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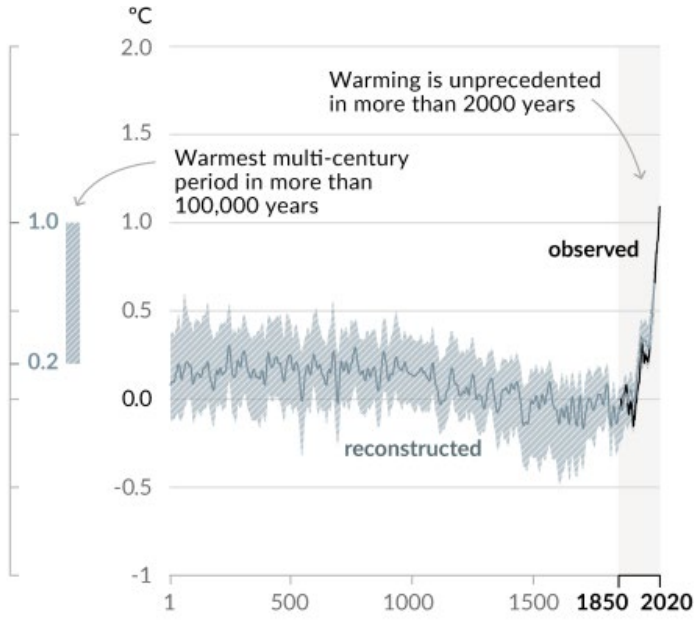
Climate(s) of the future – predicted conditions and their impact on the biosphere, and forests in particular

Campus-Alpin

The latest climate change projections (IPCC WG1 AR6)

Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C)



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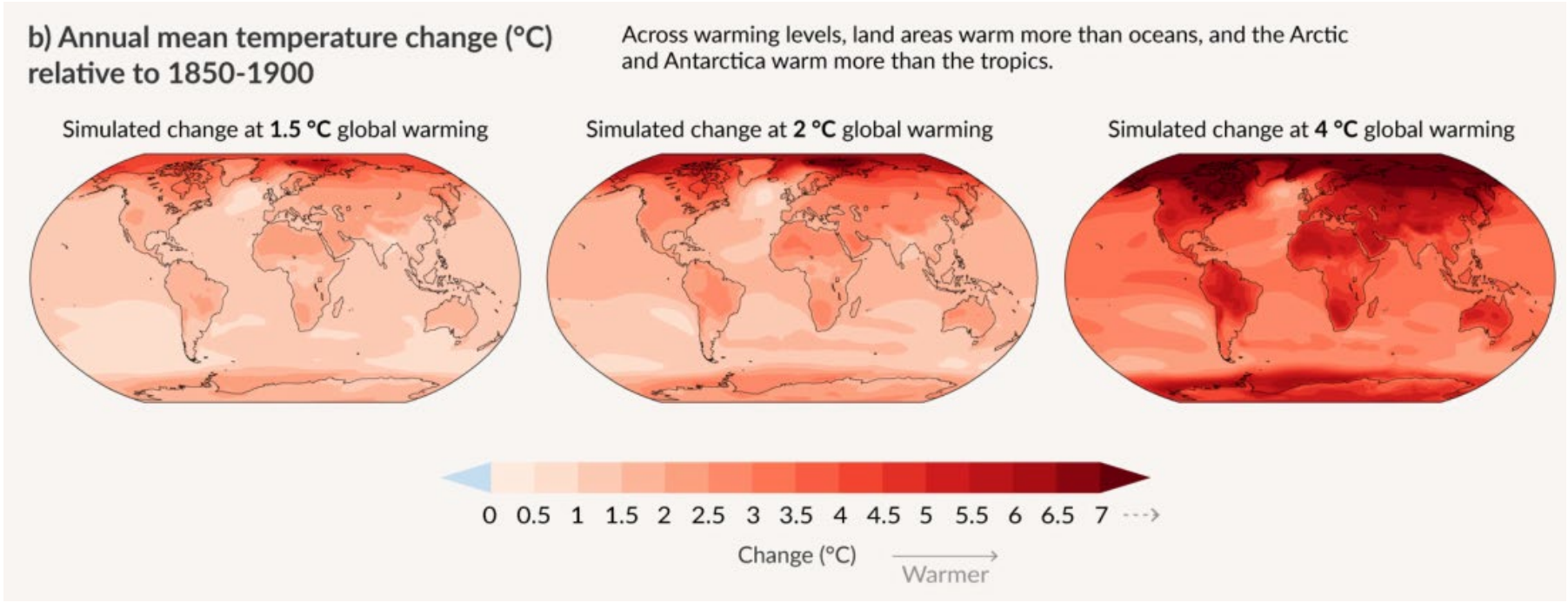

