Climate change and mountain vegetation

Forest mitigation, adaptation and management

UNIVERSITÀ DEGLI STUDI DI MILANO
LA STATALE

DiSAA
DIPARTIMENTO di SCIENZE AGRARIE e AMBIENTALI

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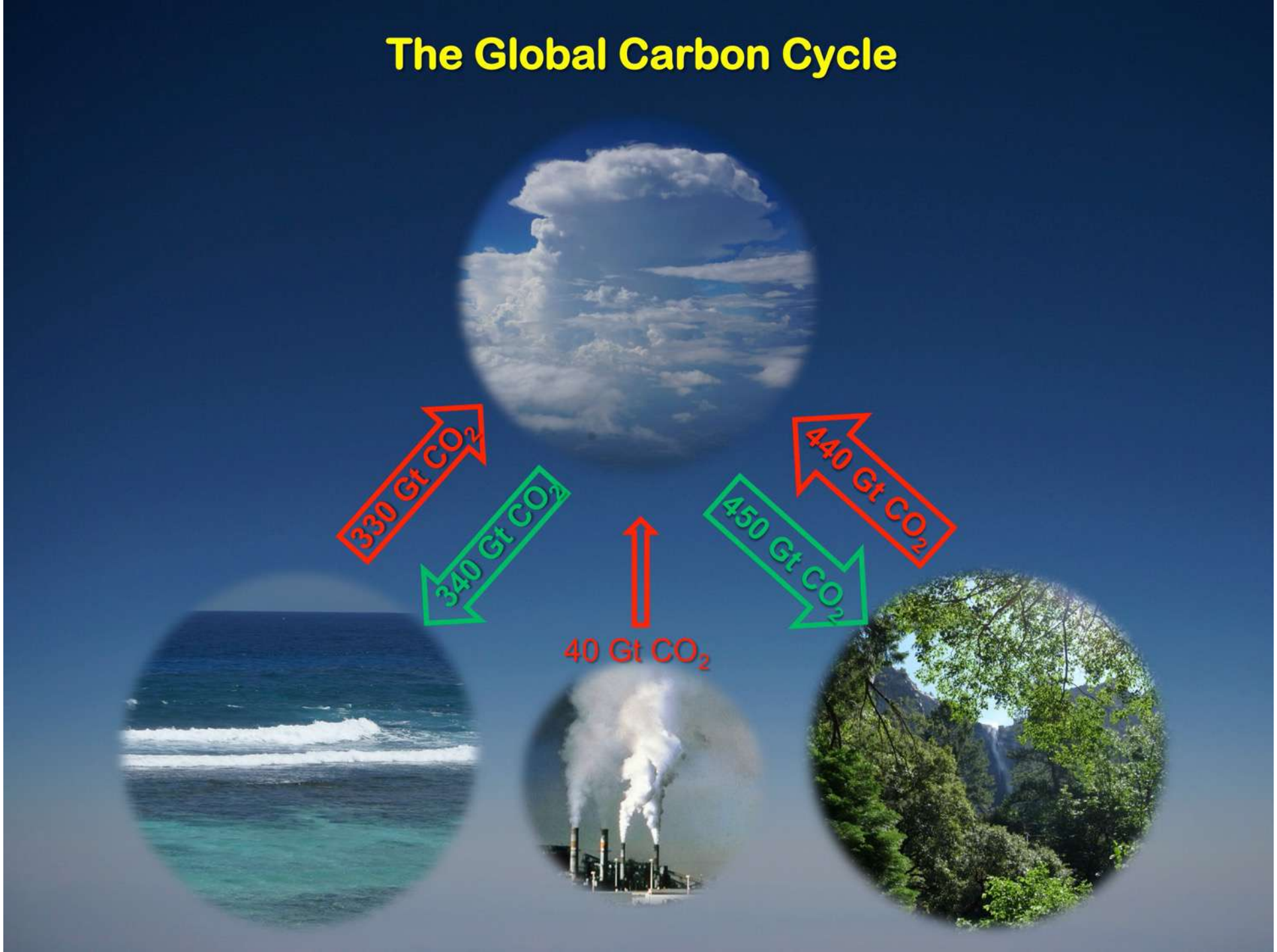
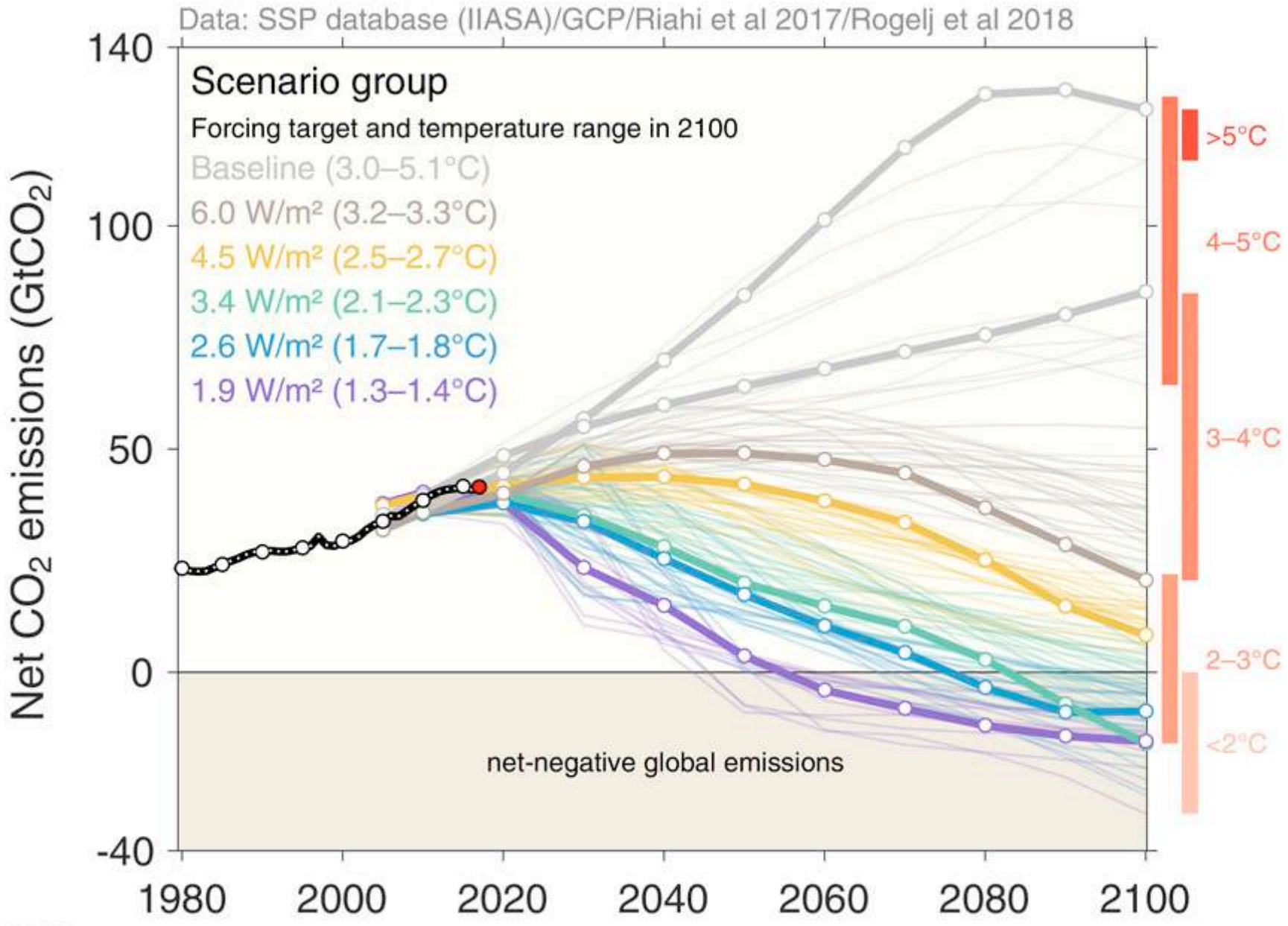
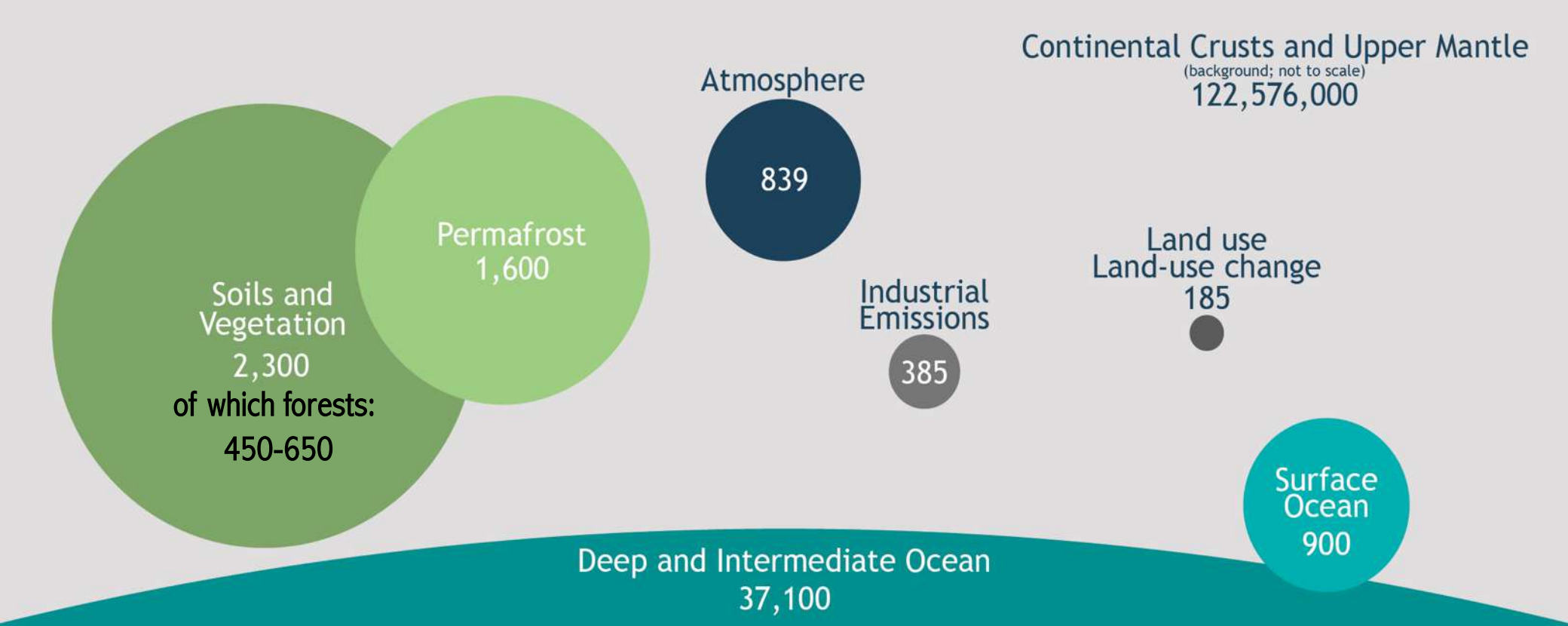
The Global Carbon Cycle

