Emission scenarios with Integrated Assessment Models and links with Earth System Models, 9-11th July 2024, Ispra, Italy

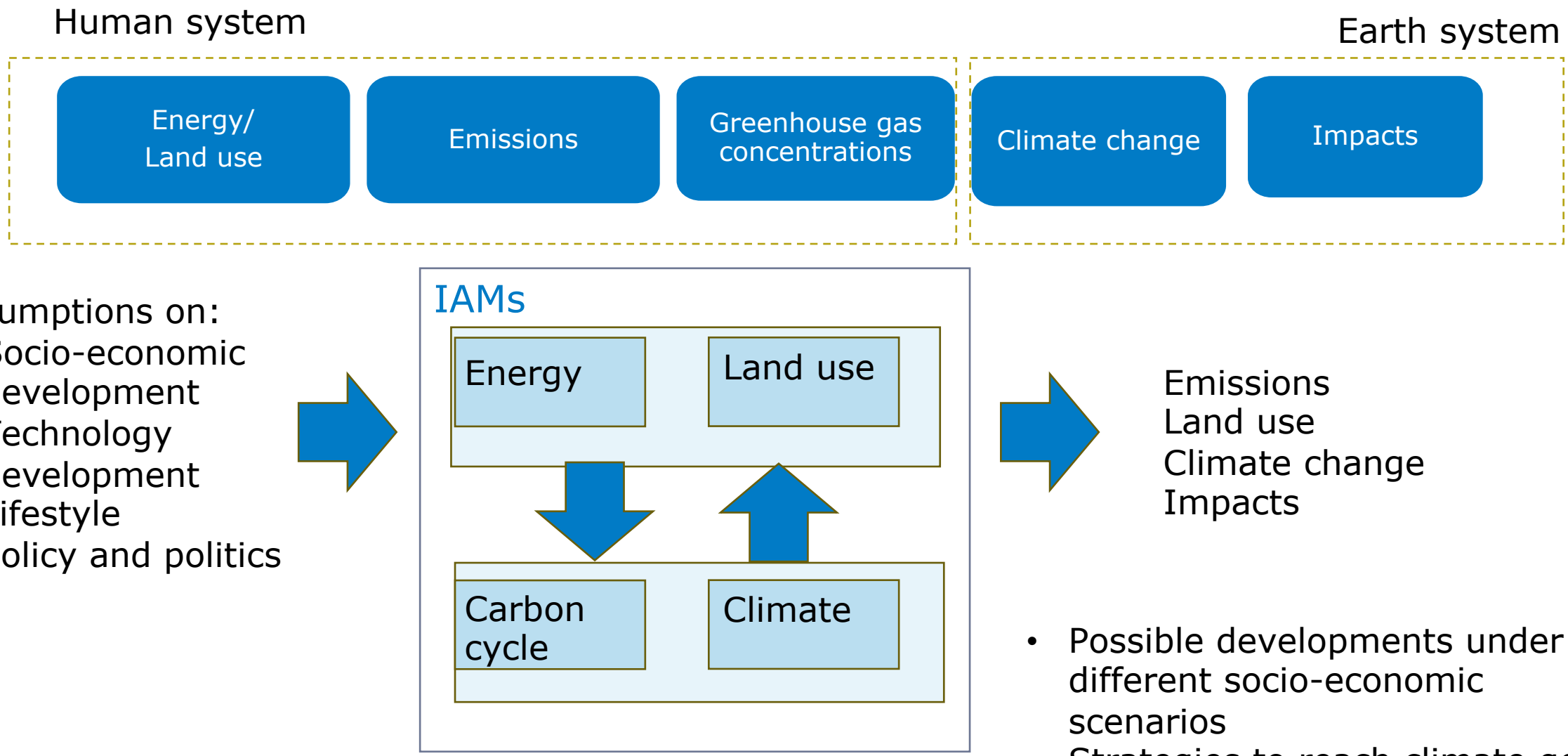
Detlef van Vuuren (PBL/UU), Thomas Gasser (IIASA), Elke Stehfest (

9 July 2024

INTERGOVERNMENTAL PANEL ON climate change

WMO

UN environment programme


Human system
Earth system
Energy/
Land use
Emissions
Greenhouse gas
concentrations
Climate change
Impacts
Assumptions on:
• Socio-economic development
• Technology development
• Lifestyle
• Policy and politics
IAMs
Energy
Land use
Carbon cycle
Climate
Emissions
Land use
Climate change
Impacts
• Possible developments under different socio-economic scenarios
• Strategies to reach climate goals
• Benefits/synergies with other goals