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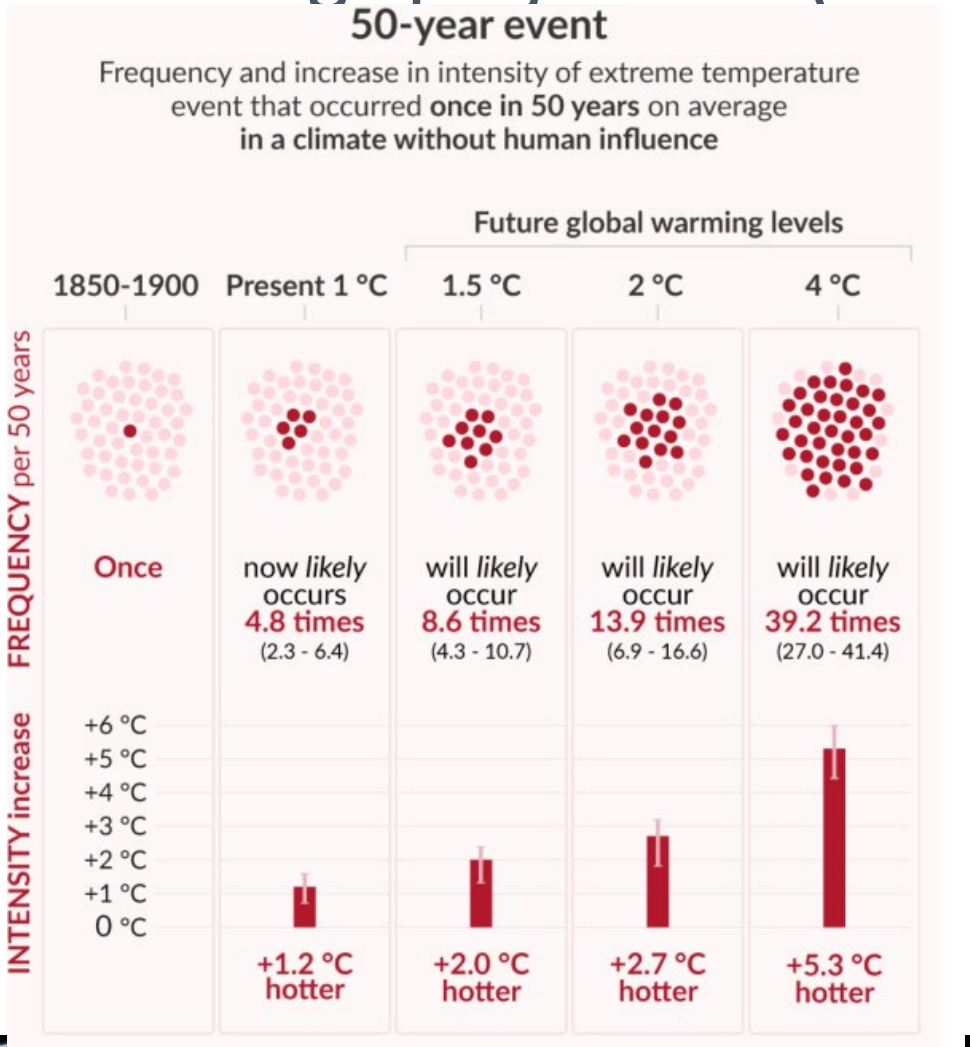
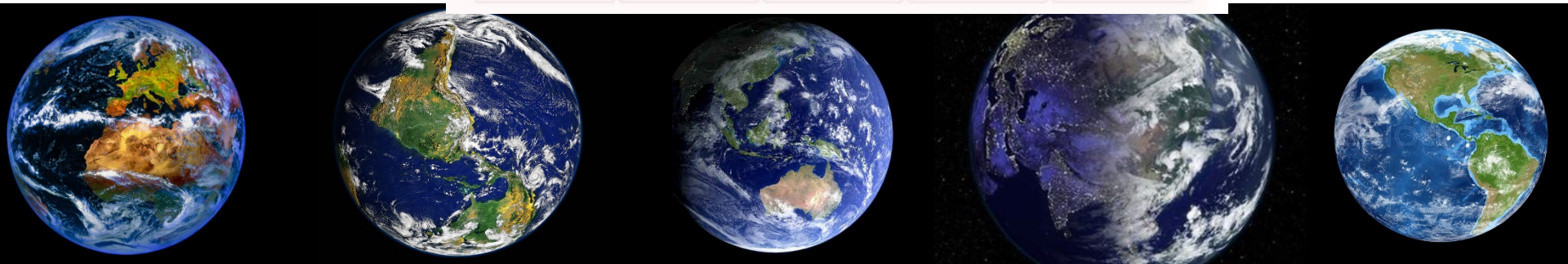


