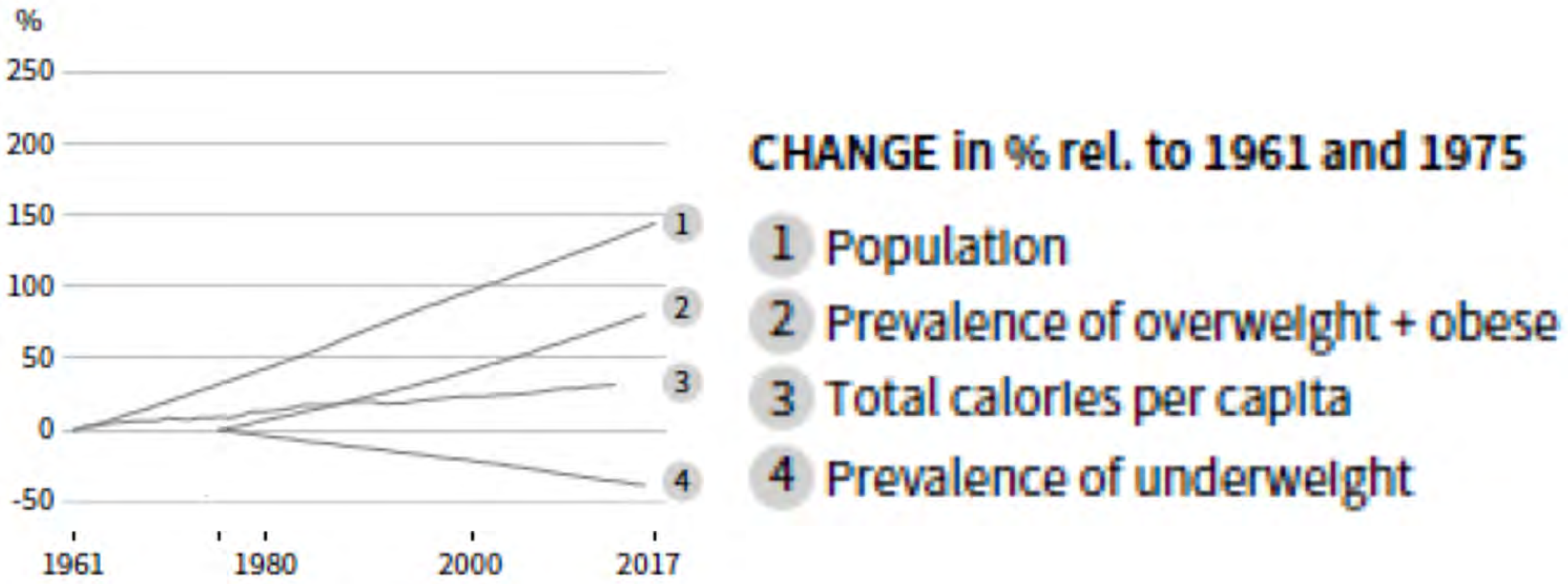


A 5. Climate change creates additional stresses on land, exacerbating existing risks to livelihoods, biodiversity, human and ecosystem health, infrastructure, and food systems.

- **Increasing impacts on land are projected under all future GHG emission scenarios. Some regions will face higher risks, while some regions will face risks previously not anticipated.**

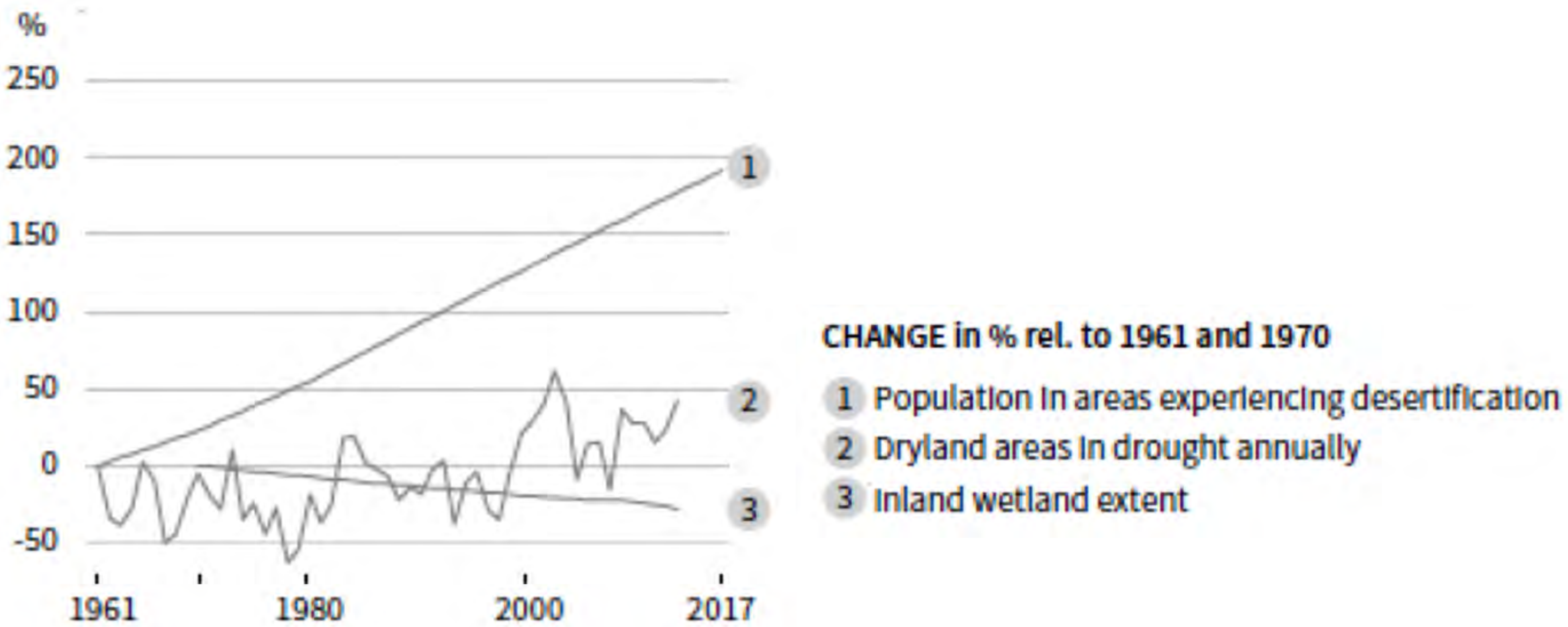
Food demand

Increases in production are linked to consumption changes.