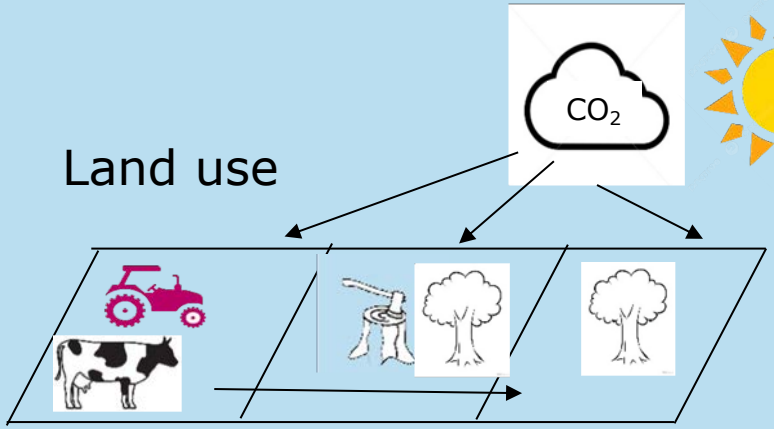
Land use

Demand for
- Food
- Timber
- Bio-energy
- Non-food crops
- Shelter

Production of
- Food
- Timber
- Bio-energy
- Non-food crops
- Urban area

Labour costs
Technology
Natural resources

Land use



Indirect impacts

Either grid or Delta function

Emission factors

Non-CO2 emissions

Land use change

CO2 emissions

Direct impacts

Typically calibrated to FAO

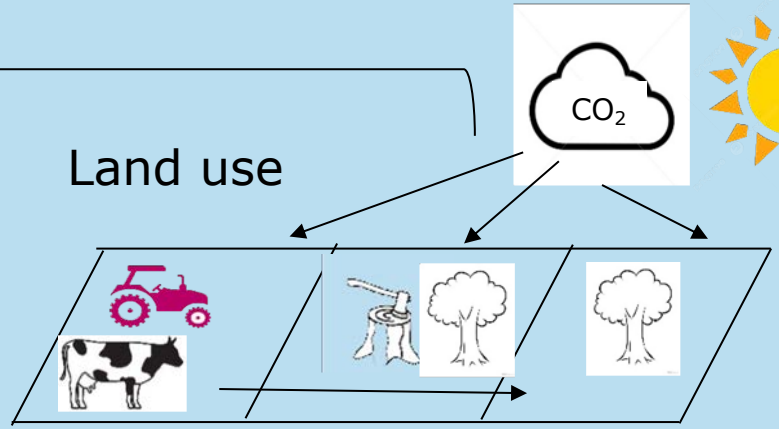
Land use

Demand for
- Food
- Timber
- Bio-energy
- Non-food crops
- Shelter

Production of
- Food
- Timber
- Bio-energy
- Non-food crops
- Urban area

Labour costs
Technology
Natural resources

Land use



Indirect impacts

Typically based on DGVMs

Either grid or Delta function

Emission factors

Non-CO2 emissions

Land use change

CO2 emissions

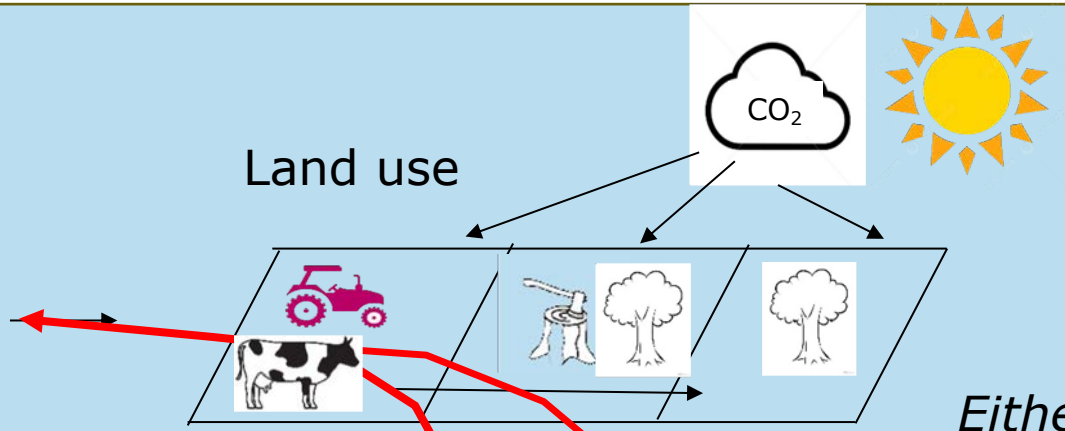
Direct impacts

Land use

Demand for
- Food
- Timber
- Bio-energy
- Non-food crops
- Shelter

Production of
- Food
- Timber
- Bio-energy
- Non-food crops
- Urban area

Labour costs
Technology
Natural resources



Either grid or Delta function

Emission factors

Non-CO2 emissions

Climate policy

Land use change

CO2 emissions

Climate policy

Land use

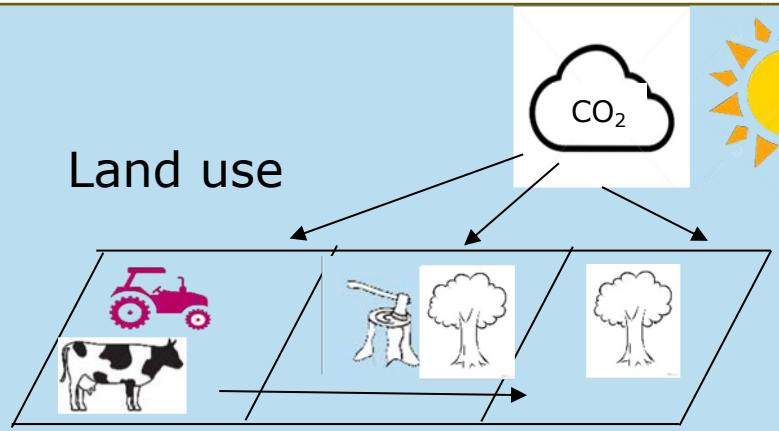
Demand for
- Food
- Timber
- Bio-energy
- Non-food crops
- Shelter

Production of
- Food
- Timber
- Bio-energy
- Non-food crops
- Urban area

Detail in representation

Labour costs
Technology
Natural resources

Land use



Are carbon densities are fixed

Forest management.

Either grid or Delta function

Emission factors

Non-CO2 emissions

Detail in representation

Land use change

CO2 emissions

Which carbon pools are considered?

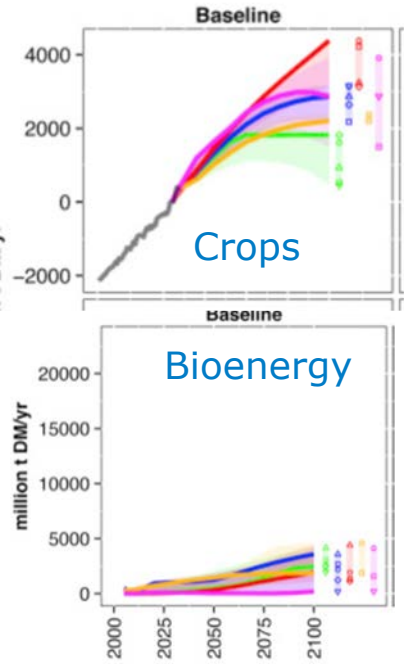
How carbon emissions are distributed over time?

Example of output (Popp et al., 2017)

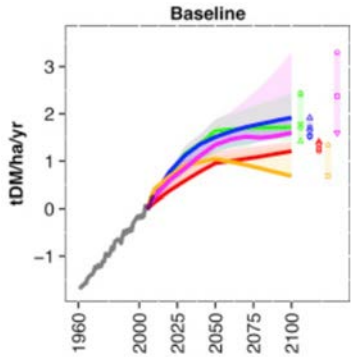
Global Environmental Change
Volume 42, January 2017, Pages 331-345
ELSEVIER

Land-use futures in the shared socio-economic pathways

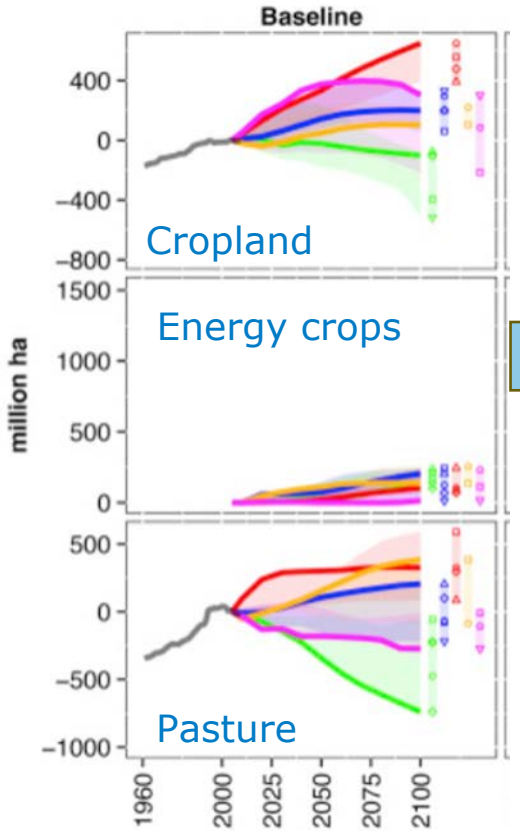
Demand



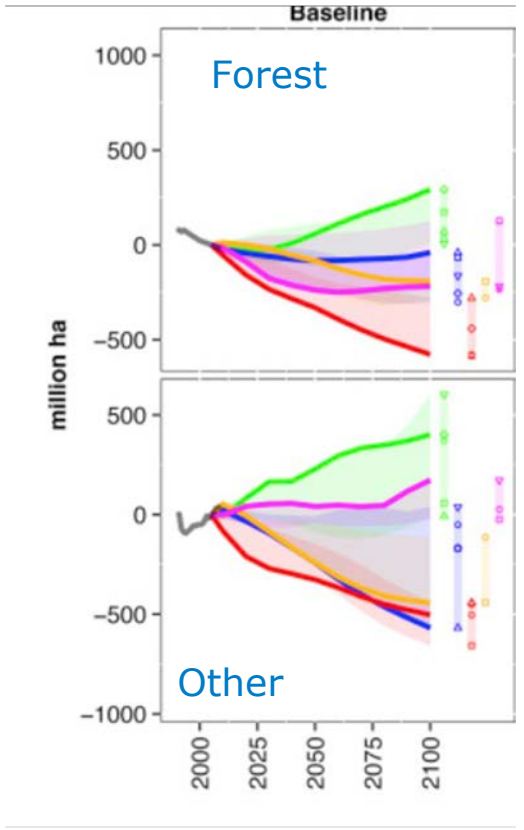
Yield



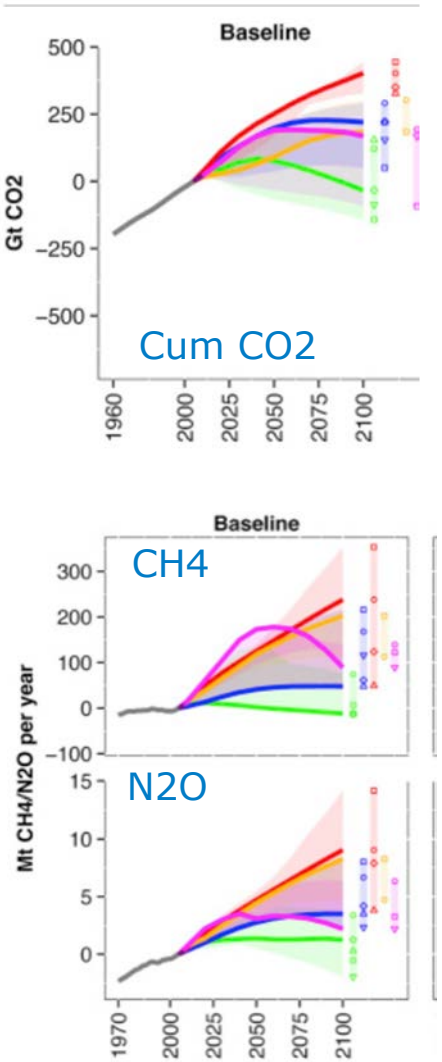
Agriculture area



Natural area



Emissions



Example of output (Popp et al., 2017)