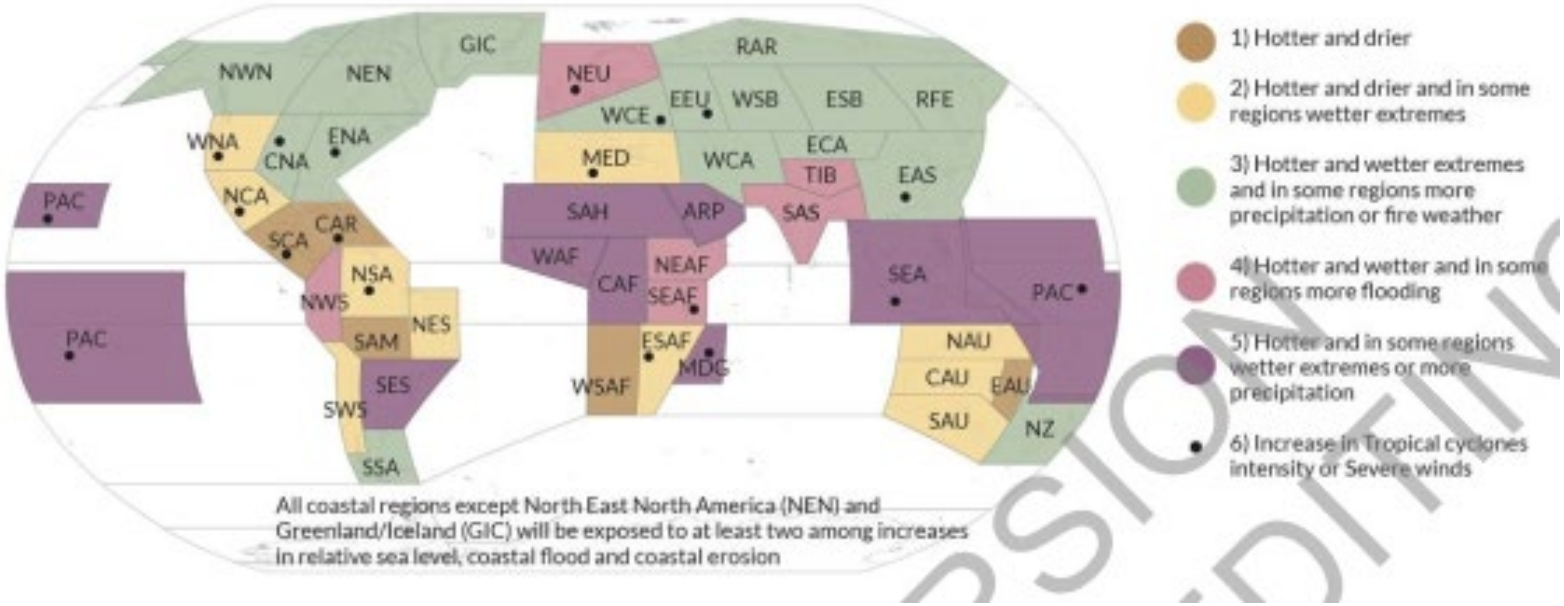


The latest climate change projections (IPCC WG1 AR6)

While changes in climatic impact-drivers will happen everywhere, there is a specific combination of changes each region will experience

World regions grouped into five clusters, each one based on a combination of changes in climatic impact-drivers

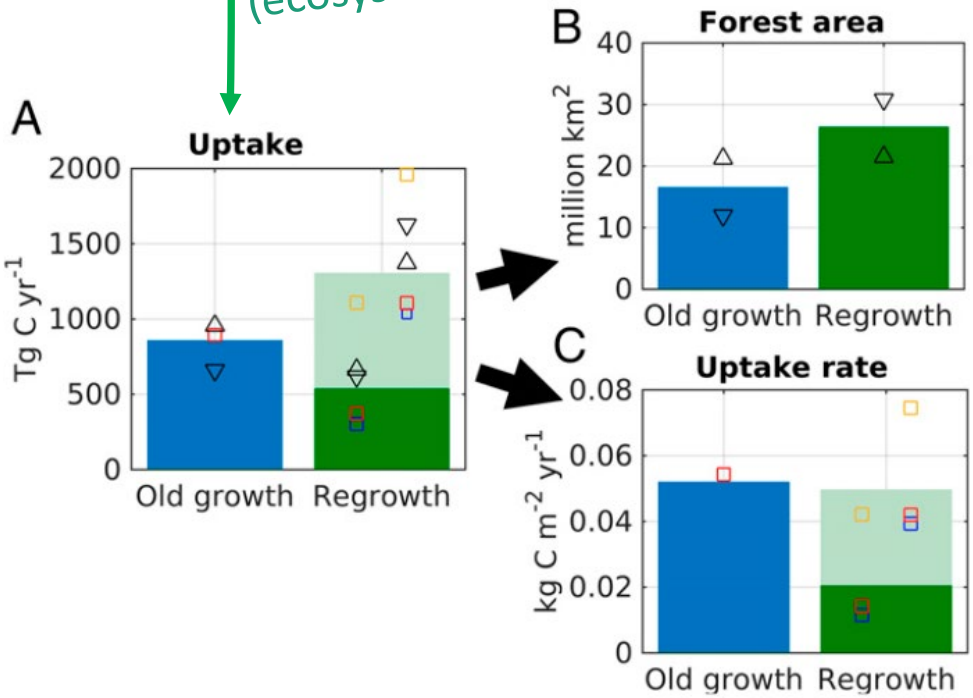
Reference period: Mid 21st century or 2oC GWL compared to a climatological reference period included within 1960-2014



The role of land ecosystems: carbon sink

Nearly 30% of annual CO_2 emissions at present taken up by land ecosystems each year
→ dampens warming considerably!
Processes: CO_2 fertilisation of photosynthesis, warming, forest area expansion, N-deposition.

(ecosystem model + forest age map)