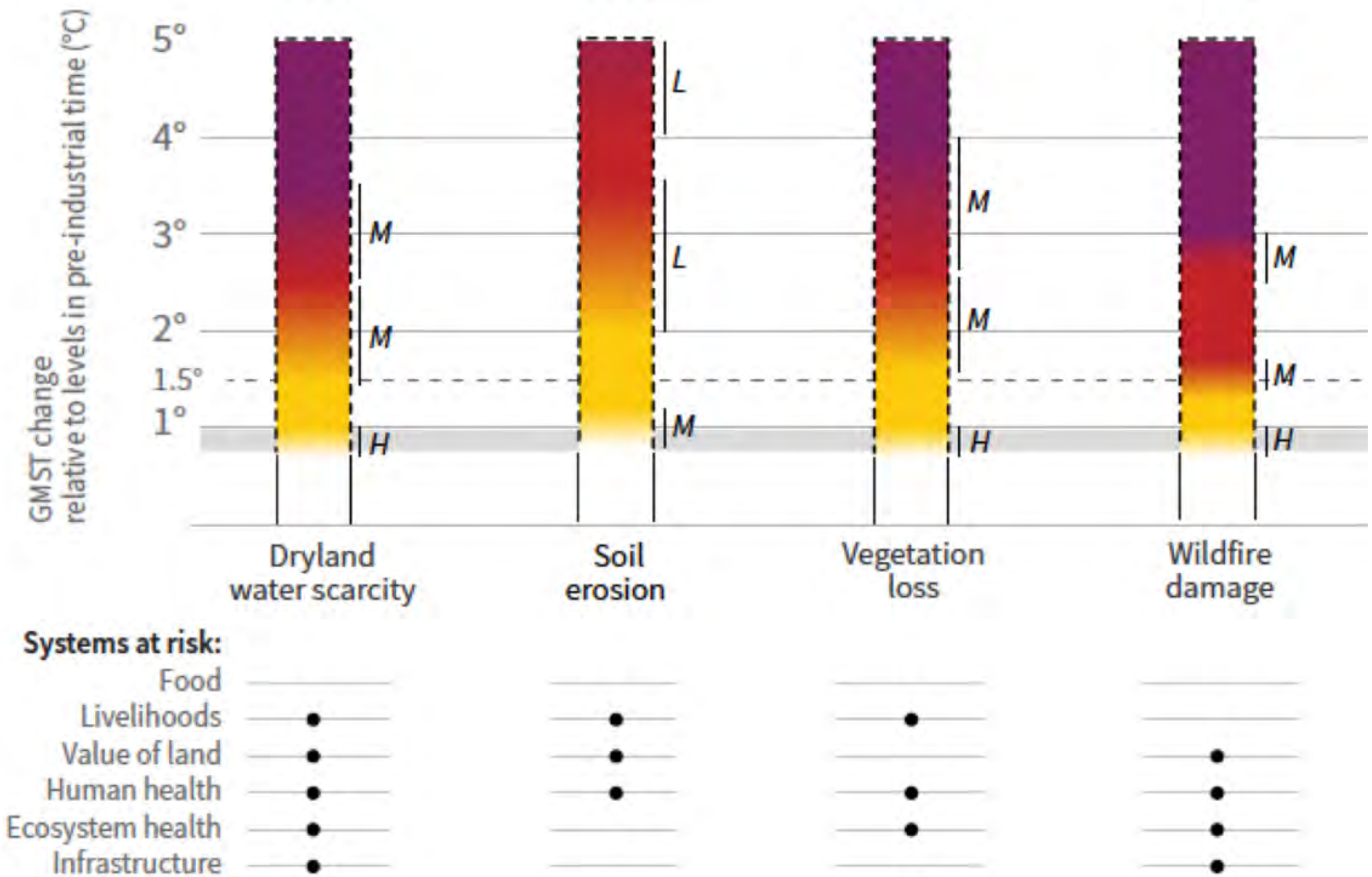


Desertification and land degradation.