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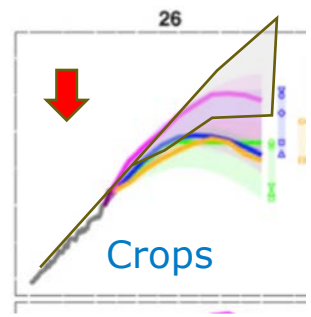
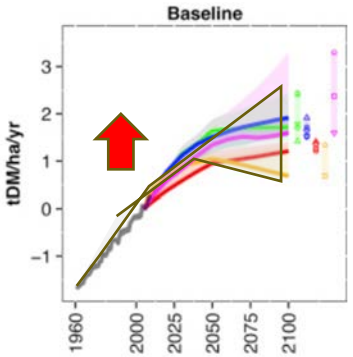
Land-use futures in the shared socio-economic pathways

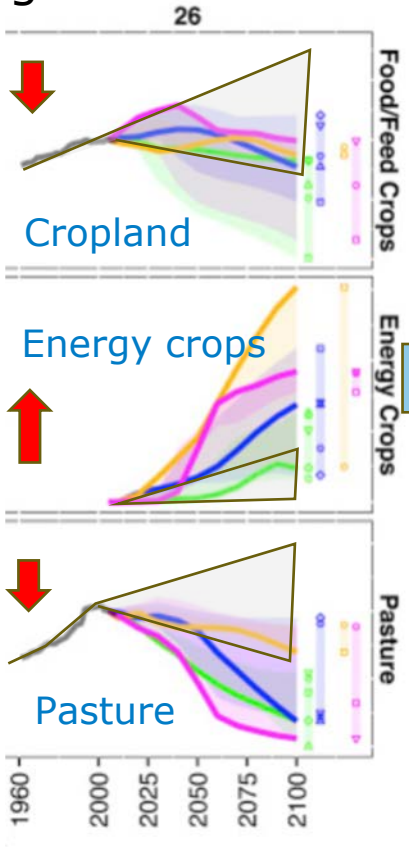
Demand



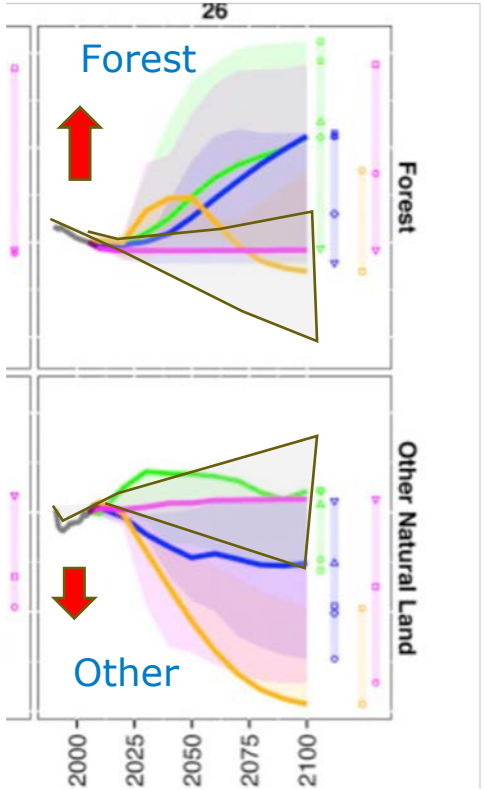
Yield



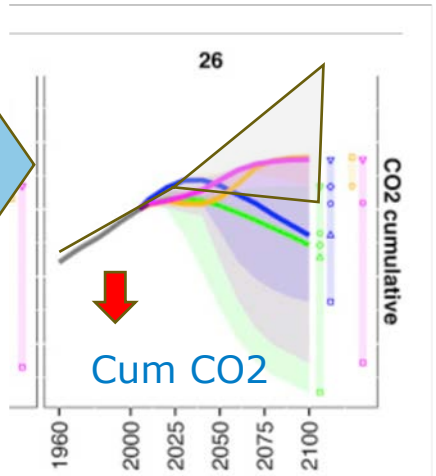
Agriculture area

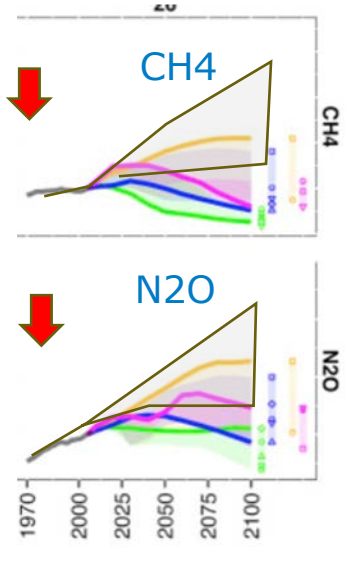


Natural area

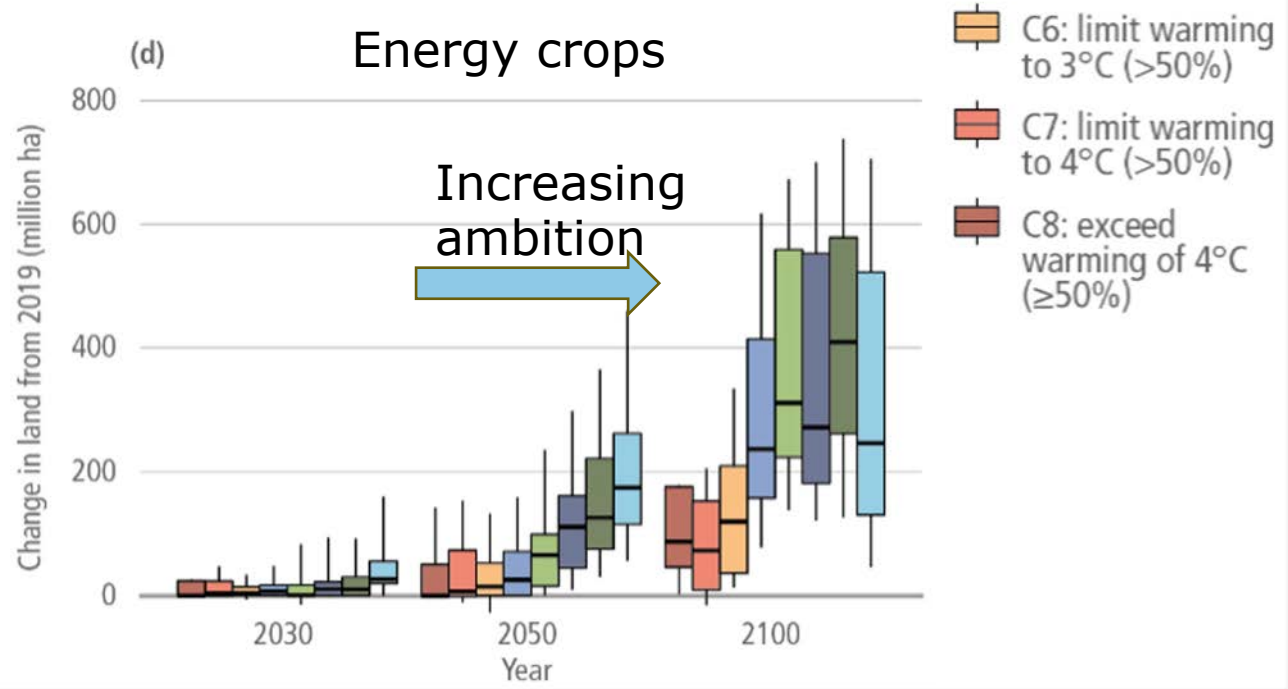


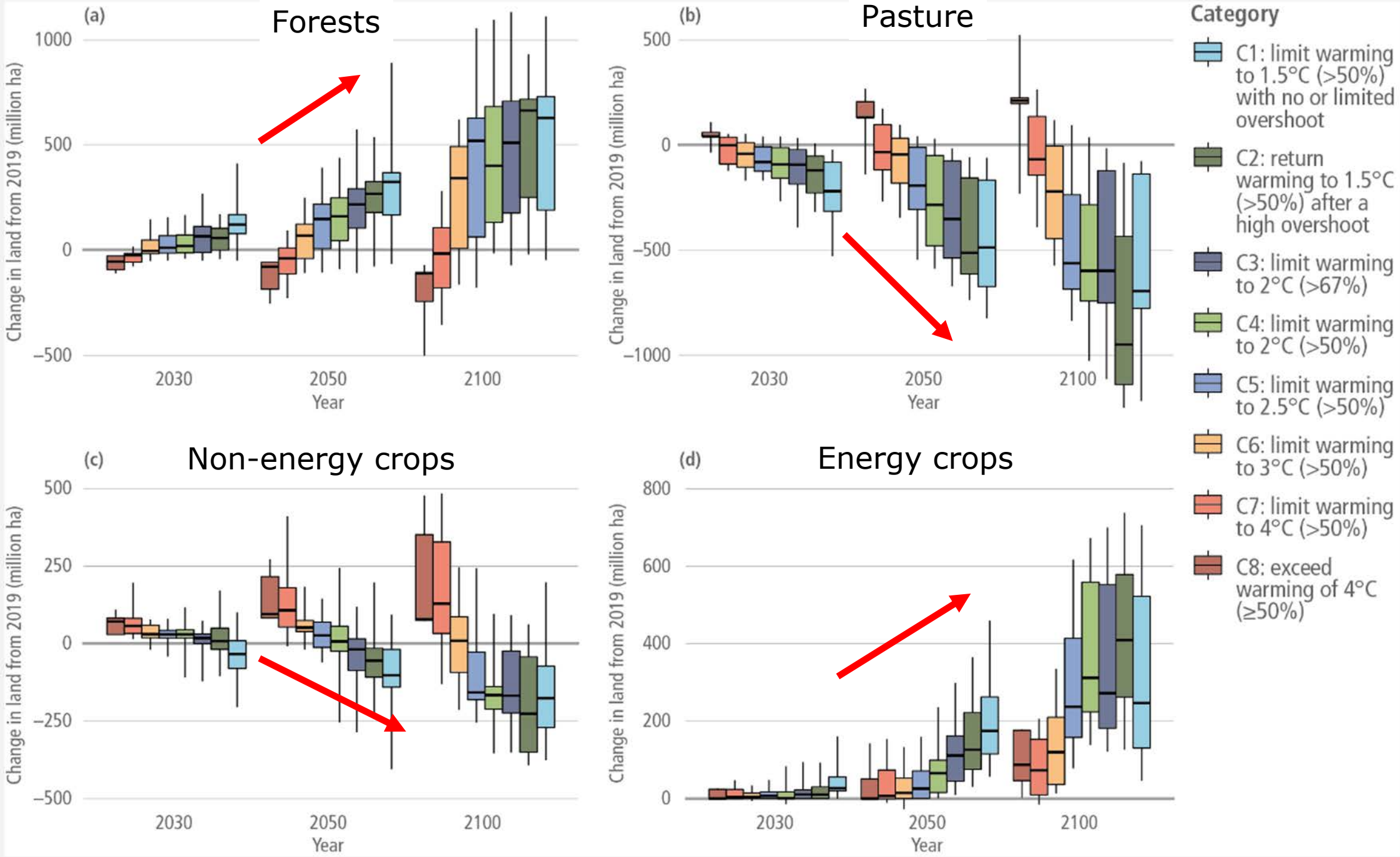
Emissions





IPCC AR6 WGIII Chapter 3




(a)
Forests
Change in land from 2019 (million ha)
1000
500
0
−500
2030
2050
2100
Year
(b)
Pasture
Change in land from 2019 (million ha)