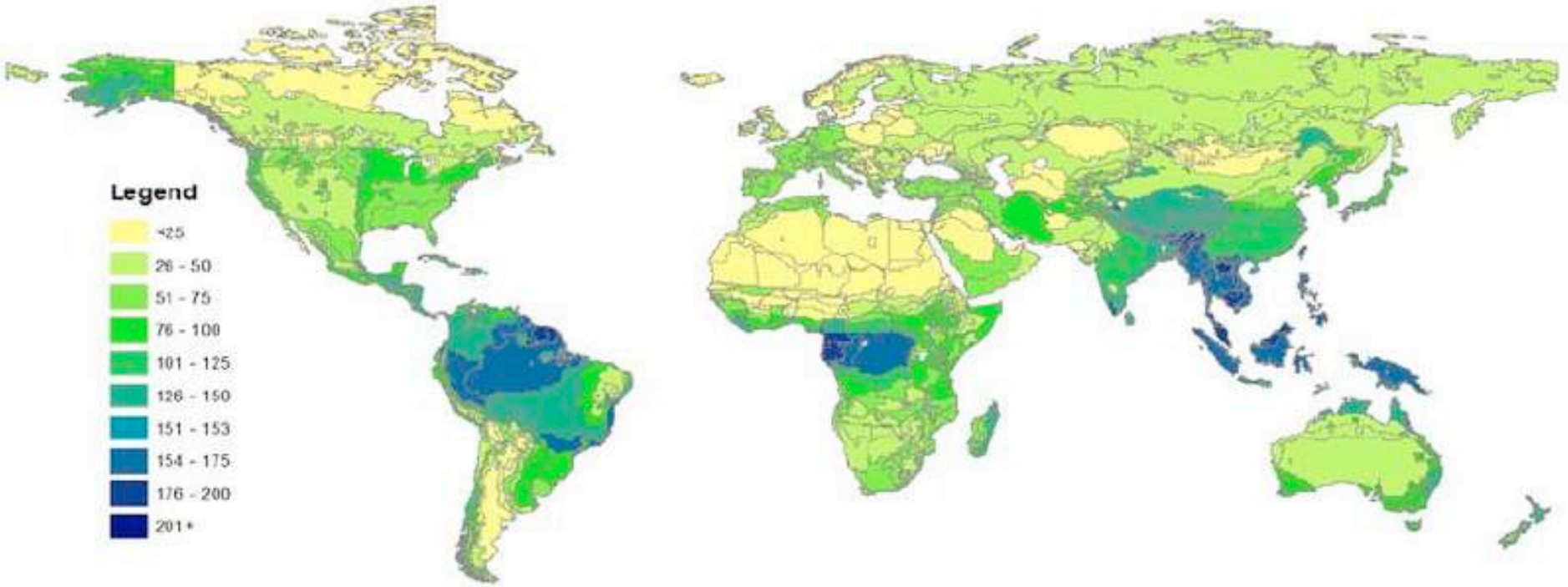