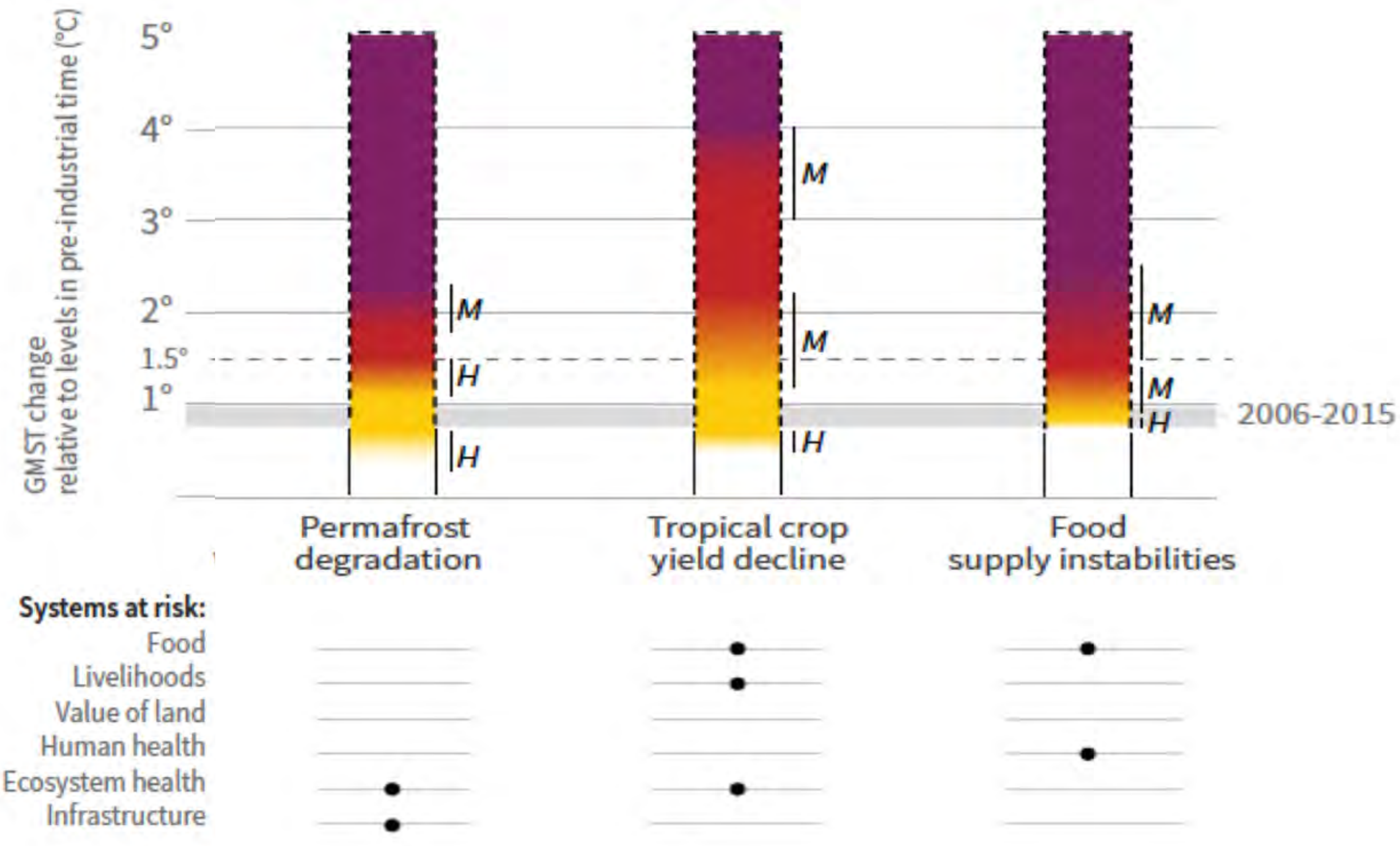
Land-use change, land-use intensification and climate change have contributed to desertification and land degradation.



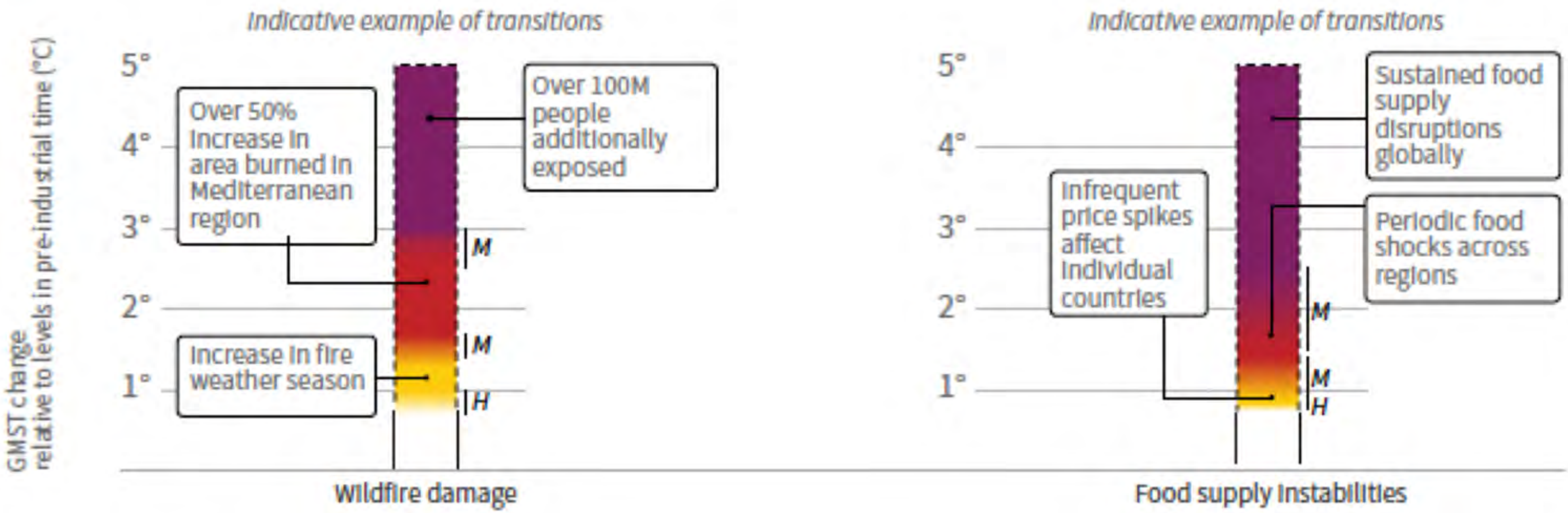
Risks to humans and ecosystems from changes in land-based processes as a result of climate change (1)