500
0
−500
−1000
2030
2050
2100
Year
Category
C1: limit warming to 1.5°C (>50%) with no or limited overshoot
C2: return warming to 1.5°C (>50%) after a high overshoot
C3: limit warming to 2°C (>67%)
C4: limit warming to 2°C (>50%)
C5: limit warming to 2.5°C (>50%)
C6: limit warming to 3°C (>50%)
C7: limit warming to 4°C (>50%)
C8: exceed warming of 4°C (≥50%)
(c)
Non-energy crops
Change in land from 2019 (million ha)
500
250
0
−250
−500
2030
2050
2100
Year
(d)
Energy crops
Change in land from 2019 (million ha)
800
600
400
200
0
2030
2050
2100
Year

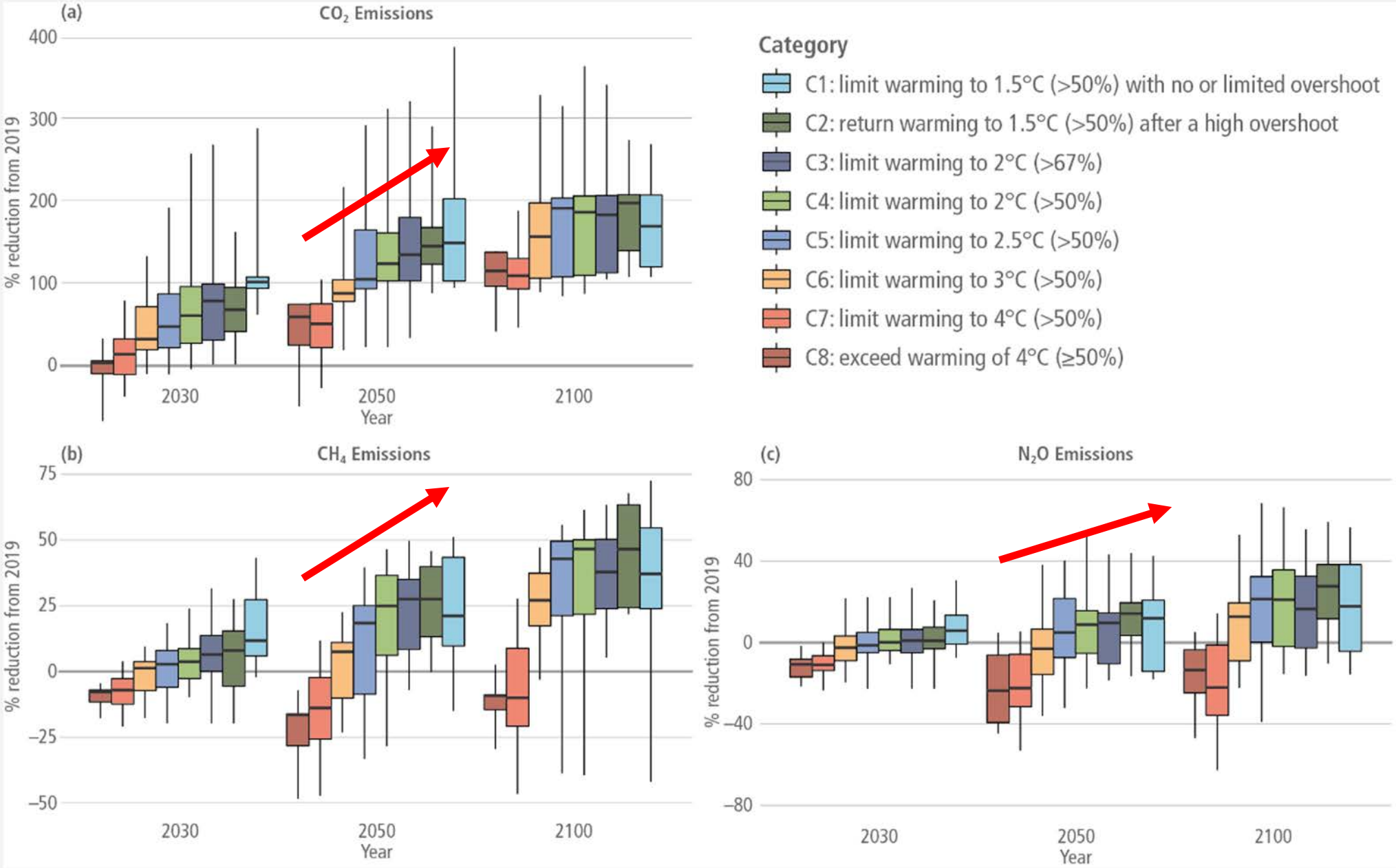
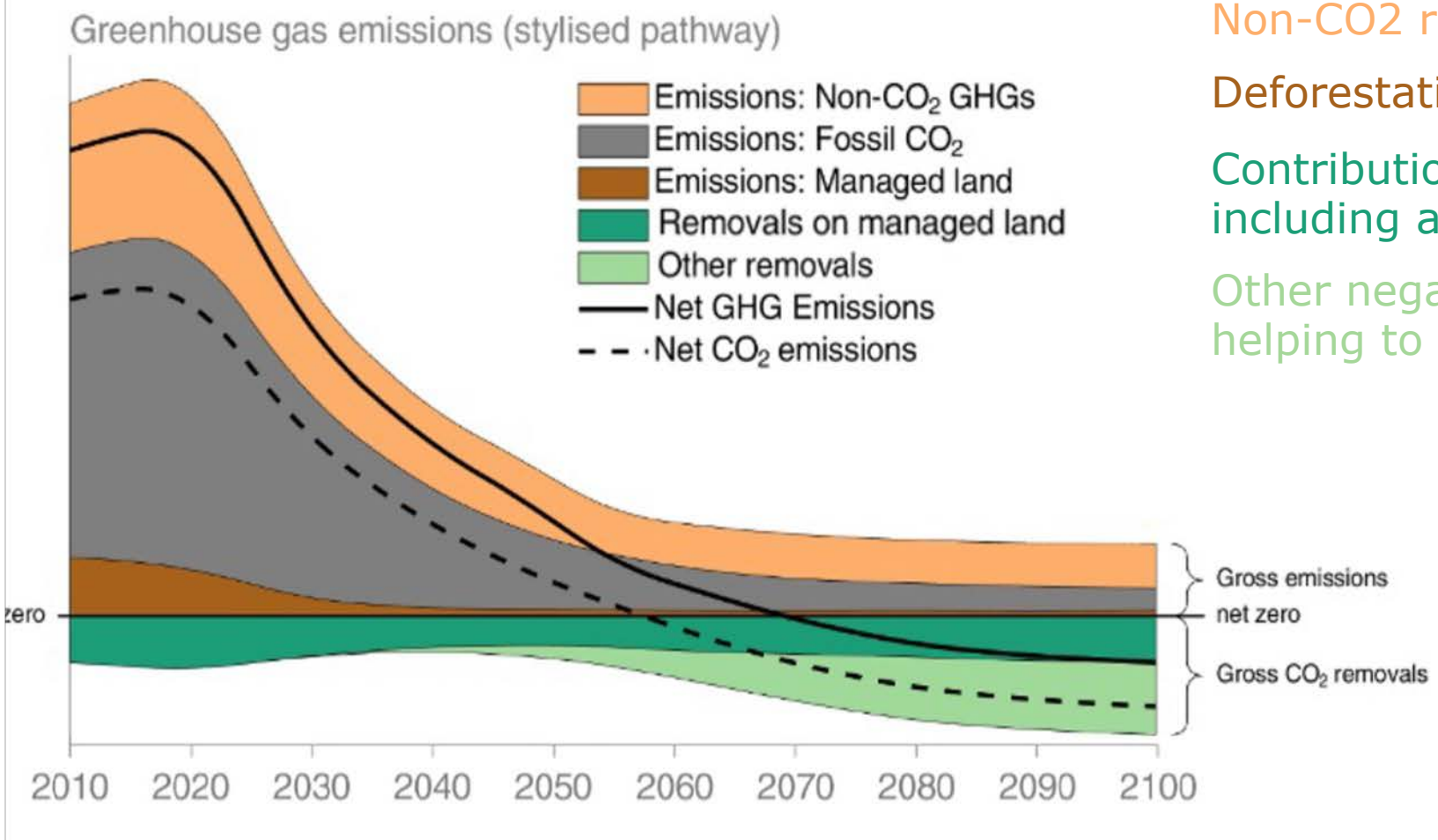


