Biodiversity conservation and ecosystem restoration to meet **the Kunming-Montreal Global Biodiversity Framework** and satisfy climate goals of **the Paris Agreement**

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OJEong Resilience Institute

The complex relationship between biodiversity and climate in different ecosystems:

Five direct drivers of biodiversity loss

Direct driver	Dominance in realms: Global		Terrestrial		Freshwater		Marine	
Land/sea use change	**2.83**	(2.32–3.09)	**3.16**	(2.77–3.40)	**2.69**	(2.42–3.51)	**1.73**	(1.19–2.15)
Direct exploitation of natural resources	**2.46**	(2.18–2.82)	**2.34**	(1.76–2.72)	**1.99**	(1.42–2.34)	**2.82**	(2.61–3.41)
Pollution	**1.91**	(1.67–2.40)	**1.40**	(0.97–2.06)	**2.18**	(1.89–2.97)	**2.11**	(1.76–2.47)
Climate change	**1.53**	(1.11–2.01)	**1.32**	(1.08–1.83)	**1.53**	(0.77–2.03)	**2.51**	(1.82–2.75)
Invasive alien species	**1.27**	(0.98–1.43)	**1.78**	(1.47–1.99)	**1.61**	(0.87–1.82)	**0.83**	(0.65–1.27)

IPBES. (2019). *Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat.
Jaureguiberry, P. et al. (2022). The direct drivers of recent global anthropogenic biodiversity loss. *Science Advances*, *8*(45), eabm9982.

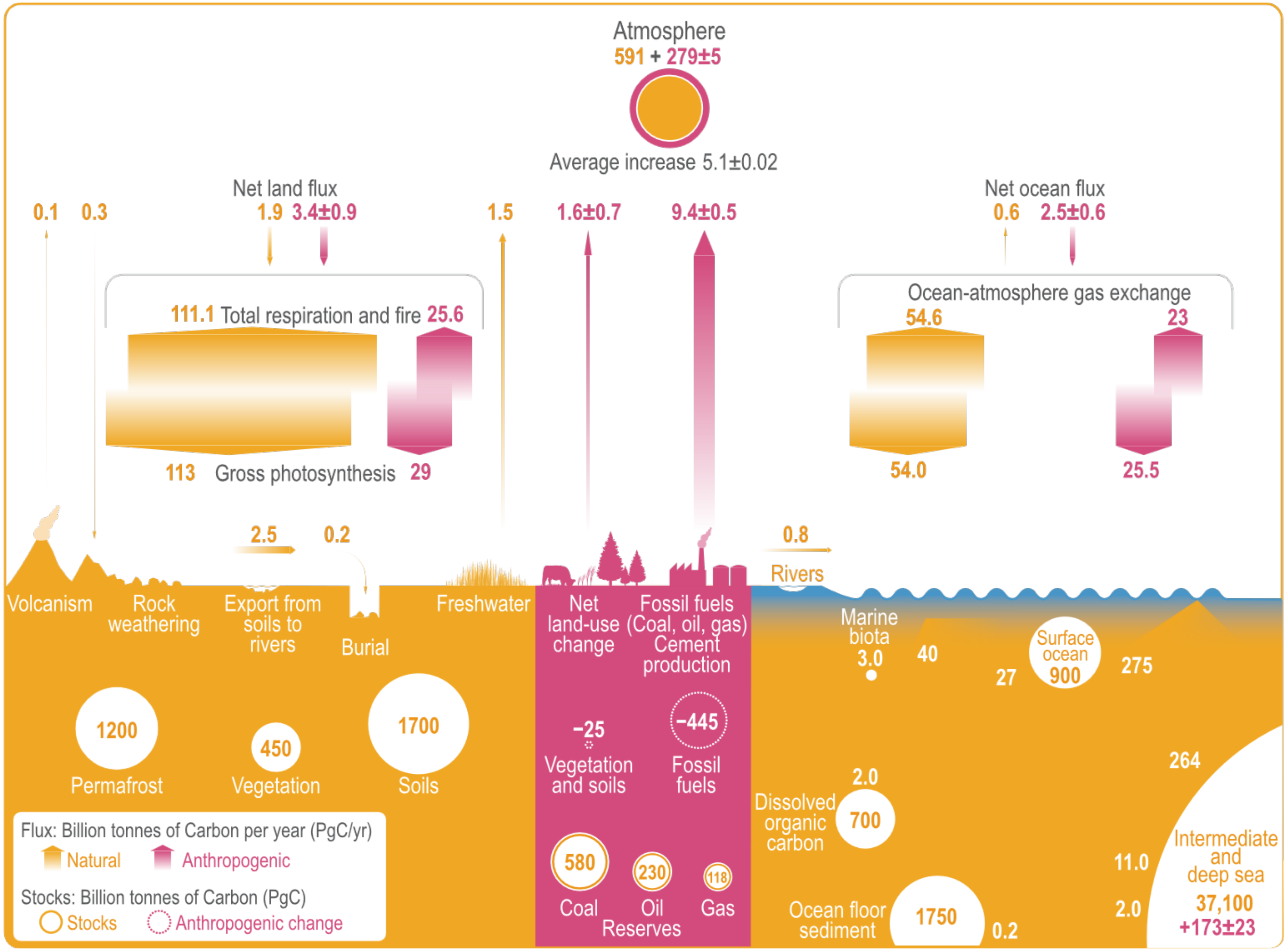
Kunming-Montreal Global Biodiversity Framework (GBF): Addressing direct drivers of biodiversity loss

- Land/sea use change
  - Target 3: Ensure and enable that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures
- Direct exploitation of natural resources
  - Target 2: Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration.
- Pollution
  - Target 7: Reduce pollution risks and the negative impact of pollution from all sources, by 2030, to levels that are not harmful to biodiversity and ecosystem functions and services, considering cumulative effects
- Climate change
  - Target 8: Minimize the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions
- Invasive alien species
  - Target 6: Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services

CBD COP15. (2022). *Kunming-Montreal Global Biodiversity Framework*. (CBD/COP/DEC/15/4).

How much carbon should be sequestered to mitigate climate change?