2001-2010
Old growth (>140 years): 0.85 (0.66-0.96) Pg C a^{-1}

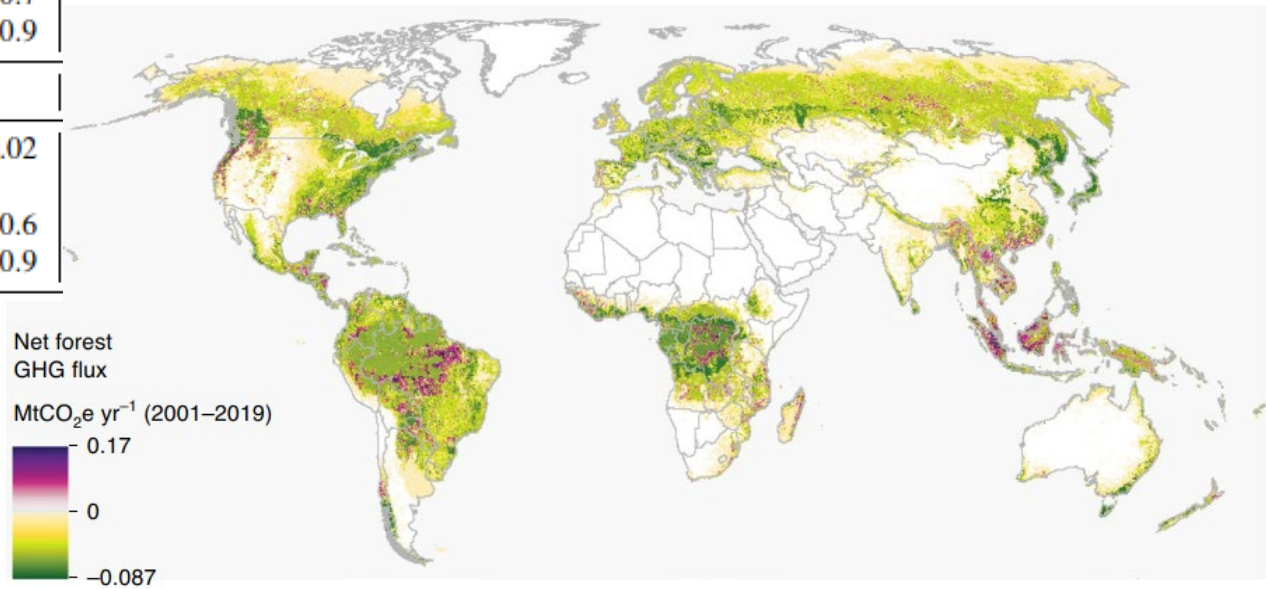
Regrowth: 1.30 (1.03-1.96) Pg C a^{-1}

Nearly 50% from demographic processes alone

Pugh et al., PNAS, 2018

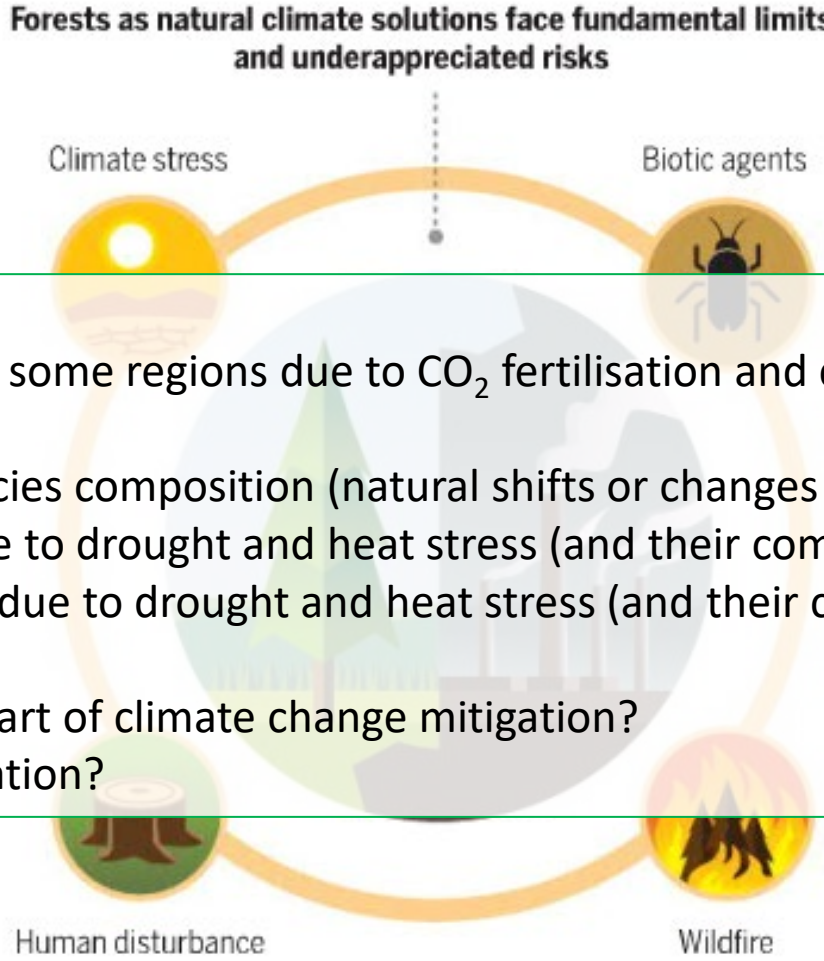
Ecosystems/forests also carbon sources!

Mean ($GtC\ yr^{-1}$)	2010–2019
Total emissions ($E_{FOS} + E_{LUC}$)	
Fossil CO_2 emissions (E_{FOS})*	9.4 ± 0.5
Land-use change emissions (E_{LUC})	1.6 ± 0.7
Total emissions	10.9 ± 0.9
Partitioning	
Growth rate in atmospheric CO_2 concentration (G_{ATM})	5.1 ± 0.02
Ocean sink (S_{OCEAN})	2.5 ± 0.6
Terrestrial sink (S_{LAND})	3.4 ± 0.9