Risks to humans and ecosystems from changes in land-based processes as a result of climate change (2)



Risks to humans and ecosystems from changes in land-based processes as a result of climate change (3)



Response options based on land management in Agriculture

- Increased food productivity
- Agro-forestry
- Improved cropland management
- Improved livestock management
- Agricultural diversification
- Improved grazing land management
- Integrated water management
- Reduced grassland conversion to cropland

Response options based on land management in Forestry

- Forest management
- Reduced deforestation and forest degradation

Response options based on land management in Soils

- Increased soil organic carbon content
- Reduced soil erosion
- Reduced soil salinization
- Reduced soil compaction

Response options based on land management in Other Ecosystems

- Fire management
- Reduced landslides and natural hazards
- Reduced pollution including acidification
- Restoration & reduced conversion of coastal wetlands
- Restoration & reduced conversion of peatlands

Response options based on value chain management with respect to Demand

- Reduced post-harvest losses
- Dietary change
- Reduced food waste (consumer or retailer)

Response options based on value chain management with respect to Supply

- Sustainable sourcing
- Improved food processing and retailing
- Improved energy use in food systems

Response options based on risk management

- Livelihood diversification
- Management of urban sprawl
- Risk sharing instruments

Key for criteria for the impact of response options.

			Mitigation $GtCO_2$ eq yr^{-1}	Adaptation Million people	Desertification Million km^2	Land Degradation Million km^2	Food Security Million people
Positive		Large	3 <	25 <	3 <	3 <	100 <
		Moderate	0.3 - 3	1 - 25	0.5 - 3	0.5 - 3	1 - 100
		Small	0.3 >	1 >	0.5 >	0.5 >	1 >
		Negligible	No effect	No effect	No effect	No effect	No effect
Negative		Small	-0.3 <	-1 <	- 0.5 <	- 0.5 <	-1 <
		Moderate	-0.3 - -3	-1 - -25	-0.5 - -3	-0.5 - -3	-1 - -100
		Large	-3 >	- 25 >	-3 >	-3 >	-100 >

Confidence level：Indicates confidence in the estimate of magnitude category
H: High confidence, M: Medium confidence , L: Low confidence
Cost range：See technical caption for cost ranges in US \$ tCO_2e^{-1} or US \$ ha^{-1}.

Response options based on Land (Agriculture) and their effects.

Response options based on land management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Agriculture						
Increased food productivity	L	M	L	M	M	No data
Agro-forestry	M	M	M	M	L	Low
Improved cropland management	M	L	L	L	L	Medium
Improved livestock management	M	L	L	L	L	High
Agricultural diversification	L	L	L	M	L	Low
Improved grazing land management	M	L	L	L	L	No data
Integrated water management	L	L	L	L	L	Medium
Reduced grassland conversion to cropland	L	No data	L	L	L	Low

Response options based on Land (Forests and Soils) and their effects.

Response options based on land management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Forests						
Forest management	M	L	L	L	L	Medium
Reduced deforestation and forest degradation	H	L	L	L	L	Medium
Soils						
Increased soil organic carbon content	H	L	M	L	L	Medium
Reduced soil erosion	Variable L	L	M	M	L	Medium
Reduced soil salinization	No data	L	L	L	L	Medium
Reduced soil compaction	No data	L	No data	L	L	Low

Response options based on value chain management and their effects.

Response options based on value chain management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Demand						
Reduced post-harvest losses	H	M	L	L	H	No data
Dietary change	H	No data	L	H	H	No data
Reduced food waste (consumer or retailer)	H	No data	L	H	M	No data
Supply						
Sustainable sourcing	No data	L	No data	L	L	No data
Improved food processing and retailing	L	L	No data	No data	L	No data
Improved energy use in food systems	L	L	No data	No data	L	No data

Potential global contribution of response options to mitigation, adaptation, combating desertification and land degradation, and enhancing food security

- The first row (high level implementation) shows a quantitative assessment of implications for global implementation at scales delivering CO_2 removals of more than 3 $GtCO_2\ yr^{-1}$ using the magnitude thresholds shown in Panel A. The yellow colored cells indicate an increasing pressure but unquantified impact. For each option, the second row (best practice implementation) shows qualitative estimates of impact if implemented using best practices in appropriately managed landscape systems that allow for efficient and sustainable resource use and supported by appropriate governance mechanisms. In these qualitative assessments, green indicates a positive impact, grey indicates a neutral interaction.

Effects of Bioenergy and BECCS under different implementation contexts.

Bioenergy and BECCS (with carbon capture and storage)

Mitigation	Adaptation	Desertification	Land degradation	Food security	Cost
H	L			L	Low-High

High level: Impacts on adaptation, desertification, land degradation and food security are maximum potential impacts, assuming carbon dioxide removal by BECCS at a scale of 11.3 $GtCO_2\ yr^{-1}$ in 2050, and noting that bioenergy without CCS can also achieve emissions reductions of up to several $GtCO_2\ yr^{-1}$ when it is a low carbon energy source.

Mitigation	Adaptation	Desertification	Land degradation	Food security

Best practice: For example, limiting bioenergy production to marginal lands or abandoned cropland would have negligible effects on biodiversity, food security, and potentially co-benefits for land degradation; however, the benefits for mitigation could also be smaller.

Blue indicates a positive impact, while brown indicates a negative impact
Yellow colored cells indicate an increasing pressure but unquantified impact.
Green indicates a positive impact, grey indicates a neutral interaction.

Effects of Reforestation and forest restoration under different implementation contexts.

Reforestation and forest restoration

Mitigation	Adaptation	Desertification	Land degradation	Food security	Cost
M	M	M	M	M	Medium

High level: Impacts on adaptation, desertification, land degradation and food security are maximum potential impacts assuming implementation of reforestation and forest restoration (partly overlapping with afforestation) at a scale of 10.1 $GtCO_2\ yr^{-1}$ removal. Large-scale afforestation could cause increases in food prices of 80% by 2050.