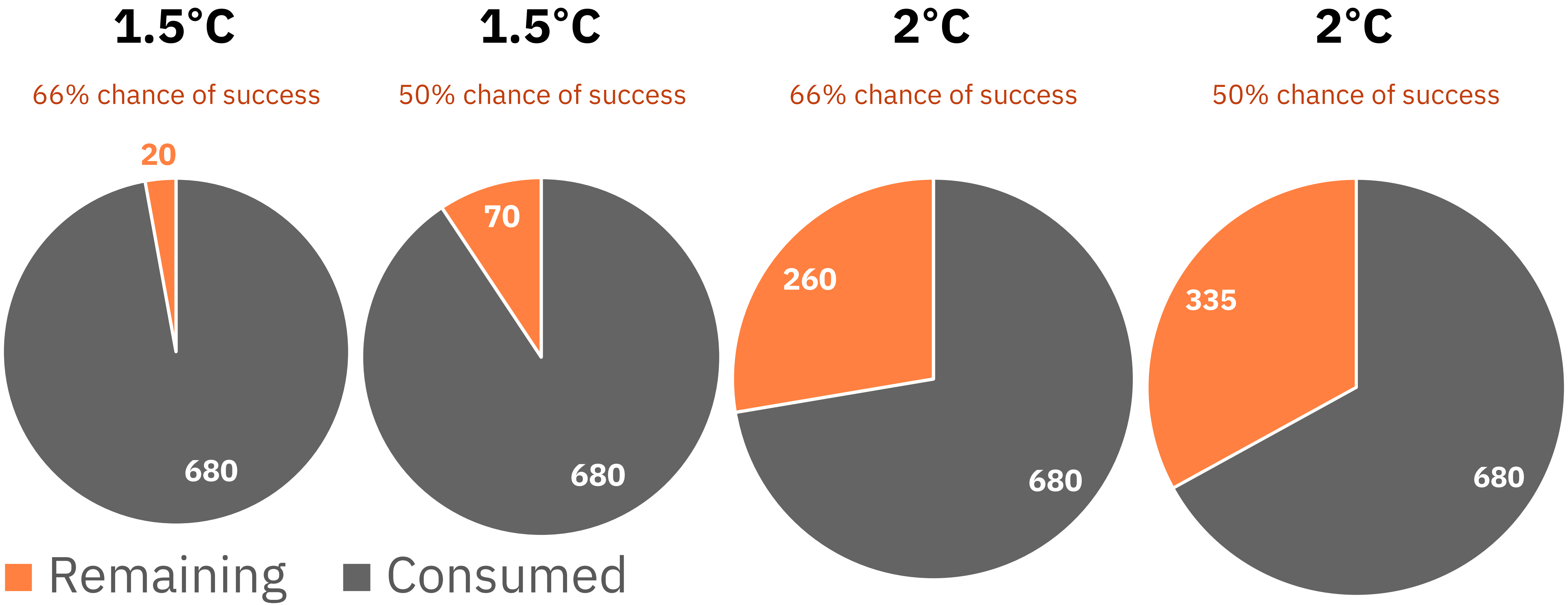
Global carbon budget (anthropogenic fluxes: averaged over the period 2010–2019)



IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

The urgency of climate action

Remaining Carbon Budgets (unit: Gt C) for each global warming limit target as of January 1, 2023
(Note: anthropogenic carbon emissions in 2022 [preliminary] = 11.3 ± 1.2 Gt C yr^{-1})



CONSTRAIN. (2022). ZERO IN ON — The Critical Decade: Insights from the latest IPCC reports on the Paris Agreement, 1.5°C, and climate impacts. *The CONSTRAIN Project Annual Report*.
Forster, P., Rosen, D., Lamboll, R., & Rogelj, J. (2022, November 11). What the tiny remaining 1.5C carbon budget means for climate policy. *Carbon Brief*.
Friedlingstein, P. et al. (2022). Global Carbon Budget 2022. *Earth System Science Data*, *14*(11), 4811–4900.
Lamboll, R., Nicholls, Z., Smith, C., Kikstra, J., Byers, E., & Rogelj, J. (2022). Assessing the size and uncertainty of remaining carbon budgets [Preprint]. *Research Square*. DOI:10.21203/rs.3.rs-1934427/v1

The carbon-sequestering potential of living biomass (1):
Global biomass distribution by taxa

Taxon	Mass (Gt C)		Uncertainty (-fold)
Plants	**450**		1.2
Bacteria	**70**		10
Fungi	**12**		3
Archaea	**7**		13
Protists	**4**		4
Animals	**2**		5
Arthropods, terrestrial		0.2	
Arthropods, marine		1	
Chordates, fish		0.7	
Chordates, livestock		0.1	
Chordates, humans		0.06	
Chordates, wild mammals		0.007	
Chordates, wild birds		0.002	
Annelids		0.2	
Molluscs		0.2	
Cnidarians		0.1	
Nematodes		0.02	
Viruses	**0.2**		20
Total	**550**		1.7

Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, *115*(25), 6506–6511.

The carbon-sequestering potential of living biomass (2):
Biomass distributions across different environments and trophic modes

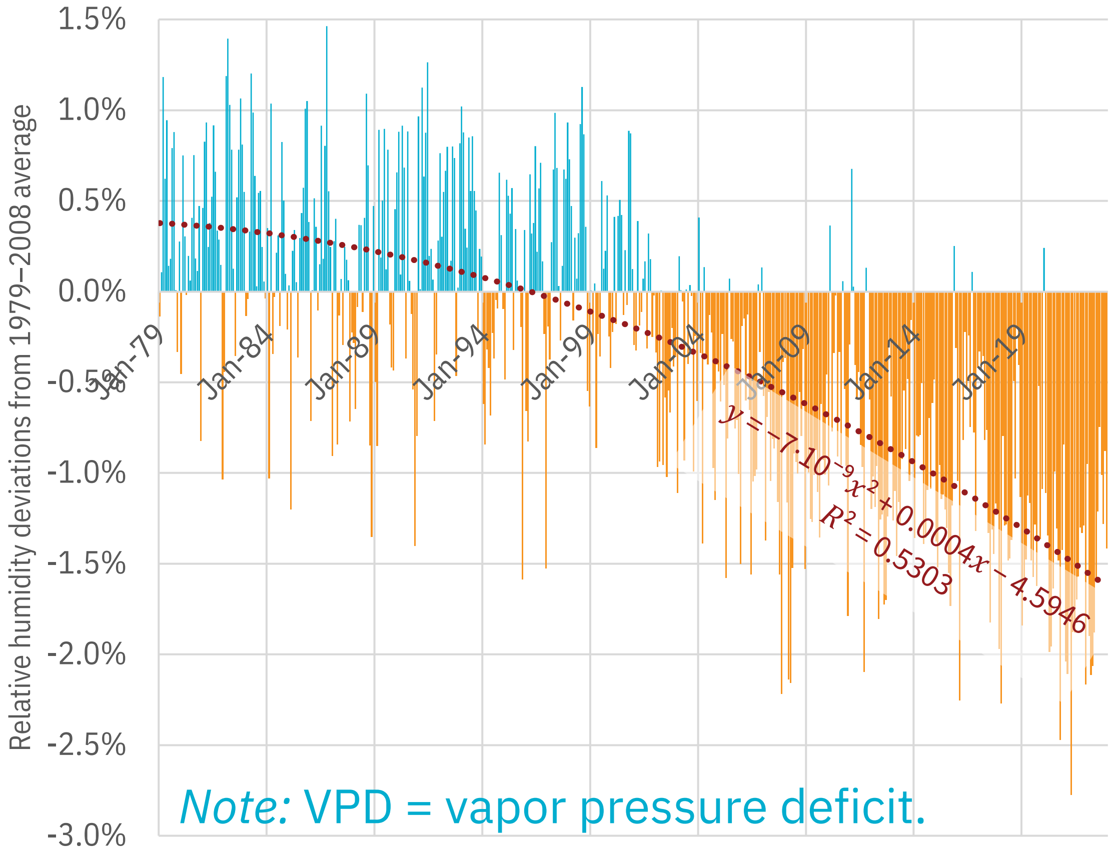
Trophic mode	Terrestrial		Marine		Deep subsurface	
	Taxon	Biomass [Gt C]	Taxon	Biomass [Gt C]	Taxon	Biomass [Gt C]
Producers	**Plants**	**450**	**Marine autotrophs**	**1.3**		
			Seagrasses	0.1		
			Macroalgaea	0.1		
			Picoplankton	0.4		
			Diatoms	0.3		
			Phaeocystis	0.3		
Consumers	**Soil fungi**	**12**	**Marine fungi**	**0.3**		
	Soil bacteria	**7**	**Marine bacteria**	**1.3**	**Terrestrial deep subsurface bacteria**	**60**
					Marine deep subsurface bacteria	**7**
	Terrestrial protists	**1.6**	**Marine protists**	**2**		
			Heterotrophic protists	1.1		
	Soil archaea	**0.5**	**Marine archaea**	**0.3**	**Terrestrial deep subsurface archaea**	**4**
					Marine deep subsurface archaea	**3**
	Terrestrial arthropods	**0.2**	**Marine arthropods**	**1**		
	Terrestrial nematodes	**0.006**	**Marine nematodes**	**0.01**		
	Annelids	**0.2**				
			Marine molluscs	**0.2**		
			Cnidaria	**0.1**		
	Livestock	**0.1**	**Fish**	**0.7**		
	Humans	**0.06**				
	Wild mammals	**0.007**	**Marine mammals**	**0.004**		
	Wild birds	**0.002**				
	Sum	**470**	**Sum**	**6**	**Sum**	**70**

Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, *115*(25), 6506–6511.