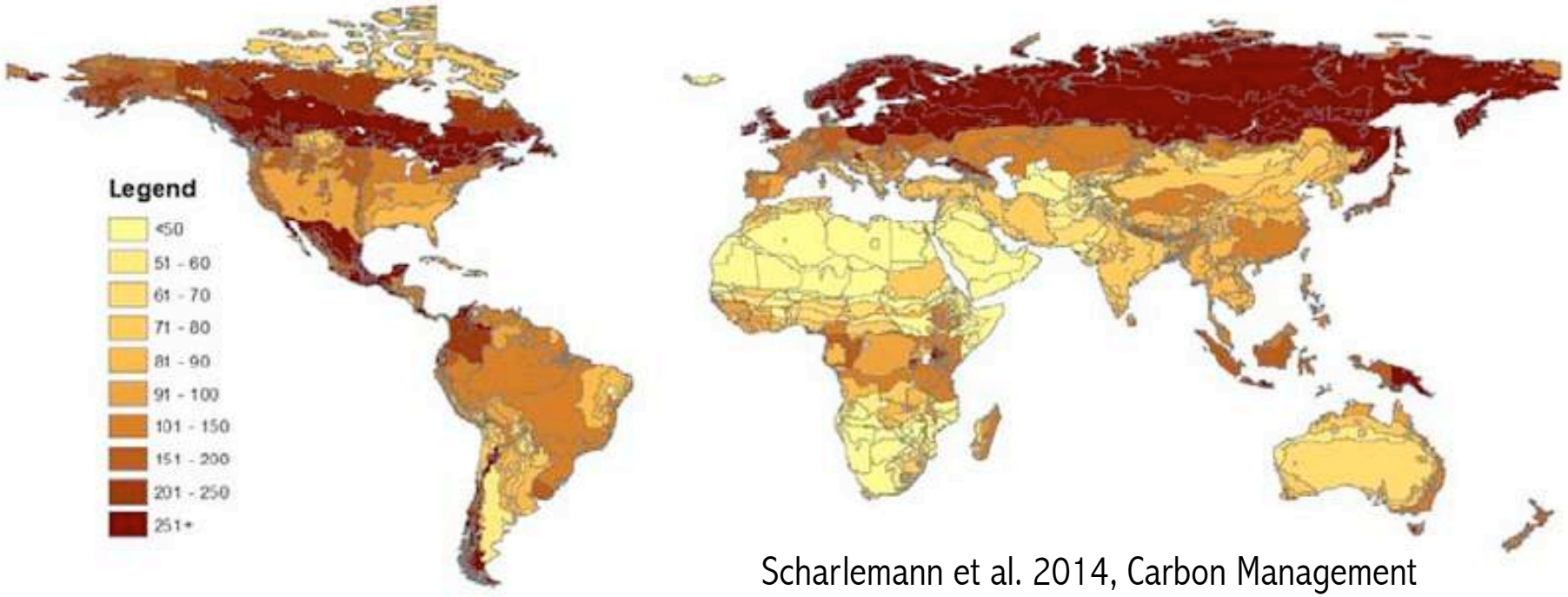


«Negative emissions»?