Mitigation	Adaptation	Desertification	Land degradation	Food security

Best practice: There are co-benefits of reforestation and forest restoration in previously forested areas, assuming small scale deployment using native species and involving local stakeholders to provide a safety net for food security. Examples of sustainable implementation include, but are not limited to, reducing illegal logging and halting illegal forest loss in protected areas, reforesting and restoring forests in degraded and desertified lands.

Blue indicates a positive impact, while brown indicates a negative impact
Green indicates a positive impact, grey indicates a neutral interaction.

Effects of Afforestation under different implementation contexts.

Afforestation

Mitigation	Adaptation	Desertification	Land degradation	Food security	Cost
M	M	M	L	M	Medium

High level: Impacts of afforestation (partly overlapping with reforestation and forest restoration) at a scale of 8.9 $GtCO_2$ yr^{-1} removal. Large-scale afforestation could cause increases in food prices of 80% by 2050, and more general mitigation measures in the AFOLU sector can translate into a rise in undernourishment of 80–300 million people.

Mitigation	Adaptation	Desertification	Land degradation	Food security

Best practice: Afforestation is used to prevent desertification and to tackle land degradation. Forested land also offers benefits in terms of food supply, especially when forest is established on degraded land, mangroves, and other land that cannot be used for agriculture. For example, food from forests represents a safety-net during times of food and income insecurity.

Blue indicates a positive impact, while brown indicates a negative impact
Green indicates a positive impact, grey indicates a neutral interaction.

Effects of Biochar addition to soil under different implementation contexts.

Biochar addition to soil

Mitigation	Adaptation	Desertification	Land degradation	Food security	Cost
M	No data	No data	L	L	Medium

High level: Dedicated energy crops required for feedstock production could occupy 0.4–2.6 Mkm^2 of land, equivalent to around 20% of the global cropland area, which could potentially have a large effect on food security for up to 100 million people.

Mitigation	Adaptation	Desertification	Land degradation	Food security

Best practice: Abandoned cropland could be used to supply biomass for biochar, thus avoiding competition with food production; 5-9 Mkm^2 of land is estimated to be available for biomass production without compromising food security and biodiversity, considering marginal and degraded land and land released by pasture intensification.

Blue indicates a positive impact, while brown indicates a negative impact
Green indicates a positive impact, grey indicates a neutral interaction.

Shared Socioeconomic Pathways (SSP1)

- SSP1 includes a peak and decline in population (~7 billion in 2100), high income and reduced inequalities, effective land-use regulation, less resource intensive consumption, including food produced in low-GHG emission systems and lower food waste, free trade and environmentally-friendly technologies and lifestyles. Relative to other pathways, SSP1 has low challenges to mitigation and low challenges to adaptation (i.e., high adaptive capacity).

Shared Socioeconomic Pathways (SSP2)

- SSP2 includes medium population growth (~9 billion in 2100) , medium income; technological progress, production and consumption patterns are a continuation of past trends, and only gradual reduction in inequality occurs. Relative to other pathways, SSP2 has medium challenges to mitigation and medium challenges to adaptation (i.e., medium adaptive capacity).

Shared Socioeconomic Pathways (SSP3)

- SSP3 includes high population (~13 billion in 2100) , low income and continued inequalities, material-intensive consumption and production, barriers to trade, and slow rates of technological change. Relative to other pathways, SSP3 has high challenges to mitigation and high challenges to adaptation (i.e., low adaptive capacity).

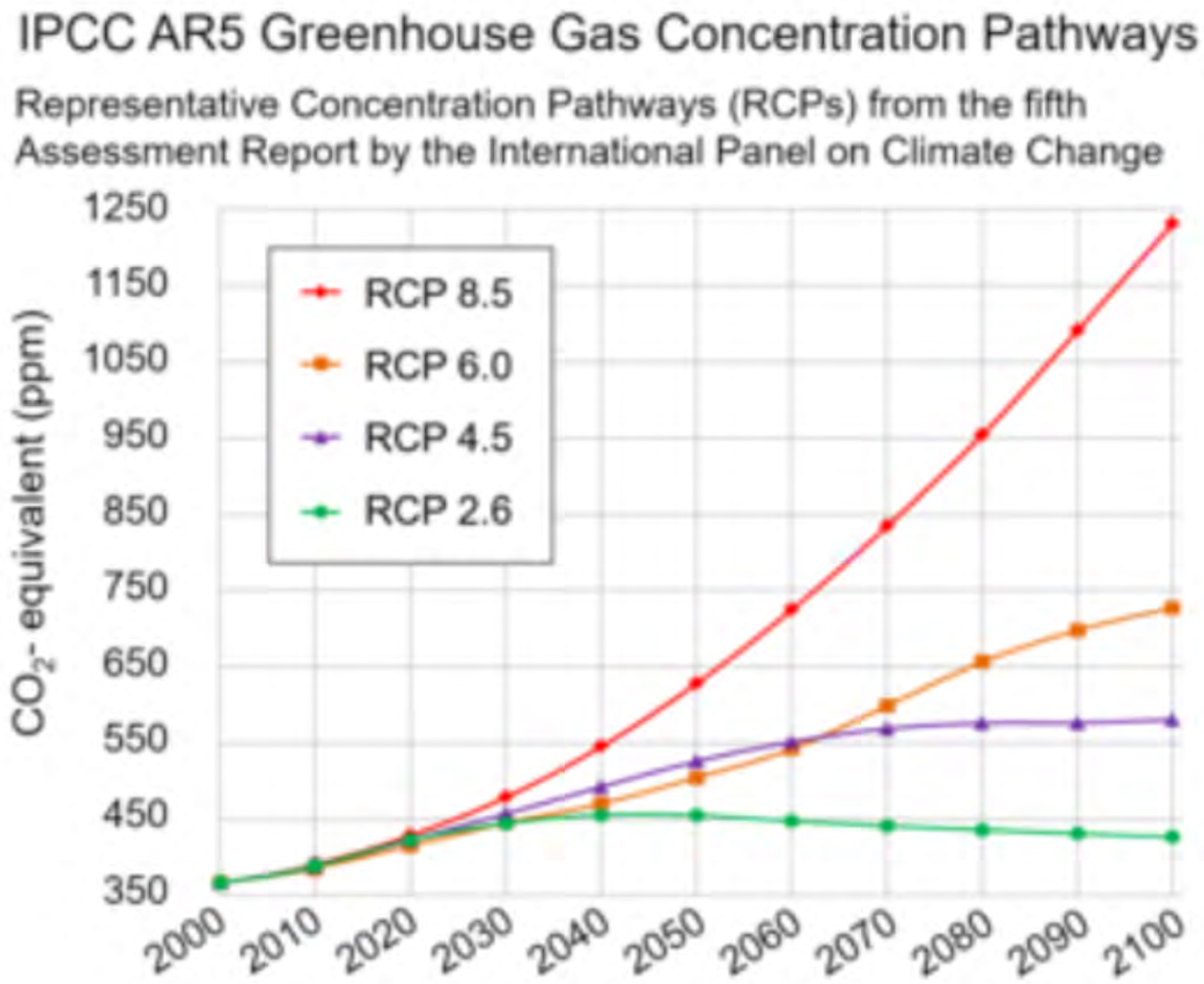
Shared Socioeconomic Pathways (SSP5)