Impact of climate change on terrestrial living biomass:

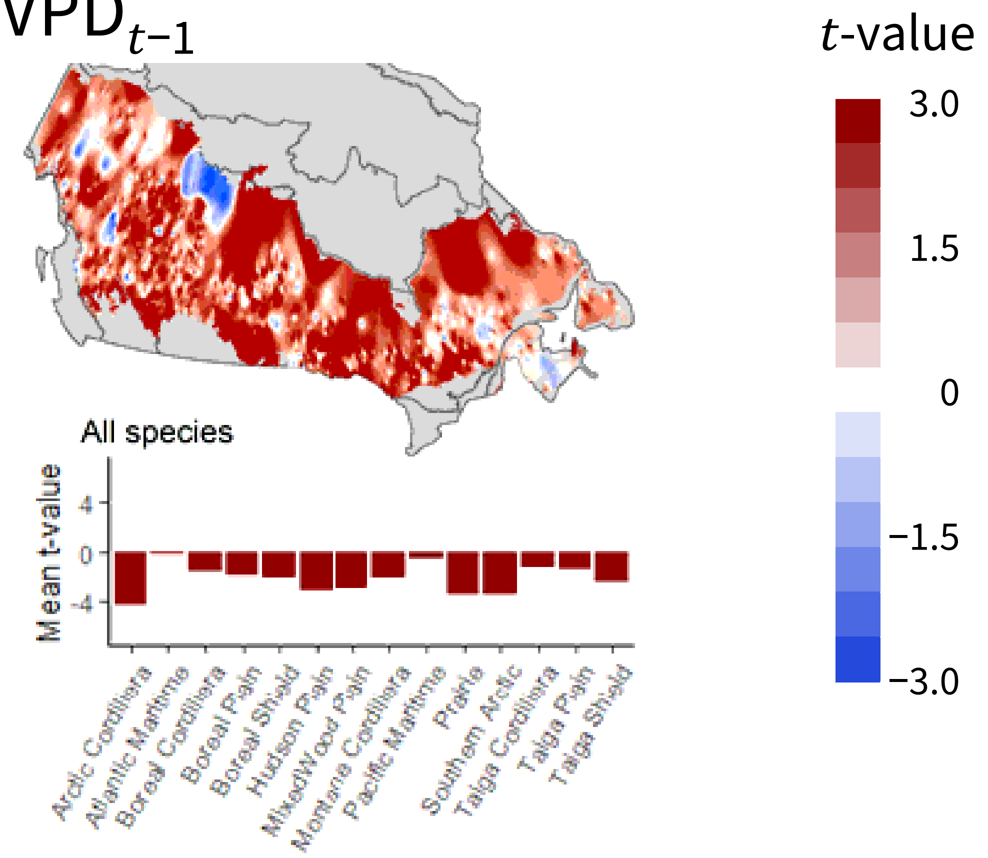
Globally accelerating air dryness could hinder tree growth

Monthly average land (180W–180E, 90S–90N) surface air relative humidity anomalies, 1979–2022 (cf. RH ∝ VPD^{-1})



The regression between annual growth fluctuations estimated from tree rings (BAI) and vapour pressure deficit (VPD)

$BAI \sim VPD_{t-1}$

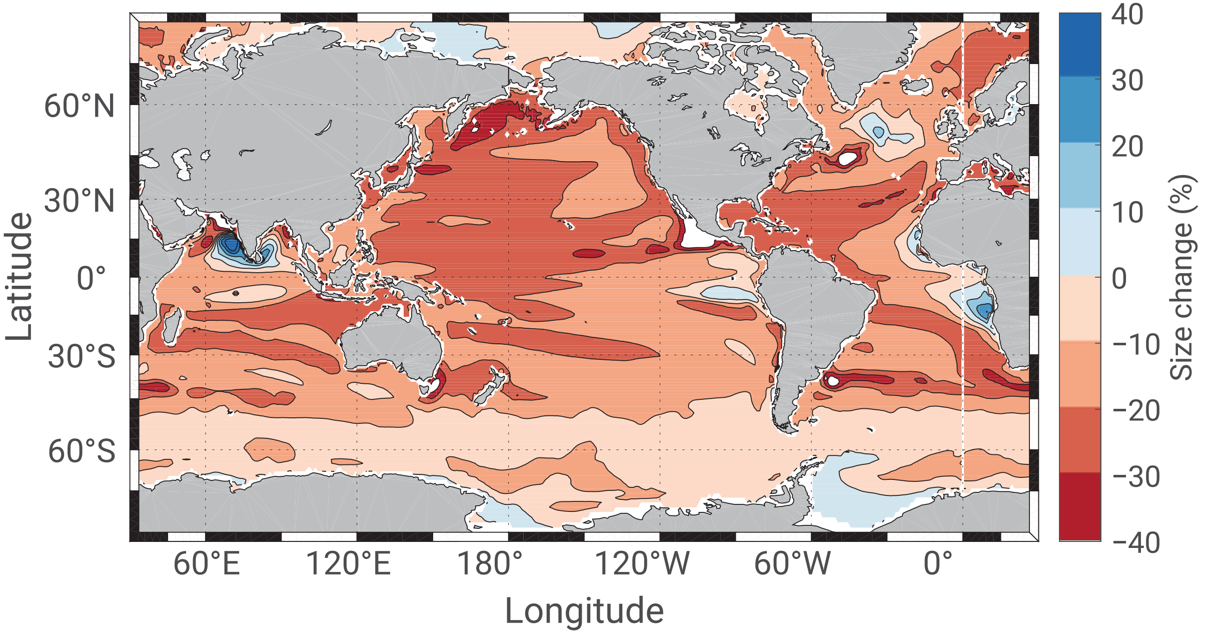


Mirabel, A., Girardin, M. P., Metsaranta, J. et al. (2023). Increasing atmospheric dryness reduces boreal forest tree growth. [PREPRINT]. *Research Square*. https://doi.org/10.21203/rs.3.rs-2611306/v1
C3S/ECMWF. (2023). ERA5 climate reanalysis. https://climate.copernicus.eu/precipitation-relative-humidity-and-soil-moisture-february-2023