Firedlingstein et al., ESSD 2020; Harris et al., NCC, 2021

Projections of the carbon source/sink



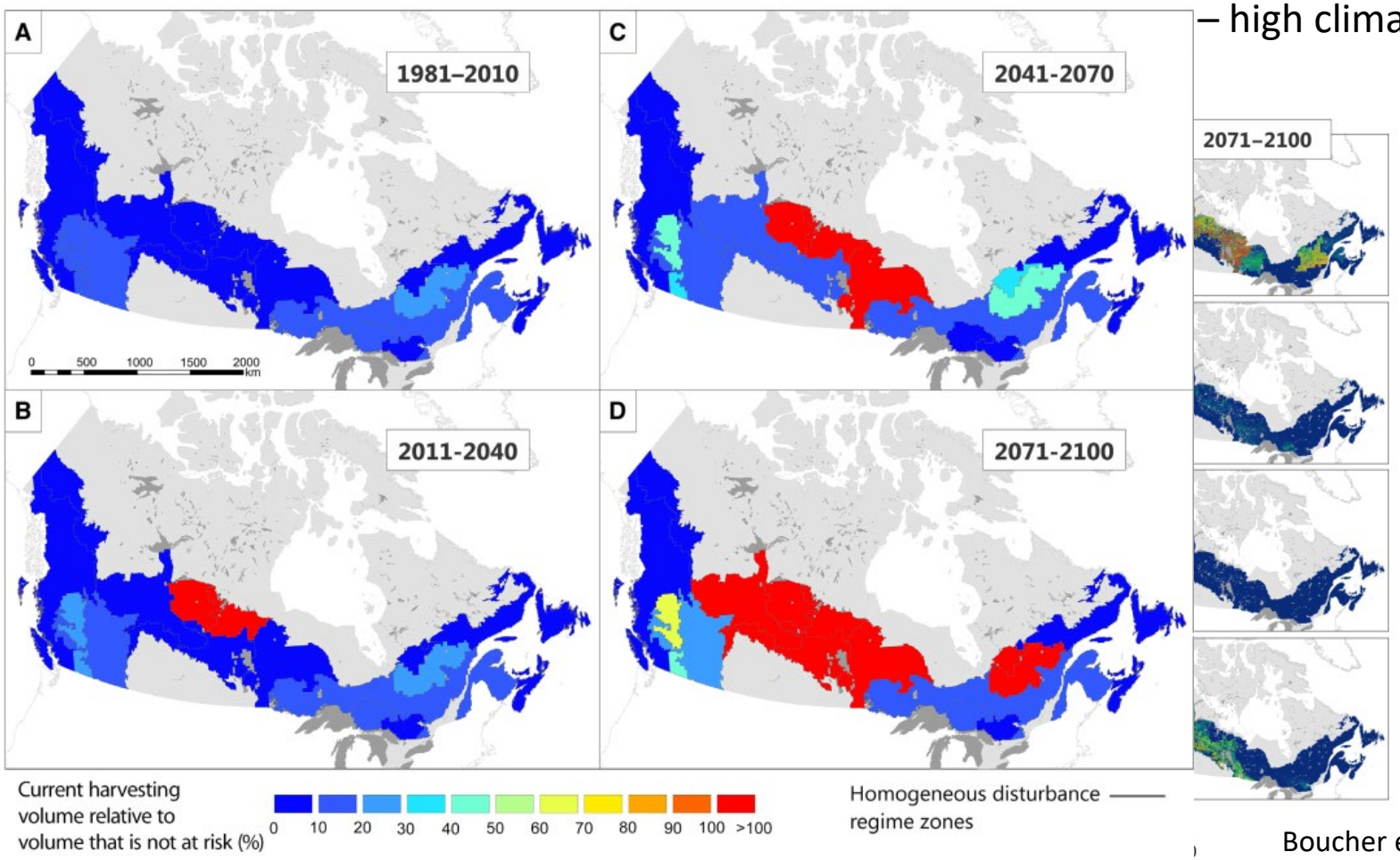
Expected:

- Enhanced growth in some regions due to CO_2 fertilisation and climate-induced longer growing season
- Changes in tree species composition (natural shifts or changes in seedlings planted)
- Reduced growth due to drought and heat stress (and their combination)
- Increased mortality due to drought and heat stress (and their combination), fire, insects, storms…
- Area expansion as part of climate change mitigation?
- Continued deforestation?

Anderegg et al., Science, 2020

Example 1: Canada

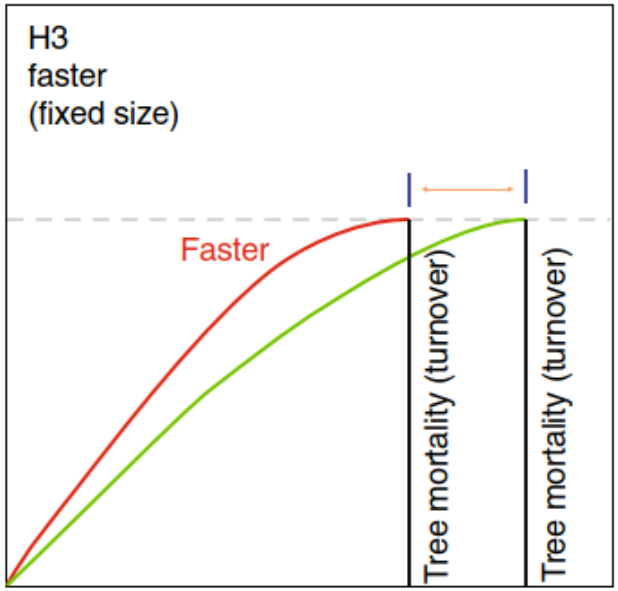
– high climate change)

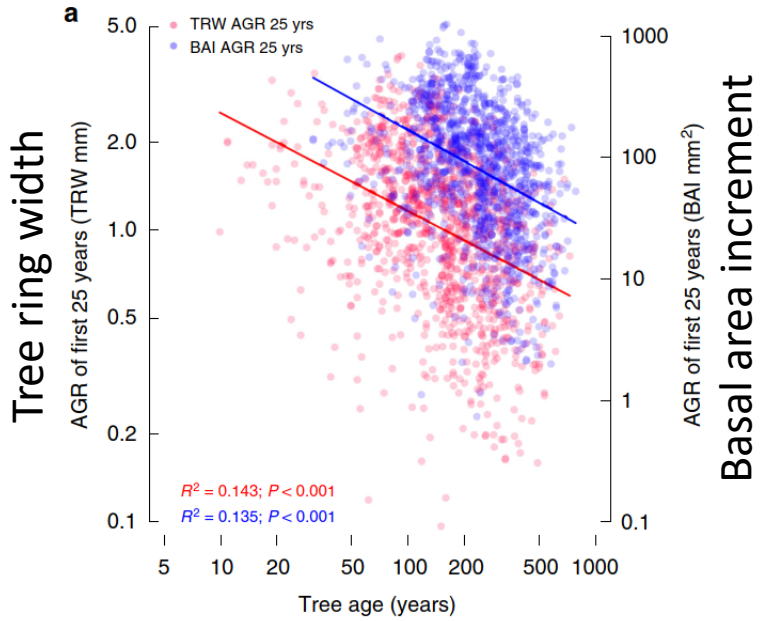


Boucher et al., Ecol. Appl. 2018

Example 2: Tree ring analysis age/lifespan

Tree old ages are reached only if juvenile growth is slow – Climate change will accelerate growth rates in many regions → Shorter forest lifetime





Büntgen et al., Nat. Comm., 2019

Will planting trees safe the climate?