Earth's carbon pools

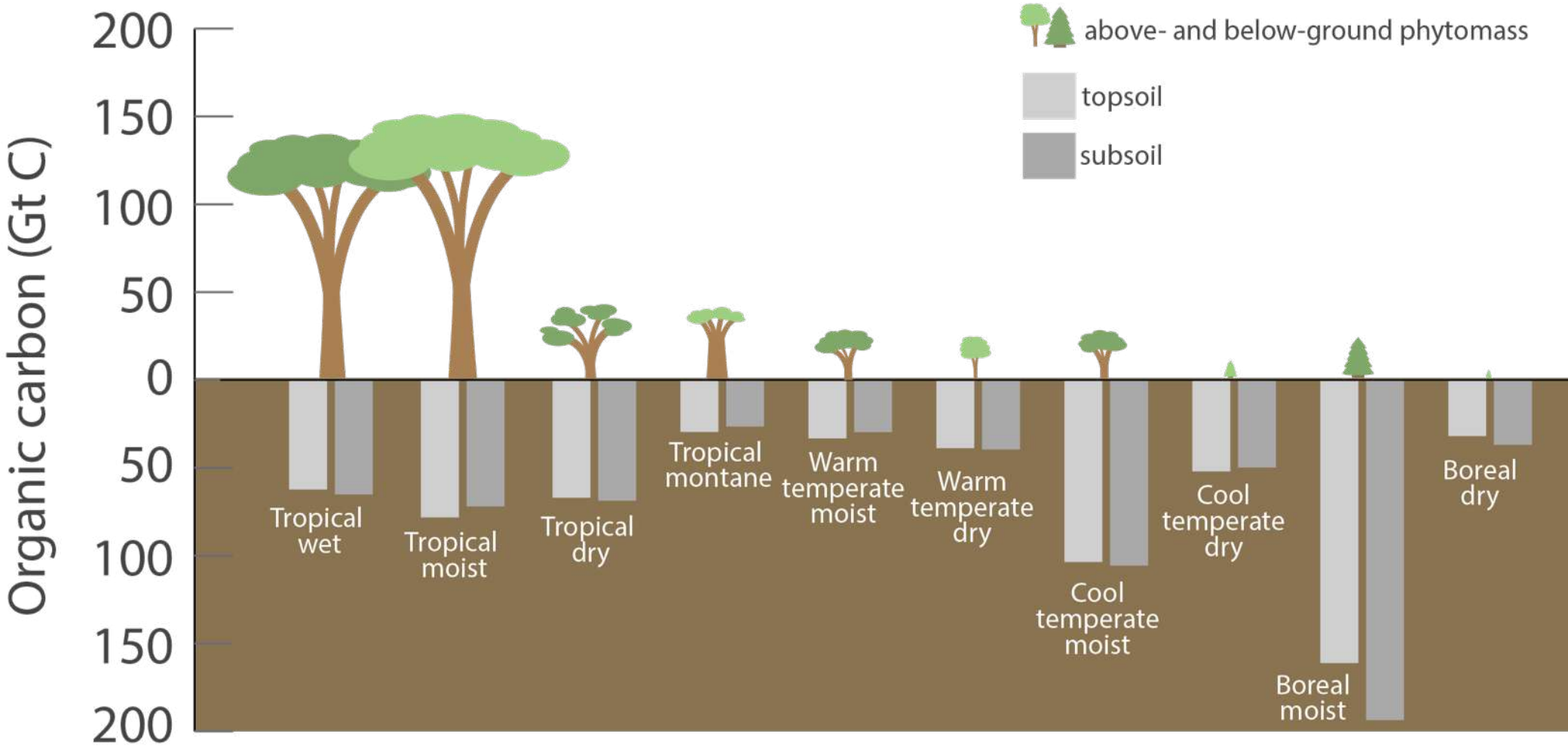




Biomass tC/ha

Soil (0-100 cm) tC/ha

Scharlemann et al. 2014, Carbon Management

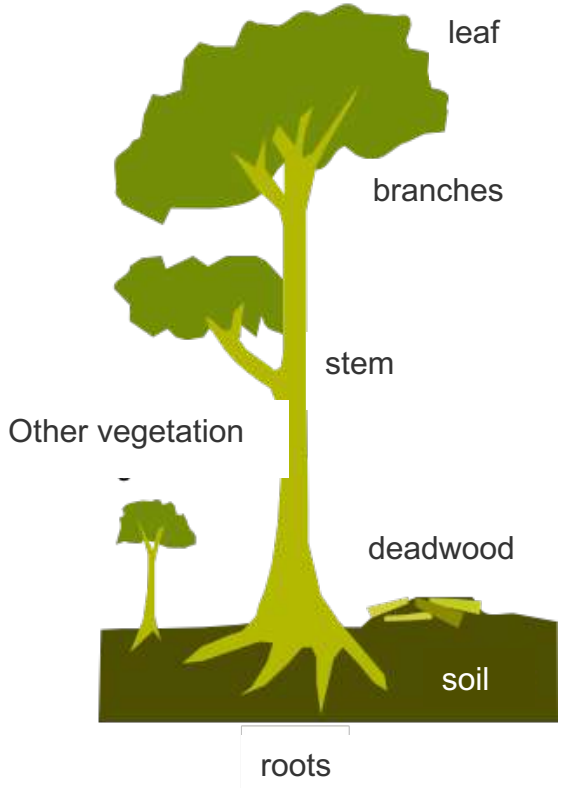


Scharlemann et al. 2014, Carbon Management