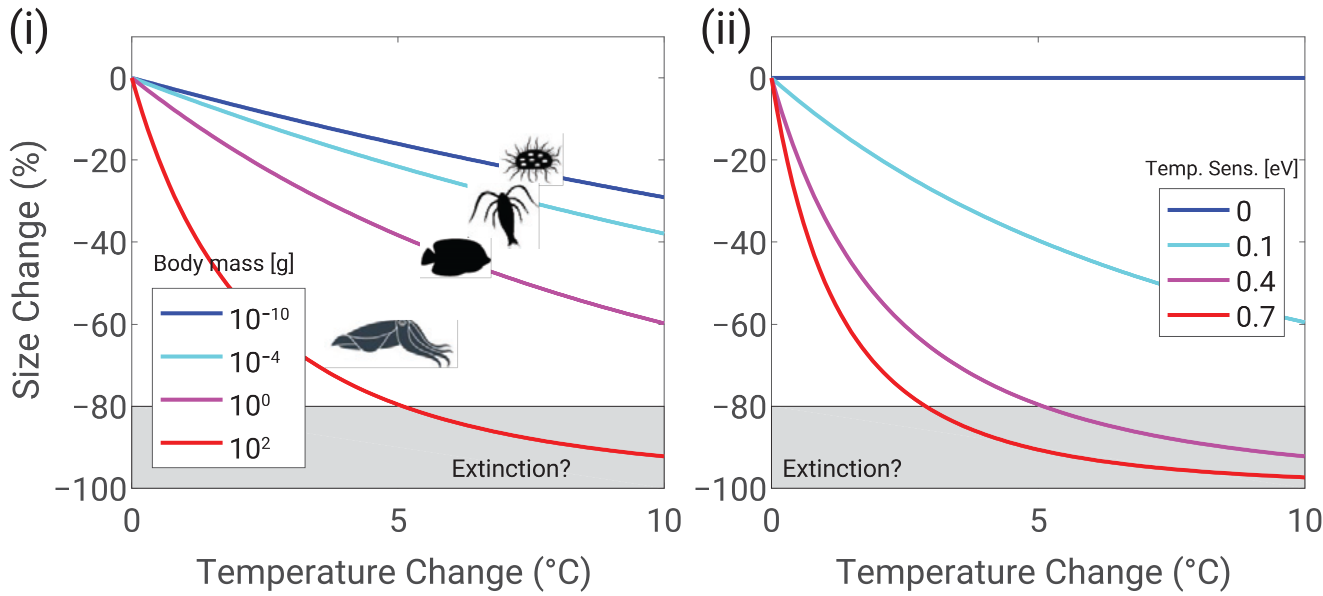
Impact of climate change on marine living biomass:

Change in body size (%) over this century based on the mechanistic data-constrained model

Fractional change in body size for a 1-g water breather for ocean climate changes in 2100 CE over the upper 500 m



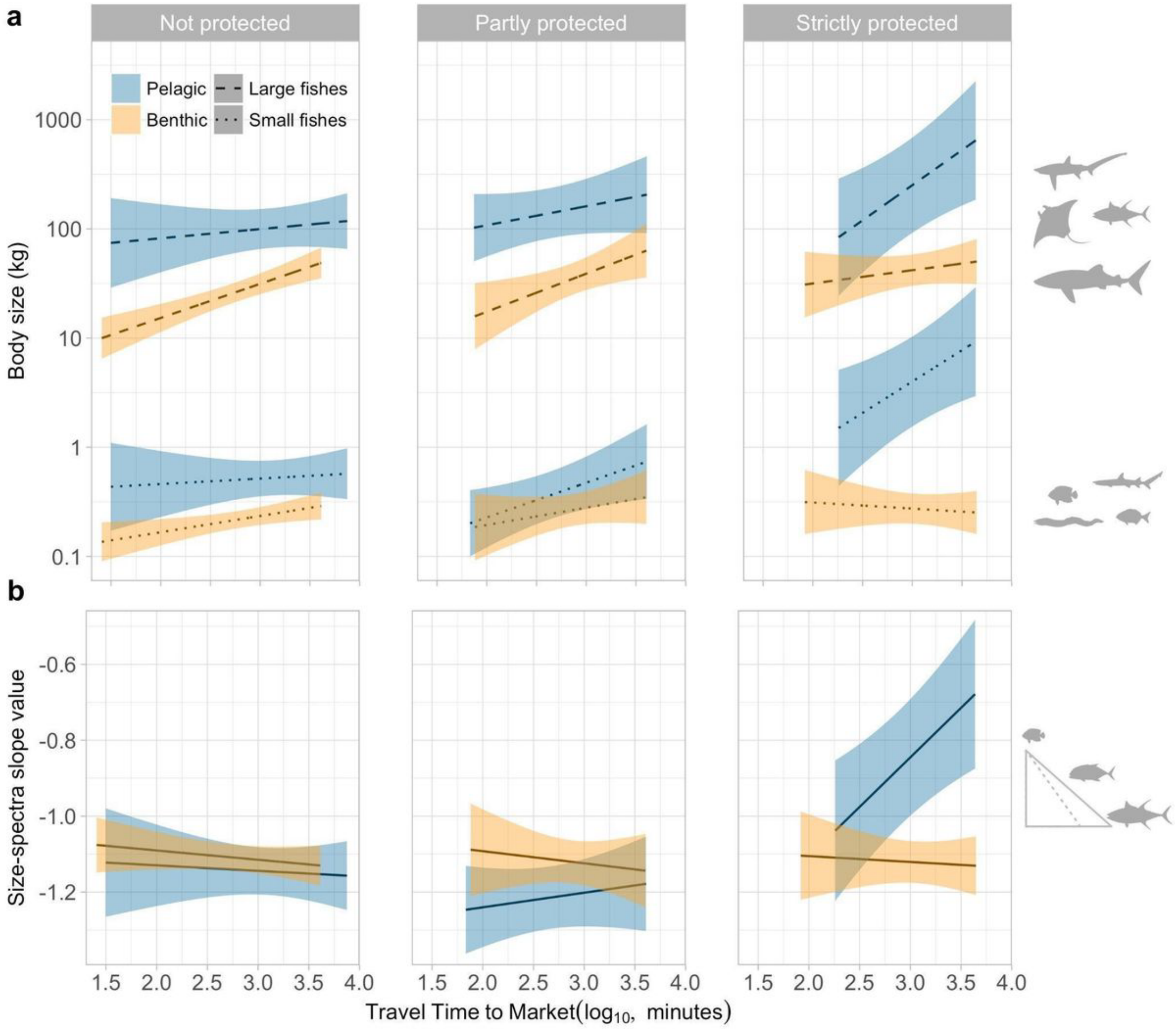
Changes in body size as temperatures rise, across a range of traits governing:
(i) allometry
(ii) temperature sensitivity of hypoxia tolerance



Hatton, I. A., Heneghan, R. F., Bar-On, Y. M., & Galbraith, E. D. (2021). The global ocean size spectrum from bacteria to whales. *Science Advances*, *7*(46), eabh3732.