Figure 3.27 | Reduction in AFOLU GHG emissions from 2019. The AFOLU CO_2 estimates in this figure are not necessarily comparable with country GHG inventories (see Chapter 7).

Future mitigation role of land use



Fossil CO2 significantly reduced

Non-CO2 reduced

Deforestation halted

Contribution of managed land, including afforestation

Other negative emissions helping to go net negative

	AIM	GCAM	GLOBIOM	IMAGE	MAgPIE
Calculation level	17 regions nd 30'x30' grid	32 energy regions; 384 land use regions	37 regions and 30'x30' grid	26 regions + 5'x5' grid	12-16 regions, up to 2000 spatial units, downscaling to 30'x30' grid
Demand detail	7 crop types and 3 animal products;	24 crops: 7 animal commodities; Forest products, biomass for energy	18 crops, 8 animal products, finished & semi-fini forest products, biomass for energy	16 crop types and 5 animal product types, 5 bioenergy commodities; 4 wood products	16 food/feed crop types, 2 bioenergy crop types, 5 animal product types, 2 wood product types
Land use classes	Crop, intensive pasture, range-land, unmanaged forest, managed forest, natural land, build-up area and others.	Crops, Cellulosic biomass, Forest (managed and unmanaged), Pasture ; Grass, Shrubs, Desert (fixed), Rock/Ice/Tundra (fixed), Urban (fixed)	Cropland, grassland, short rot. plantations, managed forests, unmanaged forests, other natural vegetation land, urban (fixed), Rock/other (fixed)	Crop, intensive pasture, extensive pasture, managed forest; unmanaged forest, natural vegetation (14 biomes), built-up area, rock/other (fixed)	Crops, 2nd generation bioenergy crops, pasture and rangeland, timber plantations, re/afforestation, primary forest, secondary forest, other natural land, urban land
Forest management types	managed or unmanaged.	Managed and unmanaged, tree crops (softwood, hardwood)	short rotation plantations, managed forests	Clearcut, selective cut, forest plantations	Timber plantations with clear-cut after a certain rotation length. Selective harvest from natural forests.
Land-use change related CO2	Delta stock with fixed densities based on DGCM (VISIT). Instantaneous except sequestration (regrowth curve based on DGVM).	Delta stock with fixed densities. Instantaneous for above ground sources of CO2 except afforestation (regrowth curve), but below ground gets emitted with a decay rate.	Delta stock with fixed densities. Instantaneous except afforestation (regrowth curve).	LPJml calculates all stocks and flows, for natural vegetation dynamics, and land use transitions. After a transition, net flux assumed anthropogenic for a number of years, then natural.	Carbon stocks based on LPJml (input data) are used to calculate annual emissions. Emissions include both direct anthropogenic and indirect natural / environmental effects.
CO2 stocks included	Vegetation, litter and soil carbon	Biomass and soil	above- and below ground biomass changes, dead organic matter, soil carbon	LPJmL's carbon pools: Vegetation, litter and soil carbon (divided in different stocks)	vegetation, litter and soil carbon
Non-CO2	Activity and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) for different mgmt. systems in combination with MAC curves (explicit mitigation technologies)	Activity levels and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) in combination with MAC curves

	AIM	GCAM	GLOBIOM	IMAGE	MAgPIE
Calculation level	17 regions nd 30'x30' grid	32 energy regions; 384 land use regions	37 regions and 30'x30' grid	26 regions + 5'x5' grid	12-16 regions, up to 2000 spatial units, downscaling to 30'x30' grid
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Land use classes	Crop, intensive pasture, range-land, unmanaged forest, managed forest, natural land, build-up area and others.	Crops, Cellul… Forest (man… unmanaged), Pasture ; Grass, S… (fixed), … (fixed), …	forests, unmanaged forests,	pasture, …ure, managed forest; unmanaged forest,	Crops, 2nd generation bioenergy crops, pasture and rangeland, timber …antations, re/afforestation, …imary forest, secondary …rest, other natural land, …ban land
Forest management types	managed or unmanaged.	Manage… tree crops (softwood, hardwood)	managed forests	plantations	…mber plantations with clear-cut after a certain rotation length. Selective harvest from natural forests.
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CO2 stocks included	Vegetation, litter and soil carbon	Bioma…			vegetation, litter and soil carbon
Non-CO2	Activity and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) for different mgmt. systems in combination with MAC curves (explicit mitigation technologies)	Activity levels and emission factors (CH4, N2O) in combination with MAC curves	Activity and emission factors (CH4, N2O) in combination with MAC curves

Differences in resolution

Differences in presentation of economic processes

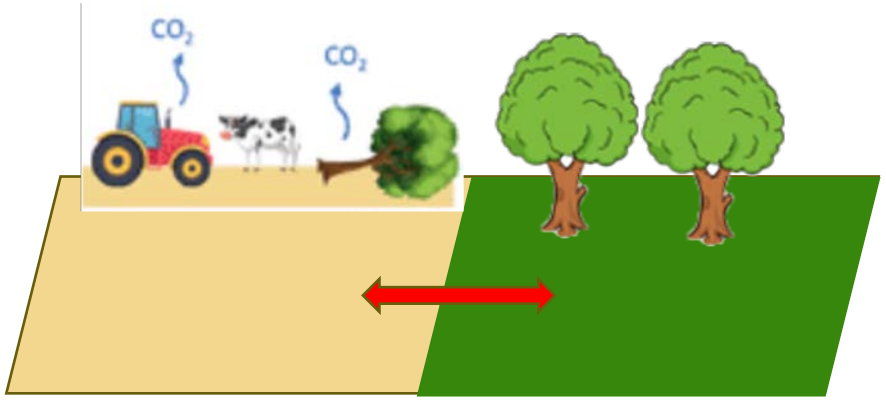
Differences of representing the carbon cycle