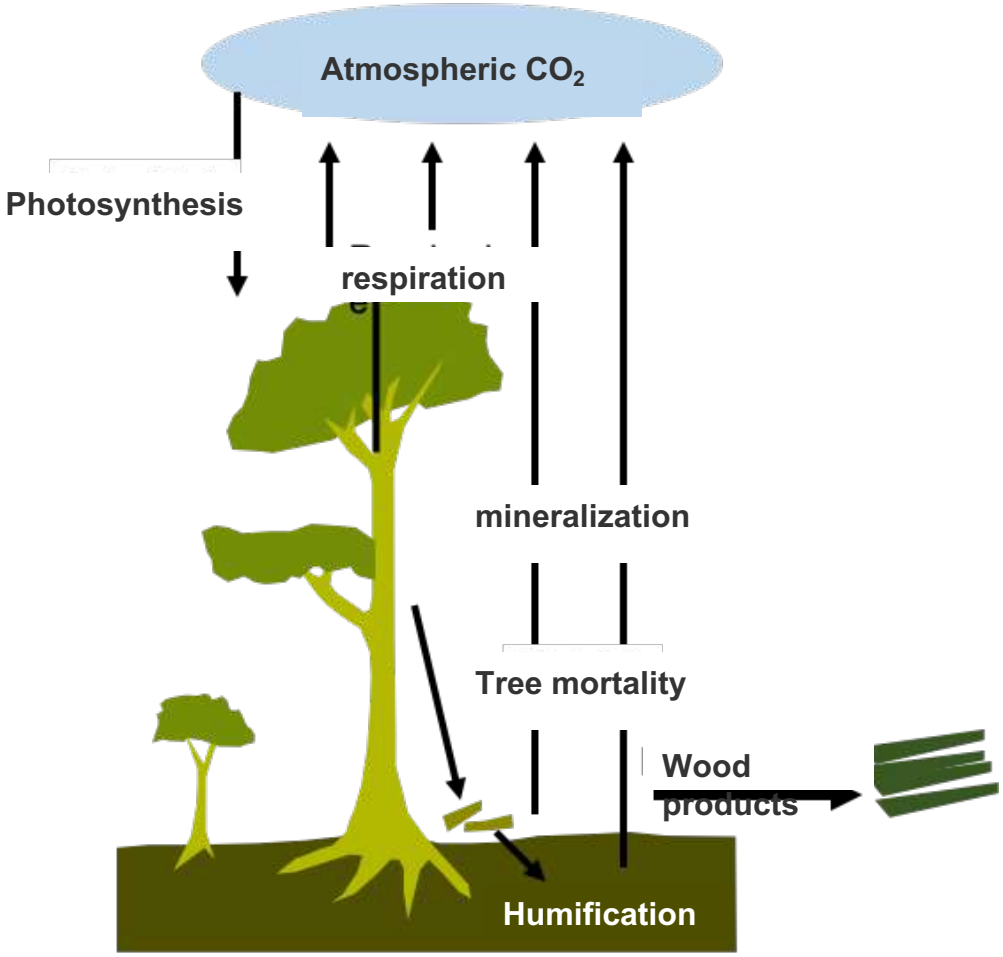
Pools and fluxes of carbon in trees

Pools

- 1 kg woody biomass (dry) ≈ 0.5 kg C
- **Aboveground biomass**: 65 - 430 tC/ha
- **Soil**: 44 -130 tC/ha (up to 60% total C pool)