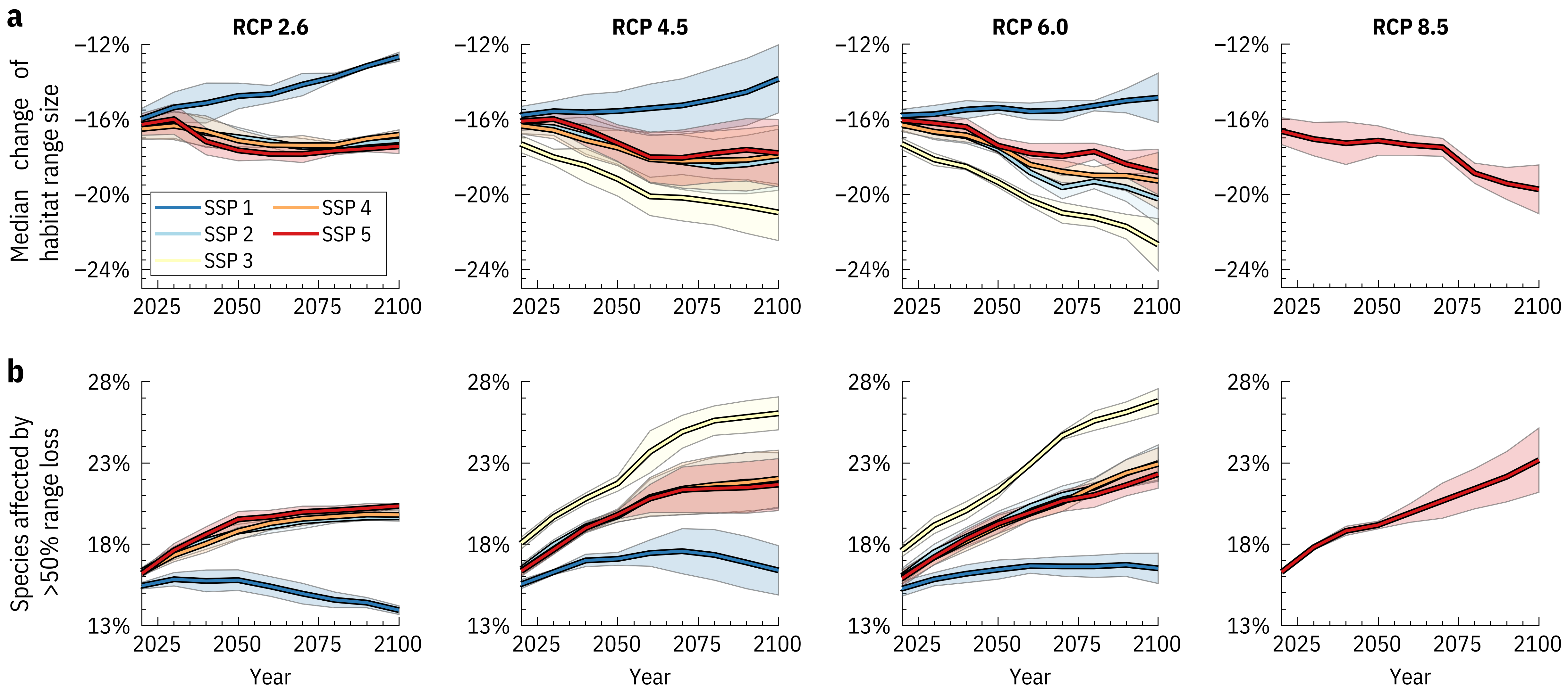
Impact of overexploitation on marine living biomass (or potential benefits of marine protected areas):

Human influence on fish body size structure in pelagic and benthic habitats



Letessier, T. et al. (2023). Global human footprint on fish size-spectra across marine ecosystems. *Research Square*, [Preprint]. https://doi.org/10.21203/rs.3.rs-2570676/v1

Projected future range changes of mammals, birds and amphibians for representative concentration pathways (RCPs) 2.6, 4.5, 6.0, 8.5, and shared socioeconomic pathways (SSPs) 1–5



Beyer, R. M., & Manica, A. (2020). Historical and projected future range sizes of the world's mammals, birds, and amphibians. *Nature Communications*, *11*(1), 5633.

Land and Ocean Carbon Management: Emission Reduction and Sequestration

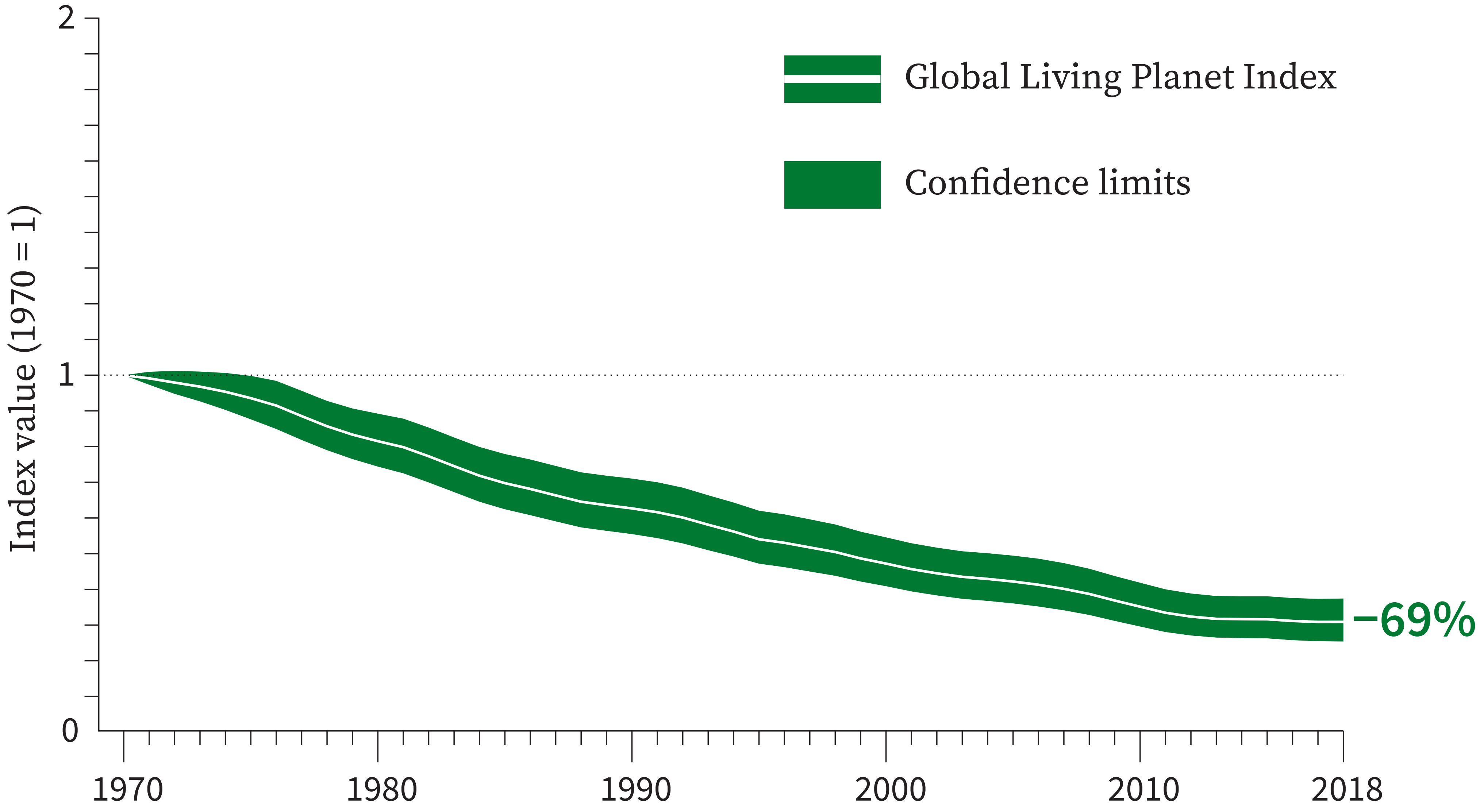
Practice	Mitigation potential	Biodiversity Impact (positive unless otherwise stated)
(a) Ocean		
Carbon storage in seabed	0.5–2.0 Gt CO_2e yr^{-1}	Low
Coastal and marine ecosystems	0.5–1.38 Gt CO_2e yr^{-1}	Medium/High
Fisheries, aquaculture and dietary shifts	0.48–1.24 Gt CO_2e yr^{-1}	Medium/High
(b) Land		
Increased food productivity	>13 Gt CO_2e yr^{-1}	High[1] or Low[2]
Improved cropland management	1.4–2.3 Gt CO_2e yr^{-1}	Medium
Improved grazing land management	1.4–1.8 Gt CO_2e yr^{-1}	Medium
Improved livestock management	0.2–2.4 Gt CO_2e yr^{-1}	Medium
Agroforestry	0.1–5.7 Gt C22e yr^{-1}	High
Agricultural diversification	>0	High
Reduced grassland conversion to cropland	0.03–0.7 Gt CO_2e yr^{-1}	High[3]
Improved and sustainable forest management	0.4–2.1 Gt CO_2e yr^{-1}	High
Reduced deforestation and degradation	0.4–5.8 Gt CO_2e yr^{-1}	High
Reforestation and forest restoration	1.5–10.1 Gt CO_2e yr^{-1}	High
Afforestation	See Reforestation	Negative/low positive[4]
Increased soil organic carbon content	0.4–8.6 Gt CO_2e yr^{-1}	Medium
Reduced soil erosion	Source of 1.36–3.67 to sink of 0.44–3.67 Gt CO_2e yr^{-1}	Low
Biochar addition to soil	0.03–6.6 Gt CO_2e yr^{-1}	Low[5]
Fire management	0.48–8.1 Gt CO_2e yr^{-1}	Low
Management of invasive species / encroachment	No global estimates	High
Restoration and reduced conversion of coastal wetlands	0.3–3.1 Gt CO_2e yr^{-1}	High
Restoration and reduced conversion of peatlands	0.6–2.0 Gt CCO_2e yr^{-1}	High
Biodiversity conservation	0.9 Gt CO_2e-e yr^{-1}	High
Bioenergy and BECCS	0.4–11.3 Gt CO_2e yr^{-1}	Negative/low positive[4]
(c) Demand changes (related to land)		
Dietary change	0.7–8.0 Gt CO_2e yr^{-1} (land)	High[6]
Reduced post-harvest losses	4.5 Gt CO_2e yr^{-1}	Medium/High
Reduced food waste (consumer or retailer)	0.8–4.5 Gt CO_2e yr^{-1}	Medium/High
Management of supply chains	No global estimates	Medium[7]
Enhanced urban food systems	No global estimates	Medium
Total mitigation potential:	**6.95–109.79 Gt CO_2e yr^{-1}**	
	1.90–29.96 Gt C yr^{-1}	