“Excluding existi e found that there is room for an extra 0.9 b l store 205 gigatonnes of carbon in areas th forests. This highlights global tree restora olution to date. “

Will planting trees safe the climate?

"Excluding existi e found that there is room for an extra 0.9 bi l store 205 gigatonnes of carbon in areas th orests. This highlights global tree restora olution to date. "

- Mistakes in their carbon uptake calculations
- Unrealistic areas assumed available for reforestation/afforestation (all pastures)
- Some non-forest ecosystems very carbon rich (savannahs)
- Did not consider risks to forests arising from climate change
- Seedling material unavailable at those quantities

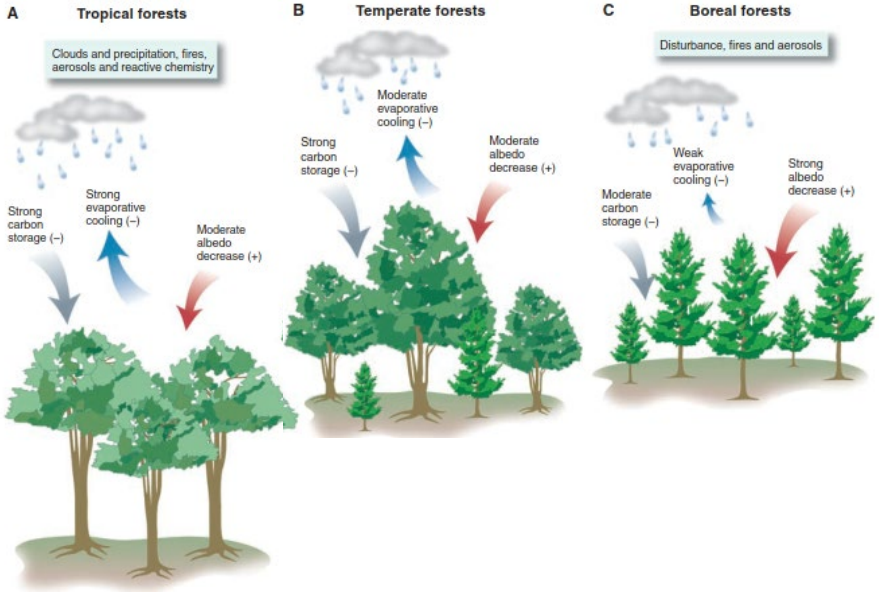
Will planting trees safe the climate?

Biophysical exchange processes complicate the matter further

→ Reforestation in tropics: cool the surface.

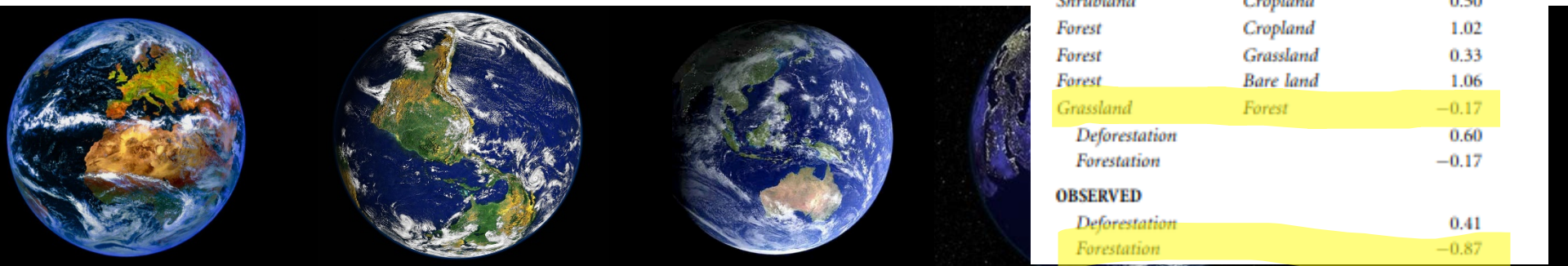
→ Reforestation in boreal env.: warm the surface

→ Reforestation in temperate env: ?