Differences of representing the carbon cycle

Regional demand

↓

Grid-based DGVM



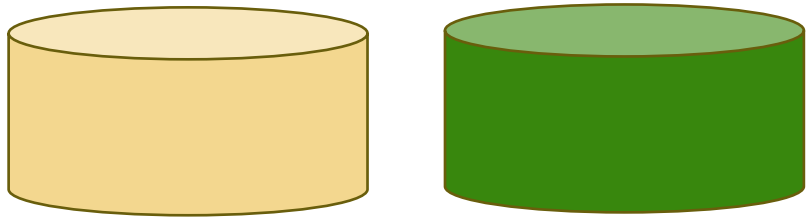
Regional demand

↓

Regional areas

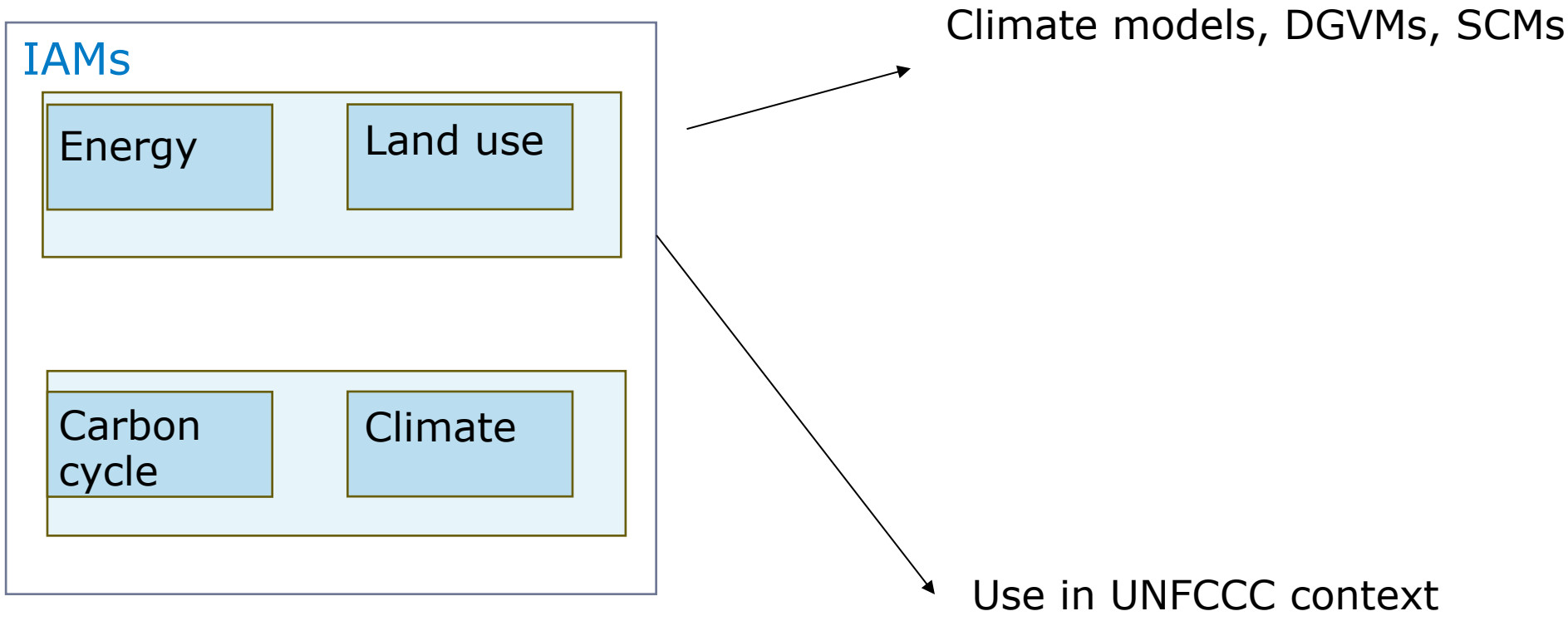
↓

Stock accounting

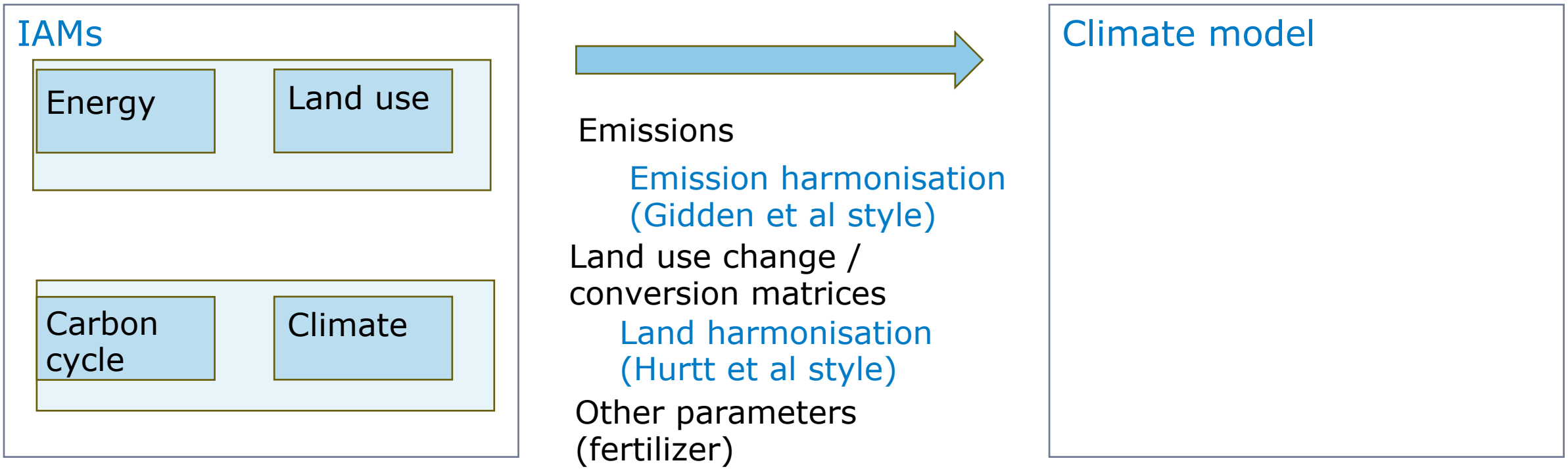


Both approaches can, in principle, account for direct/indirect – but only assigns direct as “anthropogenic” – given direct relationship with human action

Coupling with other communities



Climate models, DGVMs, SCMs



Climate models, DGVMs, SCMs

IAMs

Energy

Land use

Carbon cycle

Climate

Emissions

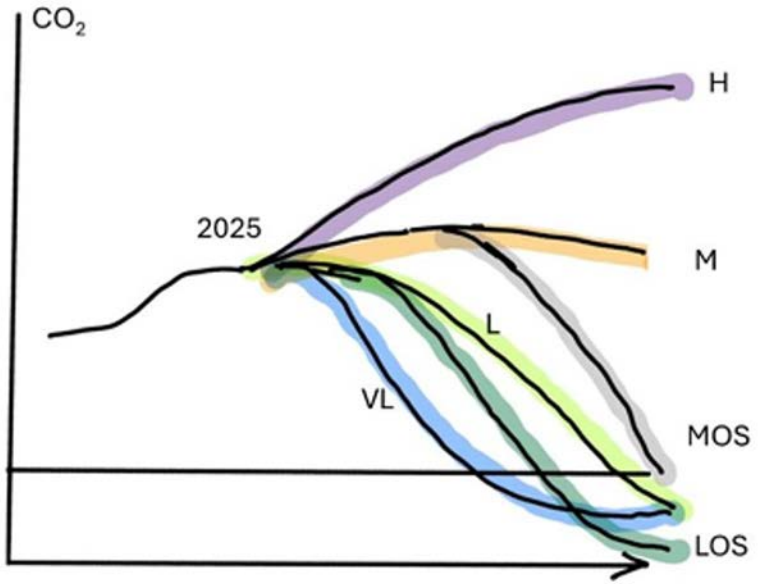
Emission harmonisation (Gidden et al style)

Land use change / conversion matrices

Land harmonisation (Hurtt et al style)