Note: 1. If achieved through sustainable intensification; 2. If achieved through increased agricultural inputs; 3. If conversion takes place in (semi-)natural grassland; 4. If small spatial scale and (for bioenergy) second generation bioenergy crops; 5. Low if biochar is sourced fro m forest ecosystems, application can be beneficial to soils locally; 6. Due to land sparing; 7. Related to increased eco-labelling, which drives consumer purchases towards more ecosystem-friendly foods.

Smith, P., Arneth, A., Barnes, D. K. A., Ichii, K., Marquet, P. A., Popp, A., Pörtner, H.-O., Rogers, A. D., Scholes, R. J., Strassburg, B., Wu, J., & Ngo, H. (2022). How do we best synergize climate mitigation actions to co-benefit biodiversity? *Global Change Biology*, *28*(8), 2555–2577.

Challenges in Implementing Natural Climate Solutions (NCS) (1):

The average change in relative abundance of 31,821 populations (representing 5,230 species)

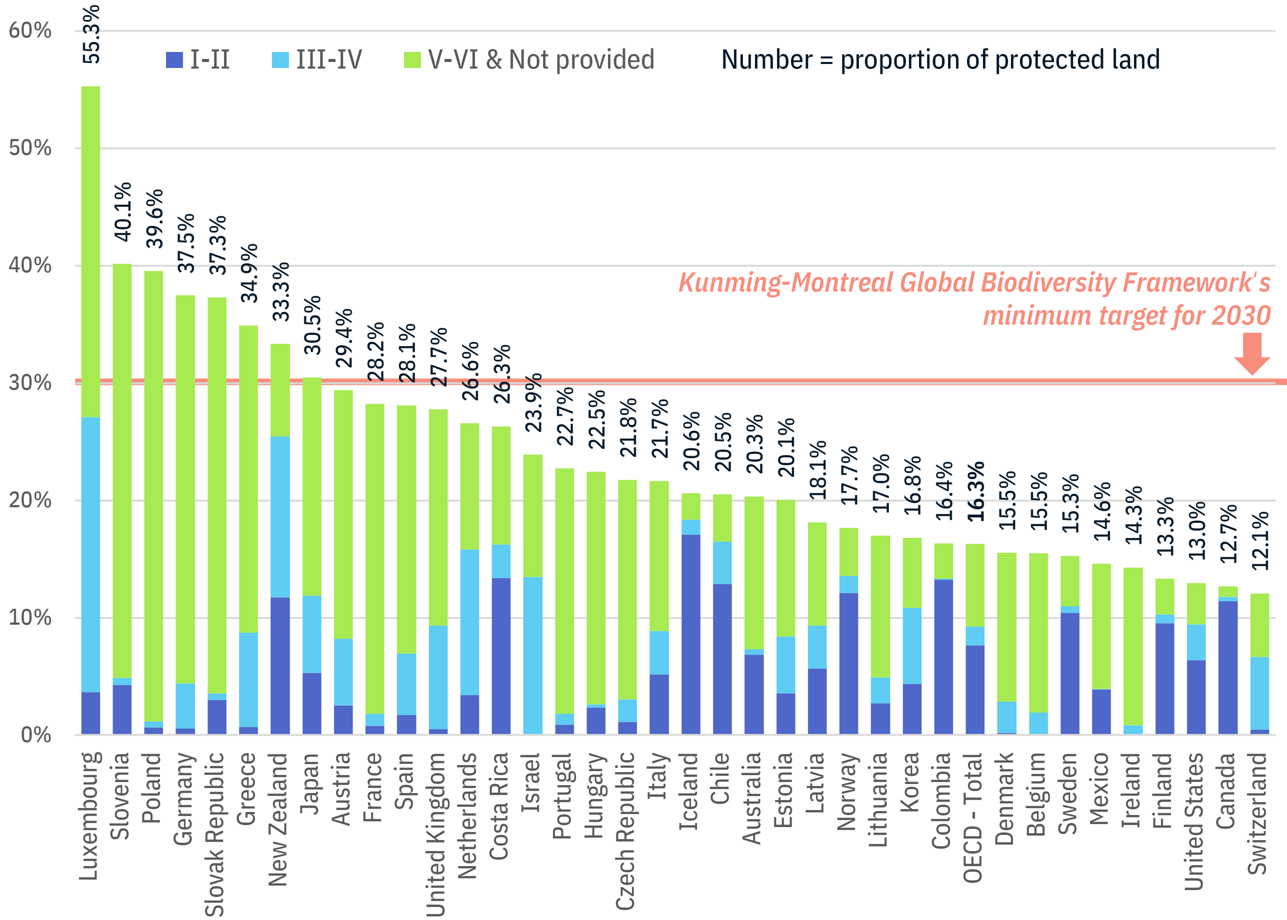


WWF. (2022). *Living Planet Report 2022 – Building a nature-positive society*. (R. E. A. Almond, M. Grooten, D. Juffe Bignoli, & T. Petersen, Eds.). WWF (World Wide Fund for Nature).