- SSP5 includes a peak and decline in population (~7 billion in 2100) , high income, reduced inequalities, and free trade. This pathway includes resource-intensive production, consumption and lifestyles. Relative to other pathways, SSP5 has high challenges to mitigation, but low challenges to adaptation (i.e., high adaptive capacity).

RCP:

- Representative Concentration Pathways imply different levels of mitigation proposed at the fifth Assessment Report of IPCC, 2014.
- Representative Concentration Pathways (RCPs) are scenarios that include timeseries of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover.

RCPs are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0 and 8.5 W m^{-2}), respectively.



SSP-RCP combinations

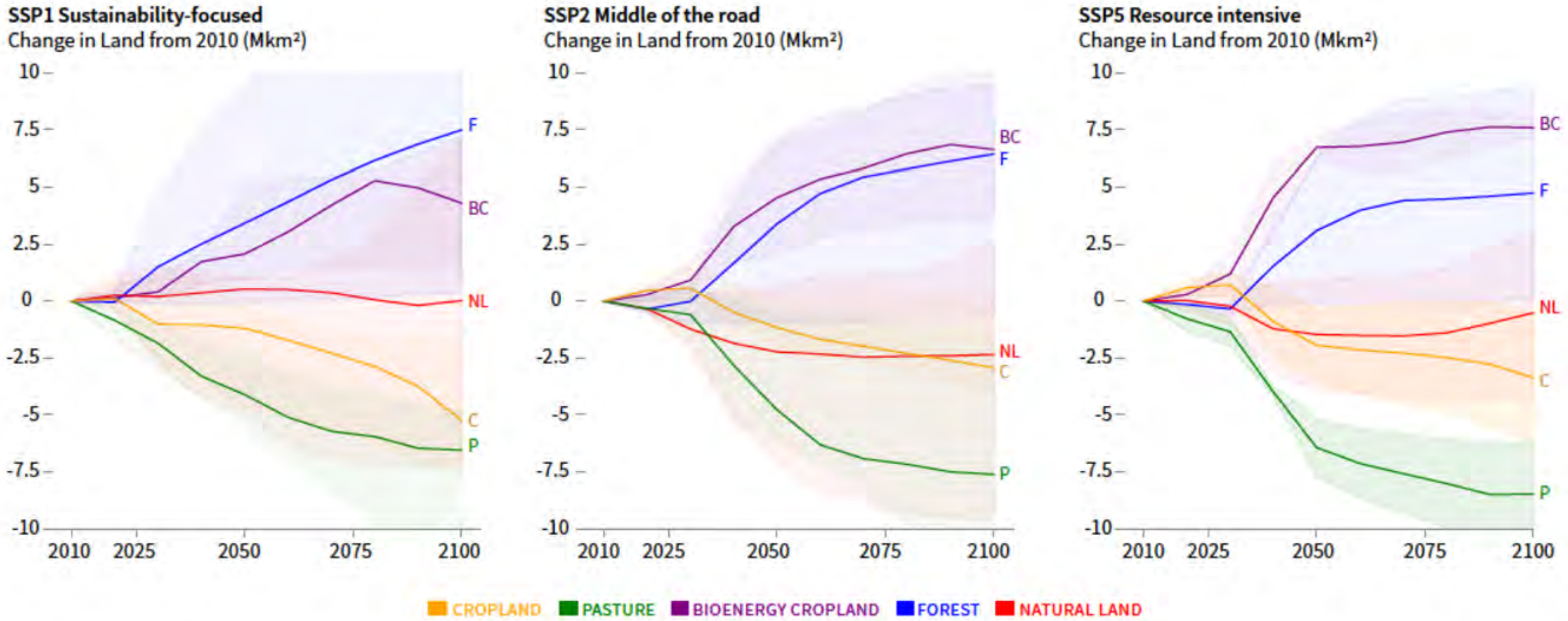
- The SSPs can be combined with Representative Concentration Pathways (RCPs) which imply different levels of mitigation, with implications for adaptation.
- Therefore, SSPs can be consistent with different levels of global mean surface temperature rise as projected by different SSP-RCP combinations.
- However, some SSP-RCP combinations are not possible; for instance RCP2.6 and lower levels of future global mean surface temperature rise (e.g., 1.5°C) are not possible in SSP3 in modelled pathways.