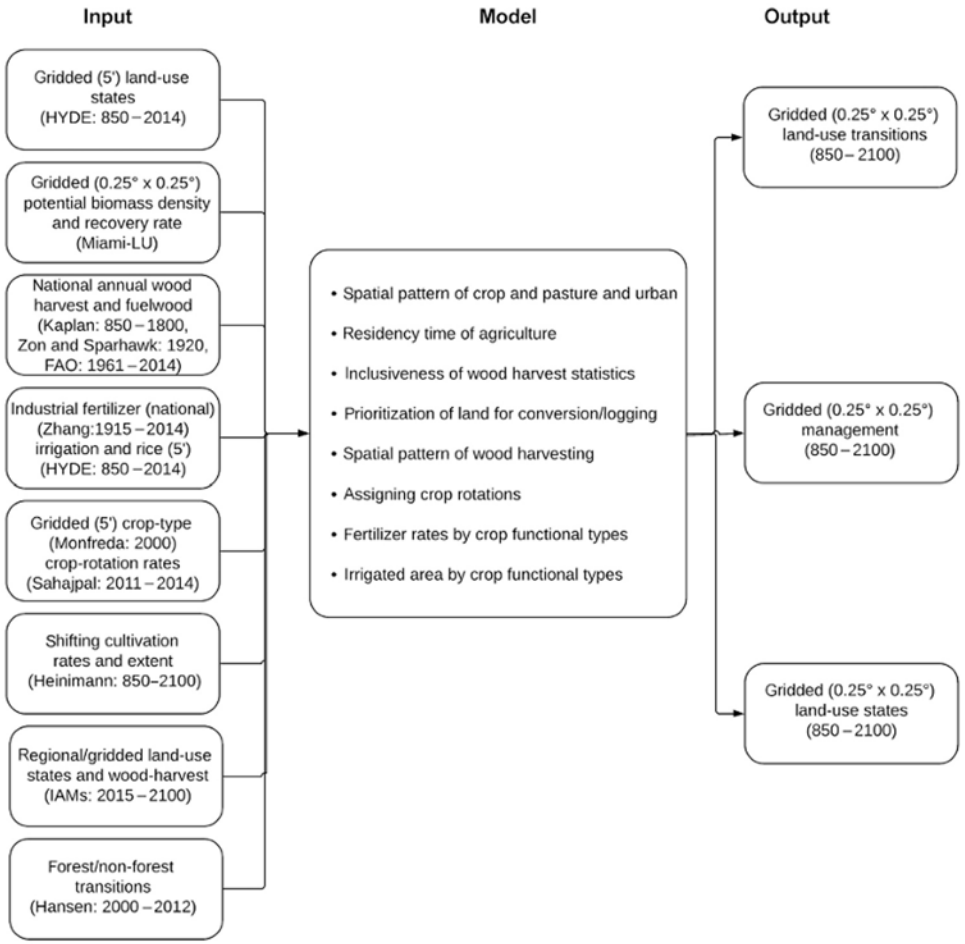
Other parameters (fertilizer)

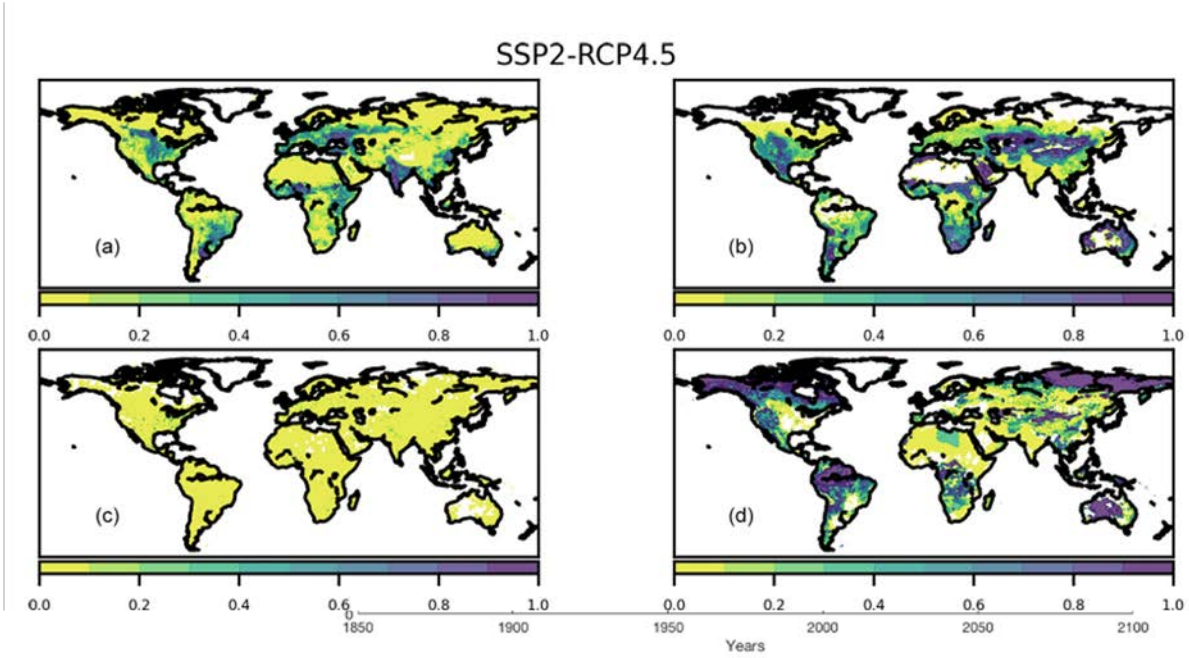
Climate model

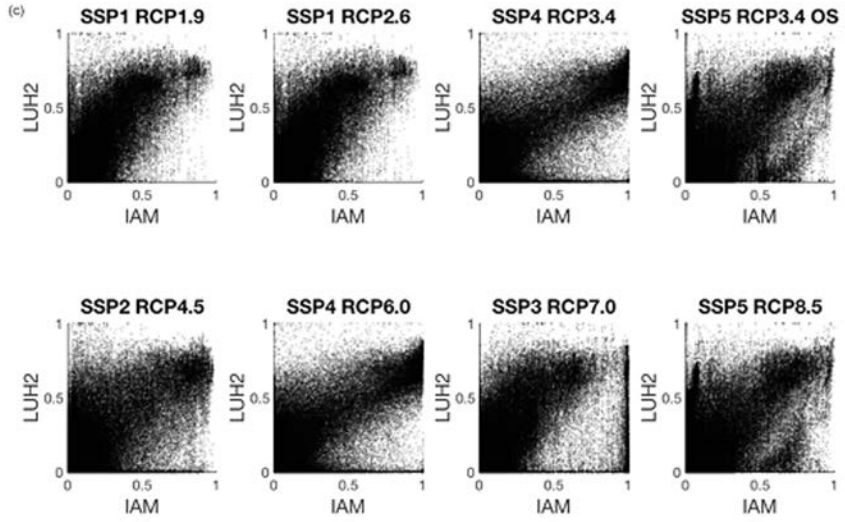


Climate models, DGVMs, SCMs

Land harmonisation (Hurtt et al style)

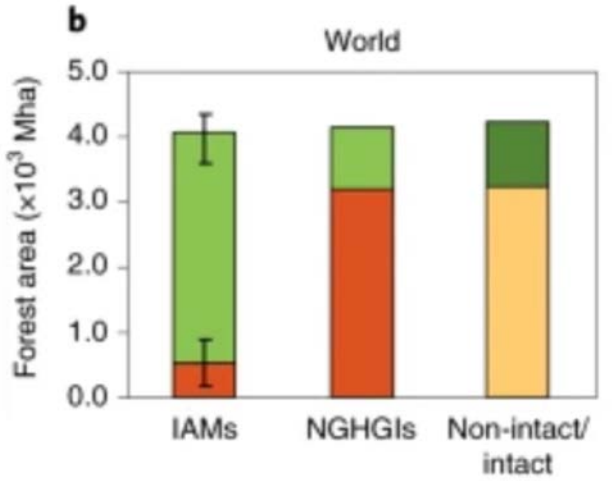




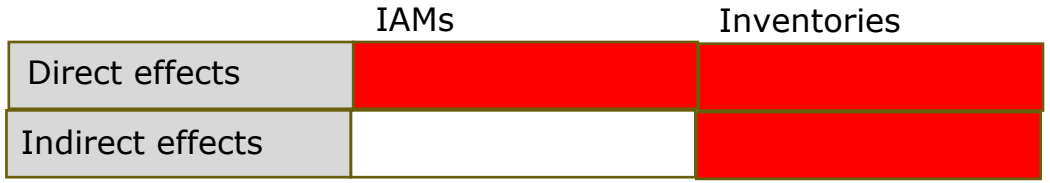


Use in UNFCCC context

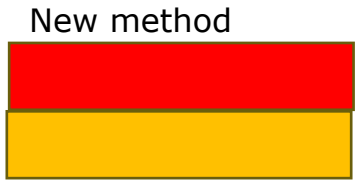
However, internal managed land definitions don't work