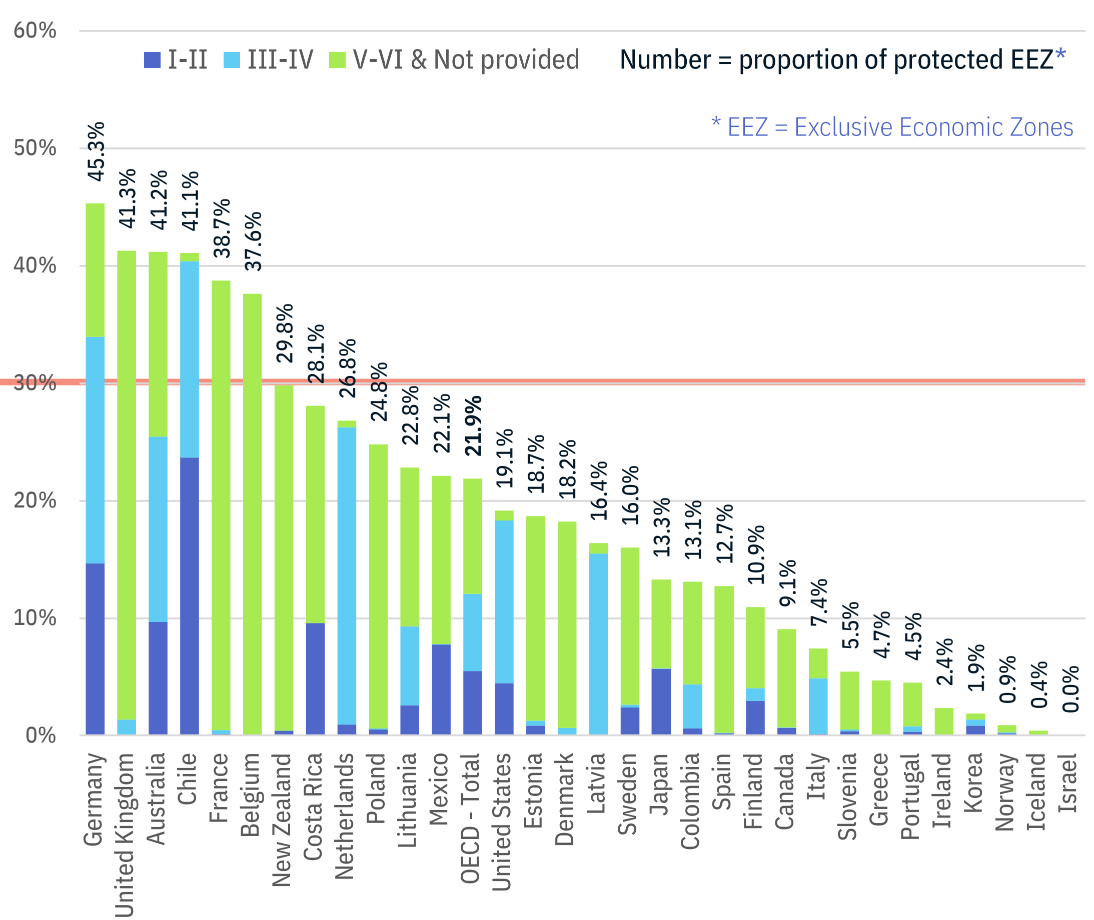
Challenges in Implementing Natural Climate Solutions (NCS) (2):

Distribution of Protected Area Designations in OECD Countries, 2022

Terrestrial protected area



Marine protected area



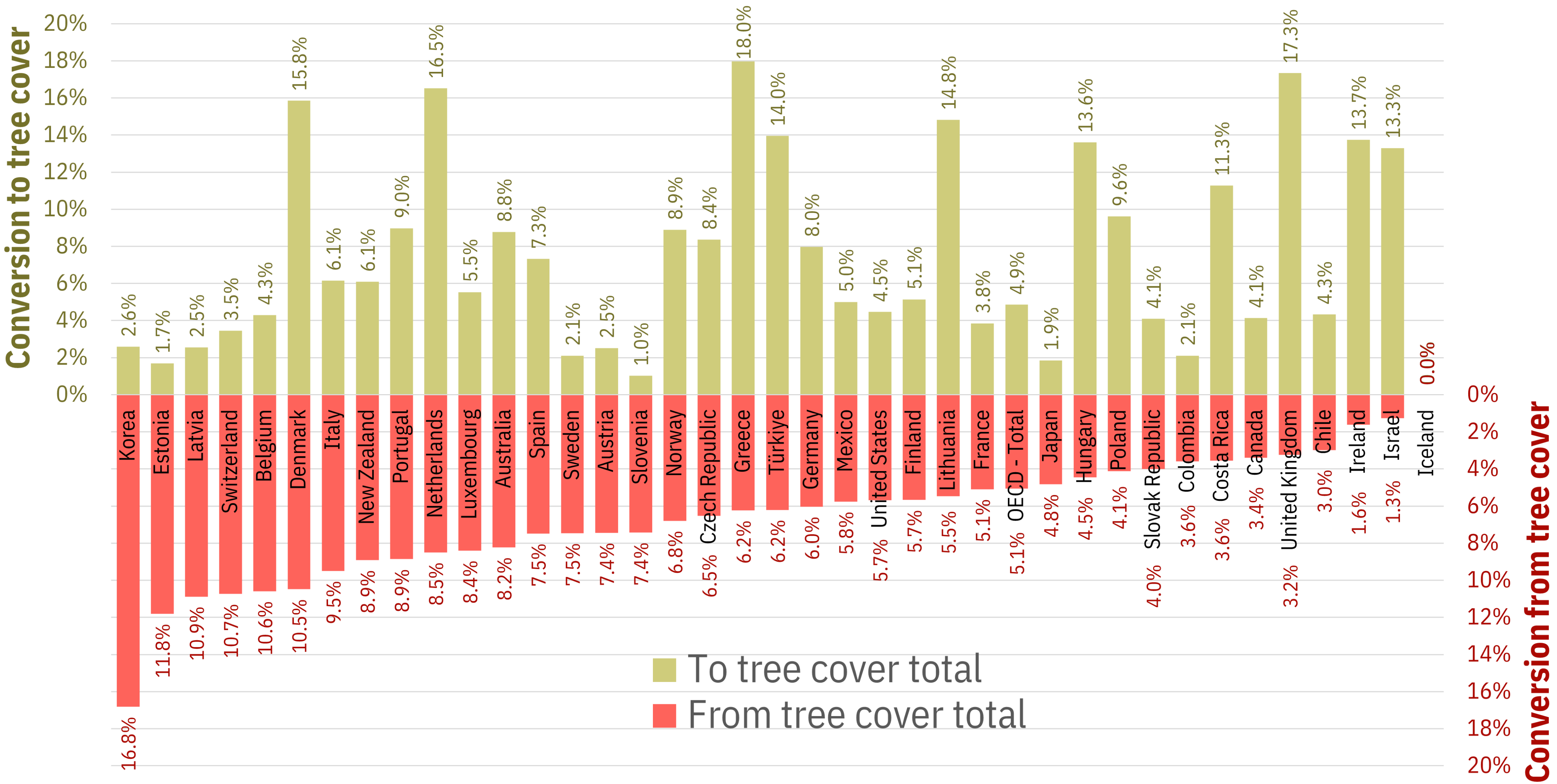
IUCN protected area management categories:

- **I - II** = [**I a**: Strict Nature Reserves] + [**I b**: Wilderness Areas] + [**II**: National Parks]
- **III-IV** = [**III**: Natural Monuments or Features] + [**IV**: Habitat/Species Management Areas]
- **V-VI & Not provided** = [**V** : Protected Landscapes and Seascapes] + [**VI**: Protected areas with sustainable use of natural resources] + [Areas with no management category provided]

OECD. (2023). *Biodiversity: Protected areas*. OECD Environment Statistics. DOI:10.1787/5fa661ce-en.