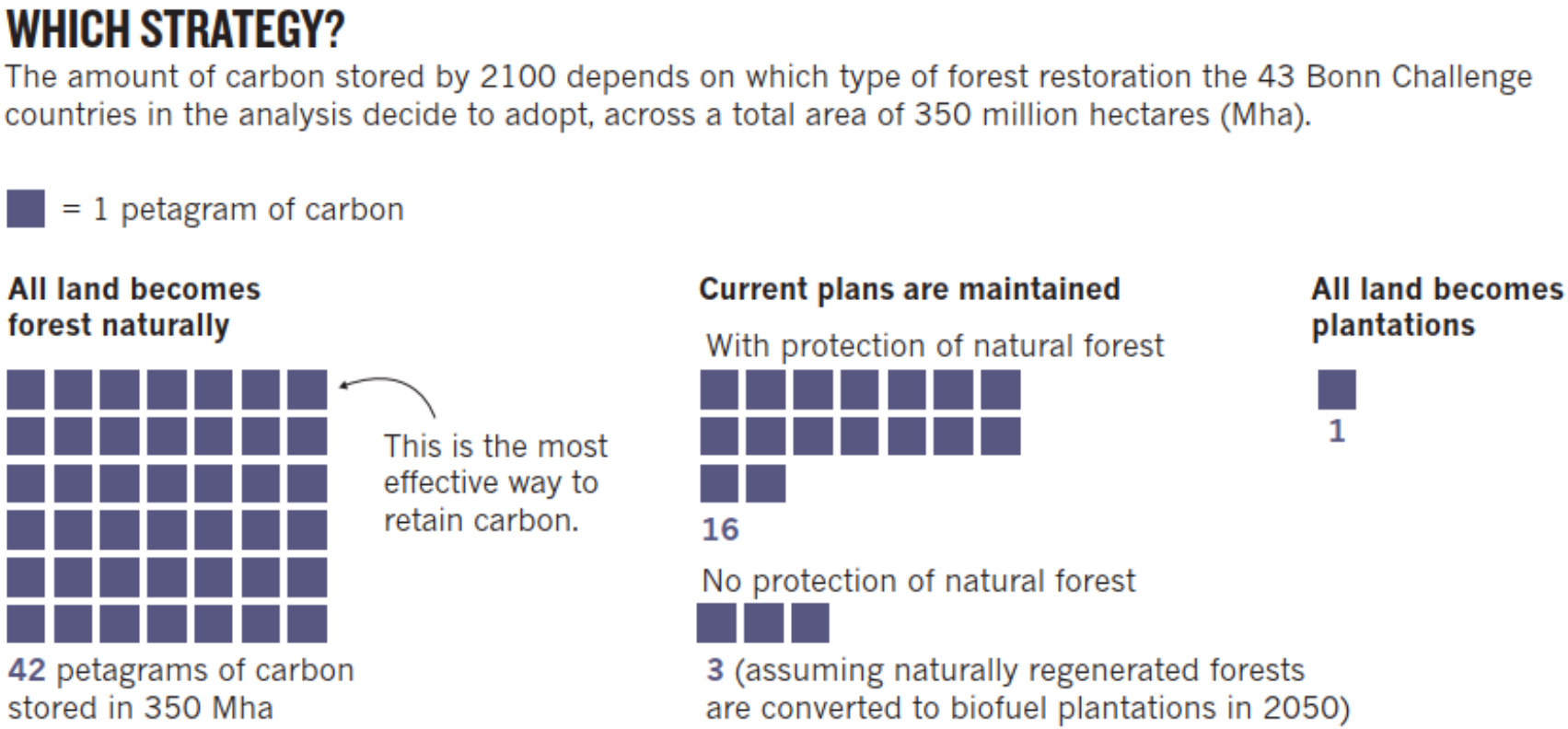
Perugini et al., ERL, 2017; Bonan et al., Science, 2010

From	To	Mean/value*
(a) Boreal		
MODELLED		
Grassland	*Forest*	1.20*
Forest	*Grassland*	−1.96
Forest	*Bare land*	−2.41
Deforestation		−2.18
Forestation		1.2*
OBSERVED		
Deforestation		−0.59
Forestation		0.59
(b) Temperate		
MODELLED		
Grassland	*Bare land*	0.55
Forest	*Bare land*	−0.82
Forest	*Cropland*	−0.30*
Forest	*Grassland*	−0.8*
Shrub land	*Bare land*	0.30*
Other land	*Forest*	0.56*
Deforestation		−0.73
Forestation		0.56*
OBSERVED		
Deforestation		0.50
Forestation		−0.50
(c) Tropical		
MODELLED		
Shrubland	*Bare land*	0.55
Shrubland	*Cropland*	0.50*
Forest	*Cropland*	1.02
Forest	*Grassland*	0.33
Forest	*Bare land*	1.06
Grassland	*Forest*	−0.17
Deforestation		0.60
Forestation		−0.17
OBSERVED		
Deforestation		0.41
Forestation		−0.87



Then shouldn‘t we plant more trees at all?

Yes – if done well!