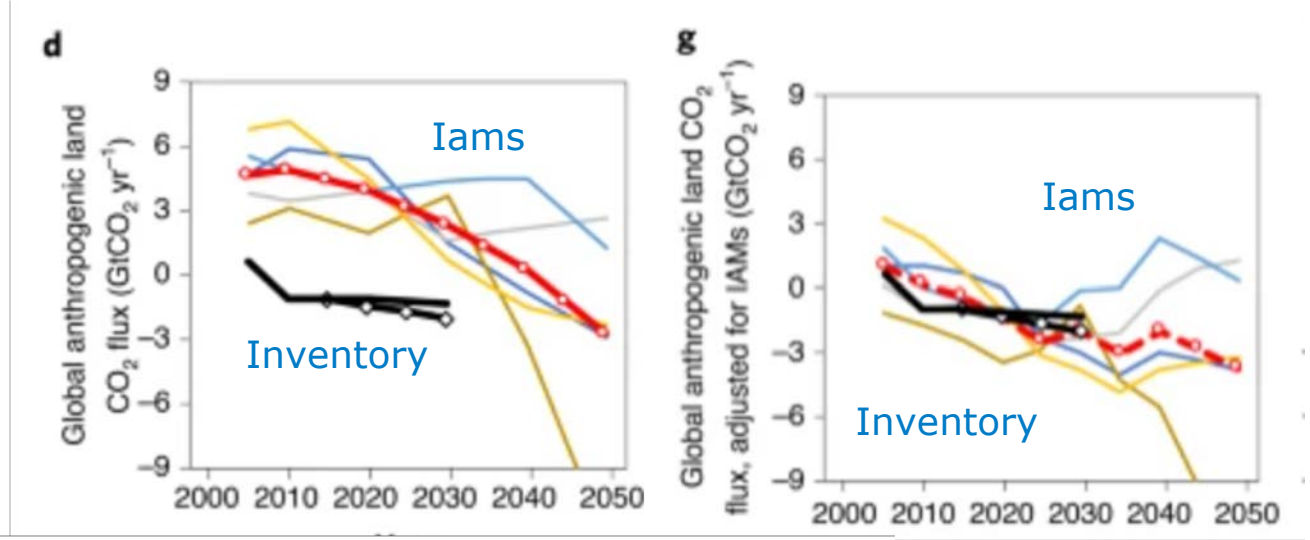
Issue: different definitions



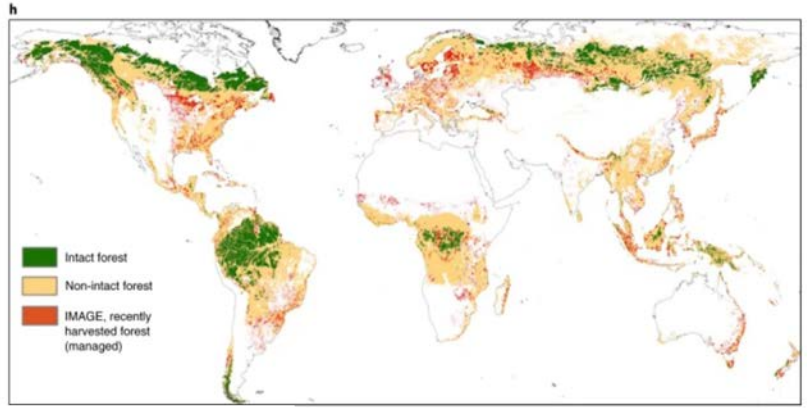
Proposal – also estimate indirect effects



Emissions



Use external layer



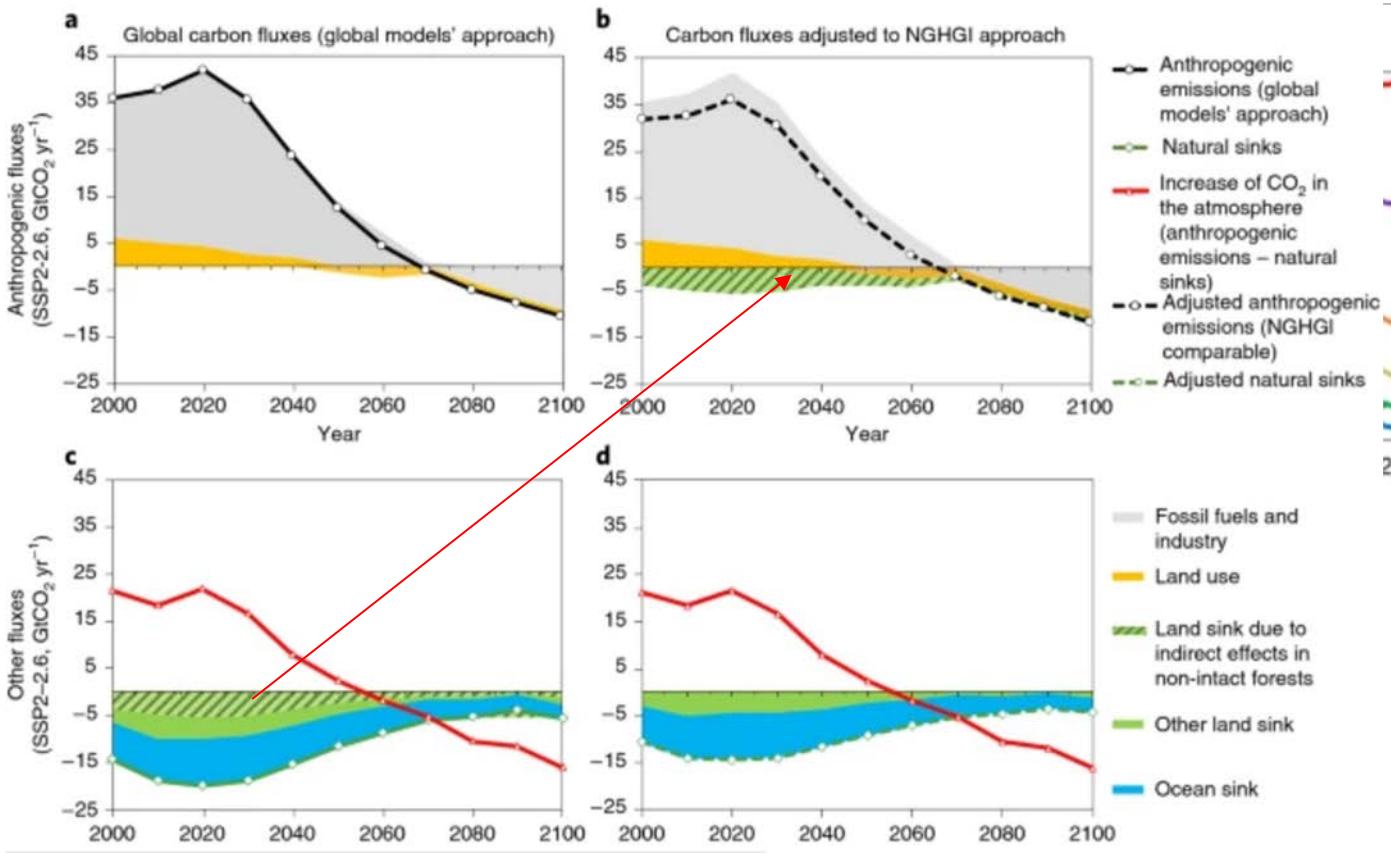
Article | Published: 26 April 2021

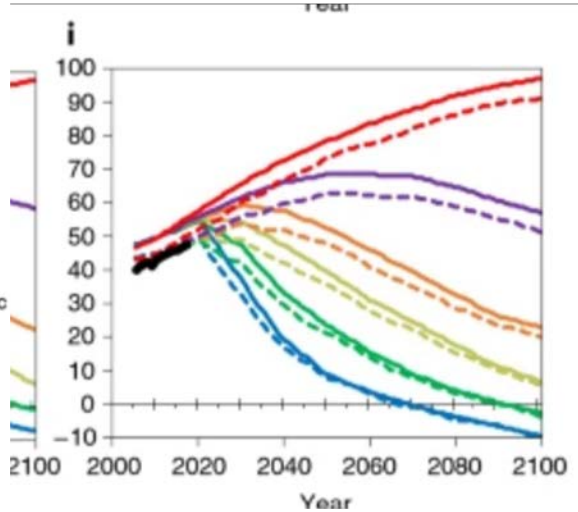
Critical adjustment of land mitigation pathways for assessing countries' climate progress

Article | Open access | Published: 22 November 2023

Aligning climate scenarios to emissions inventories shifts global benchmarks

Results





j

	GHG flux ($GtCO_2$)	Percent of original remaining GHG budget
SSP2-1.9	−120	−13
SSP2-2.6	−192	−12
SSP2-3.4	−275	−11
SSP2-4.5	−366	−10
SSP2-6.0	−475	−9
SSP2-baseline	−454	−7

- Consistent accounting needed
- Smaller carbon budget using UNFCCC accounting
- Relatively small impact on net-zero year (using this method)

Summary

IAMs helpful tools to explore different futures, key input into work of other communities

Carbon accounting similar to carbon cycle models

Range of different approaches within IAMs