Challenges in Implementing Natural Climate Solutions (NCS) (3):

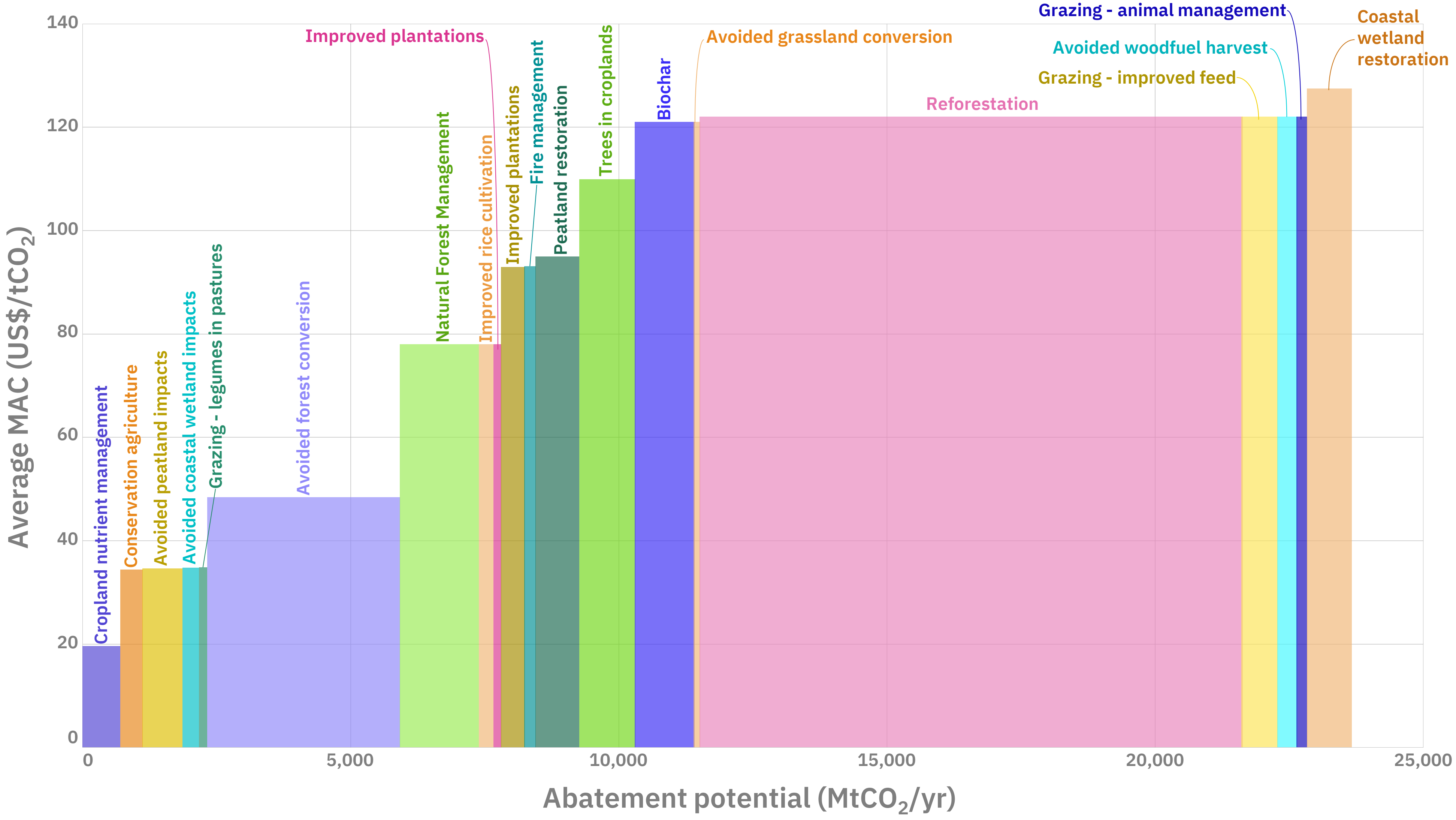
Tree cover GAIN and LOSS in OECD countries, 1992–2019 (relative to the tree cover area in 1992)



OECD. (2023). *Land resources: Land cover change in countries and regions*. OECD Environment Statistics. DOI: 10.1787/3bce4397-en.

Challenges in Implementing Natural Climate Solutions (NCS) (4):

The solution with the largest potential costs more: A Marginal Abatement Cost Curve of Natural Climate Solutions in 2030



Cook-Patton, S. C., Drever, C. R., Griscom, B. W., Hamrick, K., Hardman, H., Kroeger, T., Pacheco, P., Raghav, S., Stevenson, M., Webb, C., Yeo, S., & Ellis, P. W. (2021). Protect, manage and then restore lands for climate mitigation. *Nature Climate Change, 11*(12), 1027–1034.

Policy Implications of the Review

- Addressing direct drivers of biodiversity loss
  - Land/sea use change
    - The loss of natural habitats must be reversed. A recent policy development includes trophic rewilding* (Schmitz et al., 2023).
  - Direct exploitation and pollution
    - Developed countries should not shirk their responsibility to protect biodiversity by transferring their protected area obligations to developing countries, especially marine protected areas.
    - Trophic magnification effects of pollutants must be rigorously assessed and monitored.
  - Climate change
    - Aggressive fiscal policy (with lower social discount rates [Polasky & Dampha, 2021]) and investment are essential to realizing the full potential of NCS/NbS (Nature-based solutions) for GBF.
    - Water availability must be reassessed and revised regularly to account for changing projections of both vapor pressure deficit (VPD) and soil moisture (Wang-Erlandsson et al., 2022).
- Further study
  - Review of measures to address the invasive alien species.
  - Quantitative verification of the NCS/NbS in each country (especially in developed countries)

* Using wild animal conservation explicitly to enhance carbon capture and storage (also known as “animating the carbon cycle”).

Polasky, S., & Dampha, N. K. (2021). Discounting and Global Environmental Change. *Annual Review of Environment and Resources*, *46*, 691–717.
Schmitz, O. J. et al. (2023). Trophic rewilding can expand natural climate solutions. *Nature Climate Change*. https://doi.org/10.1038/s41558-023-01631-6
Wang-Erlandsson, L. et al. (2022). A planetary boundary for green water. *Nature Reviews Earth & Environment*, *3*(6), 380–392.

Thank you.

“Our world needs climate action on all fronts – **everything, everywhere, all at once.**”
— António Guterres, Secretary-General of the United Nations

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