Pathways linking socioeconomic development, mitigation responses and land (SSP1, SSP2 and SSP5 at RCP1.9);

A. Sustainability-focused (SSP1)
Sustainability in land management, agricultural intensification, production and consumption patterns result in reduced need for agricultural land, despite increases in per capita food consumption. This land can instead be used for reforestation, afforestation, and bioenergy.

B. Middle of the road (SSP2)
Societal as well as technological development follows historical patterns. Increased demand for land mitigation options such as bioenergy, reduced deforestation or afforestation decreases availability of agricultural land for food, feed and fibre.

C. Resource intensive (SSP5)
Resource-intensive production and consumption patterns, results in high baseline emissions. Mitigation focuses on technological solutions including substantial bioenergy and BECCS . Intensification and competing land uses contribute to declines in agricultural land.

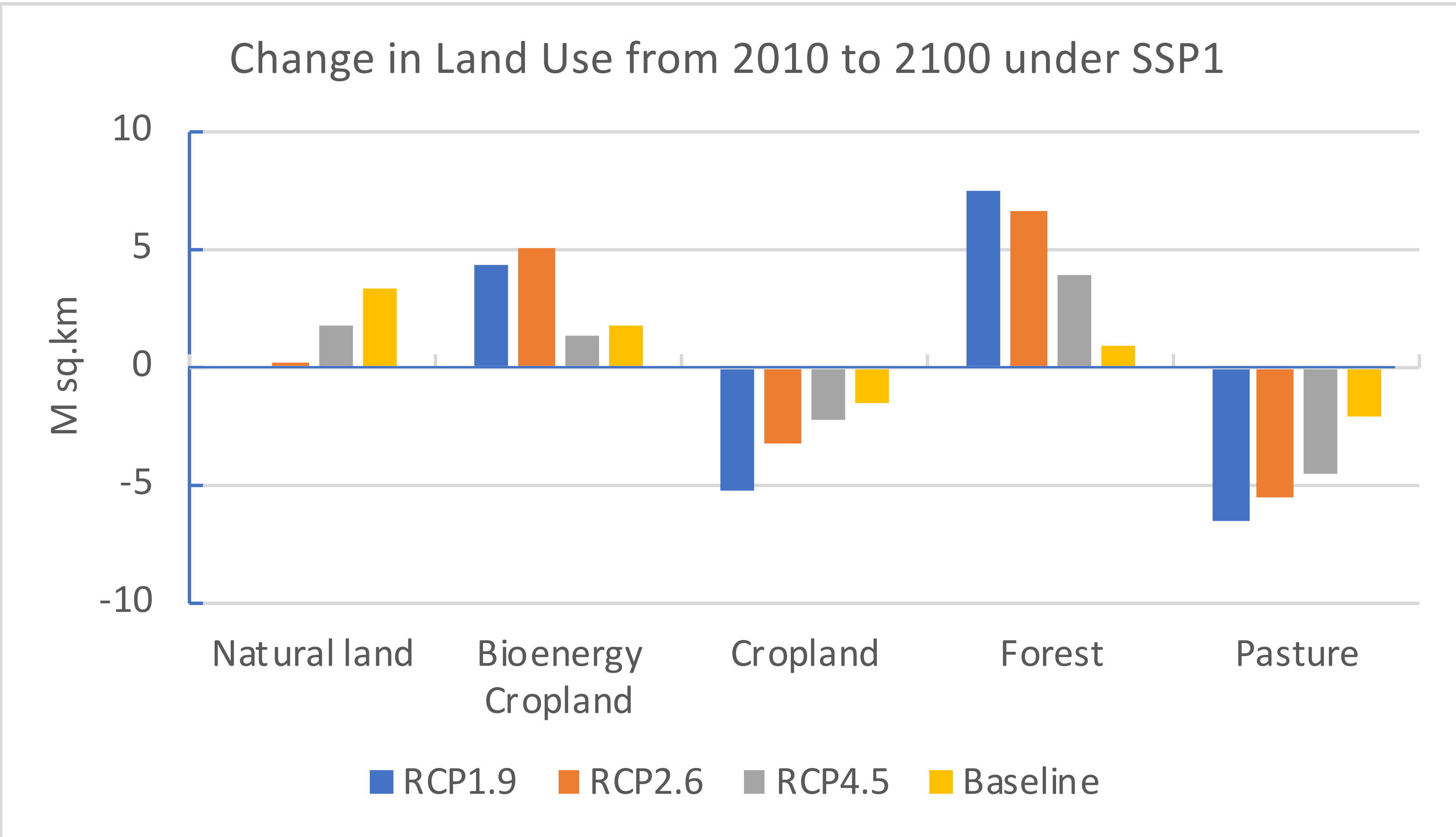


Land use and land cover change are indicated for various SSP-RCP combinations, showing multi-model median and range (min, max).