Lewis et al., Nature 2019

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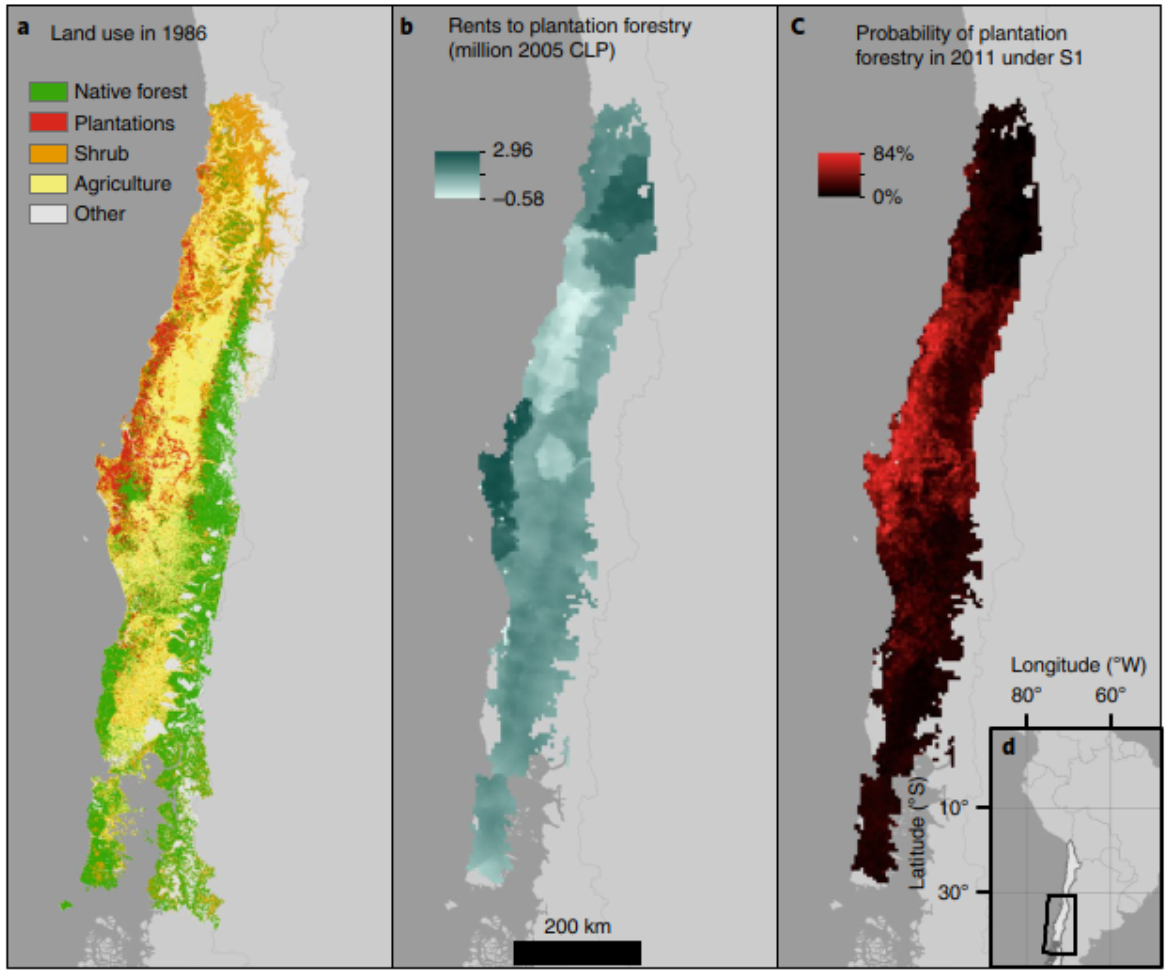
Practice	Summary/synopsis of overall expected impact	Mitigation potential	Adaptation potential (estimated number of people more resilient to climate change from intervention)	Biodiversity impact (positive unless otherwise stated)
Reforestation and forest restoration		1.5-10.1 Gt CO_2e a^{-1}	> 25 million people	High
Afforestation		See Reforestation	Unclear	Negative/Low positive[3]
Reduced deforestation and degradation		0.4-5.8 Gt CO_2e a^{-1}	1-25 million people	High
Agroforestry		0.1-5.7 Gt CO_2e a^{-1}	2300 million people	High

Arneth et al., ARER, 2021; IPCC/IPBES workshop report, 2021

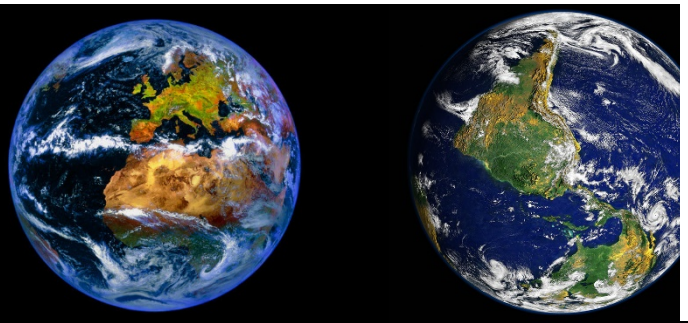
Then shouldn‘t we plant more trees at all?

But think carefully!

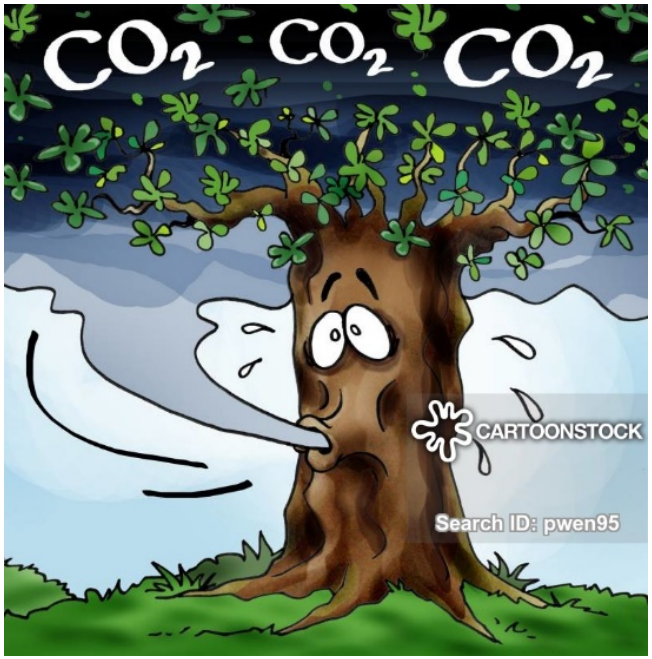
Subsidies in Chile to enhance forest cover → payments for afforestation increased tree cover through expansion of plantations of exotic species but decreased the area of native forests (1986-2011). Subsidies contributed to an additional loss of 5% of forest.



Heilmayr et al., Nat. Sust., 2020



Take home message



1) Future climate change expected to enhance risks to forests (and C sink strength), especially via extreme weather

2) Stopping deforestation and forest restoration can provide large co benefits in the climate-biodiversity nexus

3) Don't rely on forests to safe us from climate change (-see (1)) – the land area is limited…