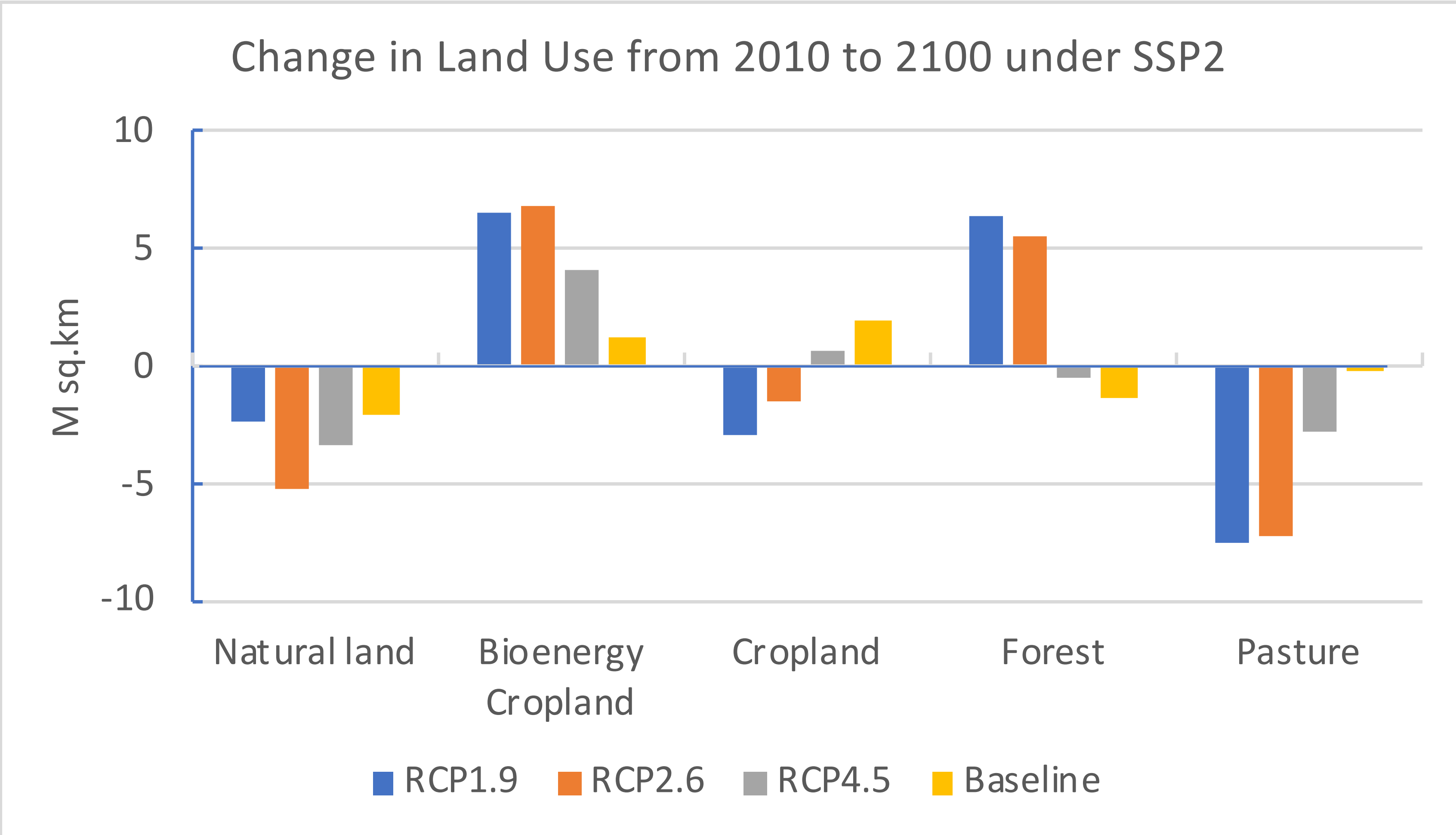
B. Land use and land cover change in the SSPs

	Quantitative indicators for the SSPs	Count of models included*	Change in Natural Land from 2010 Mkm²	Change in Bioenergy Cropland from 2010 Mkm²	Change in Cropland from 2010 Mkm²	Change in Forest from 2010 Mkm²	Change in Pasture from 2010 Mkm²
SSP1	**RCP1.9** in 2050	5/5	0.5 (-4.9, 1)	2.1 (0.9, 5)	-1.2 (-4.6, -0.3)	3.4 (-0.1, 9.4)	-4.1 (-5.6, -2.5)
	↳ 2100		0 (-7.3, 7.1)	4.3 (1.5, 7.2)	-5.2 (-7.6, -1.8)	7.5 (0.4, 15.8)	-6.5 (-12.2, -4.8)
	RCP2.6 in 2050	5/5	-0.9 (-2.2, 1.5)	1.3 (0.4, 1.9)	-1 (-4.7, 1)	2.6 (-0.1, 8.4)	-3 (-4, -2.4)
	↳ 2100		0.2 (-3.5, 1.1)	5.1 (1.6, 6.3)	-3.2 (-7.7, -1.8)	6.6 (-0.1, 10.5)	-5.5 (-9.9, -4.2)
	RCP4.5 in 2050	5/5	0.5 (-1, 1.7)	0.8 (0.5, 1.3)	0.1 (-3.2, 1.5)	0.6 (-0.7, 4.2)	-2.4 (-3.3, -0.9)
	↳ 2100		1.8 (-1.7, 6)	1.9 (1.4, 3.7)	-2.3 (-6.4, -1.6)	3.9 (0.2, 8.8)	-4.6 (-7.3, -2.7)
	Baseline in 2050	5/5	0.3 (-1.1, 1.8)	0.5 (0.2, 1.4)	0.2 (-1.6, 1.9)	-0.1 (-0.8, 1.1)	-1.5 (-2.9, -0.2)
	↳ 2100		3.3 (-0.3, 5.9)	1.8 (1.4, 2.4)	-1.5 (-5.7, -0.9)	0.9 (0.3, 3)	-2.1 (-7, 0)

Land use and land cover change are indicated for various SSP-RCP combinations. (SSP1)



Land use and land cover change are indicated for various SSP-RCP combinations. (SSP2)



Land use and land cover change are indicated for various SSP-RCP combinations. (SSP5)