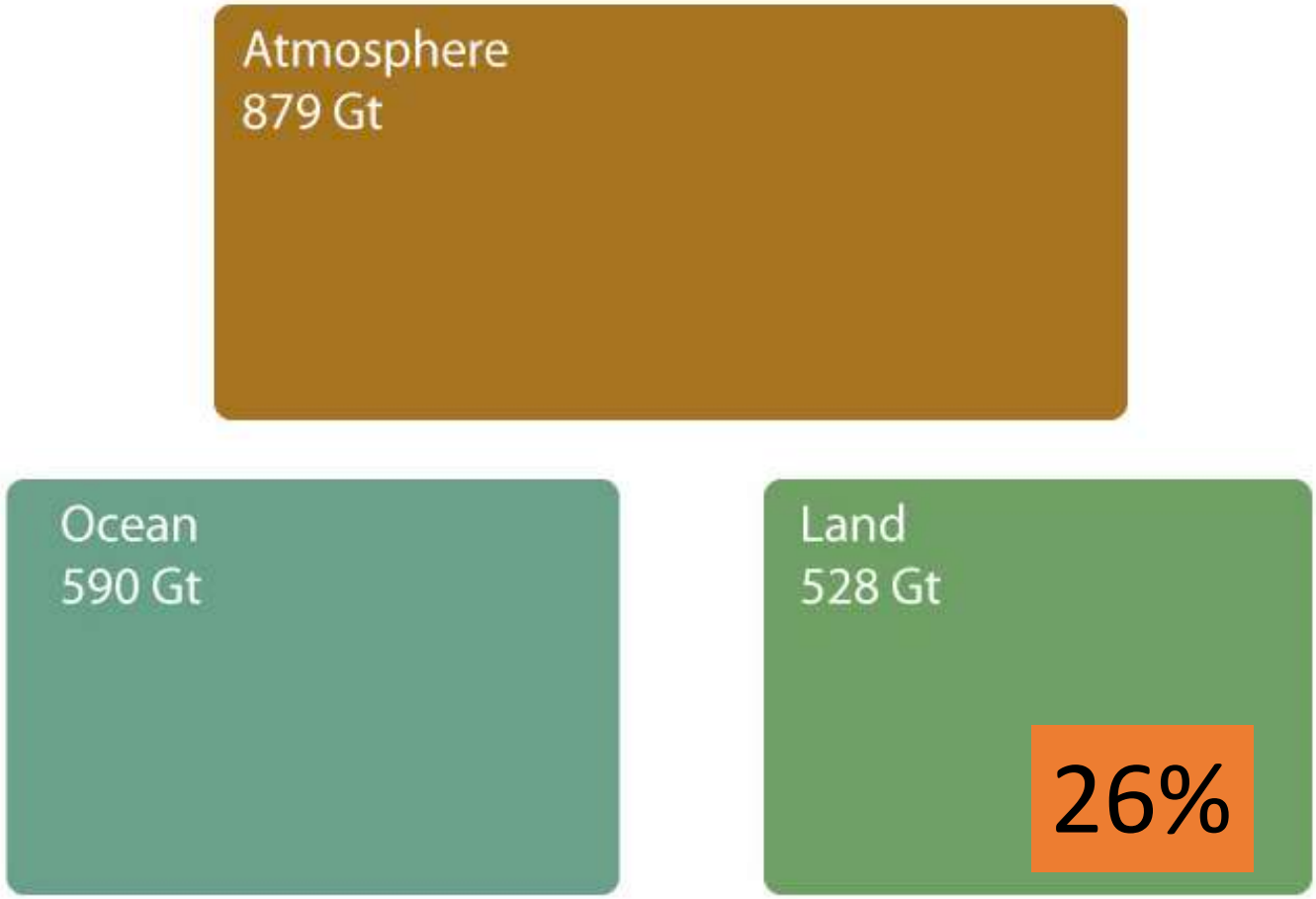


Fluxes

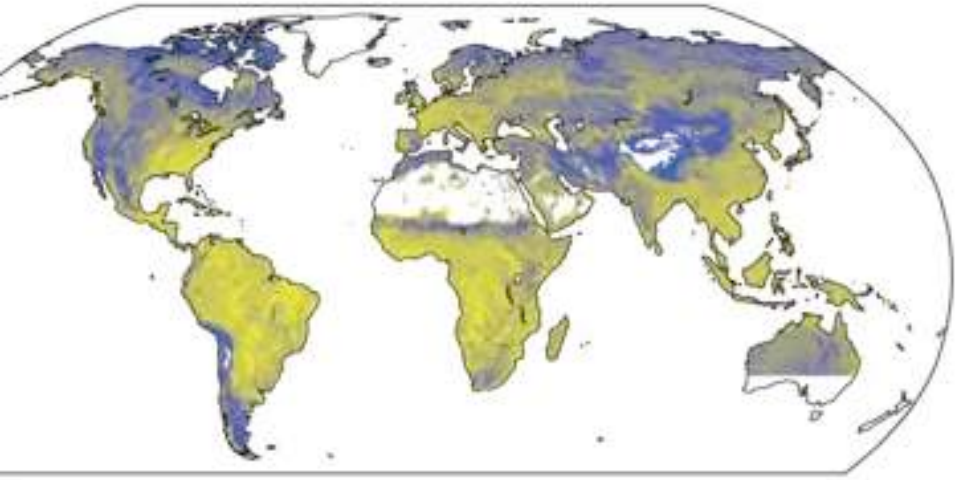


Destination of CO_2 emitted from 1750 to 2012 (in billions of tons)

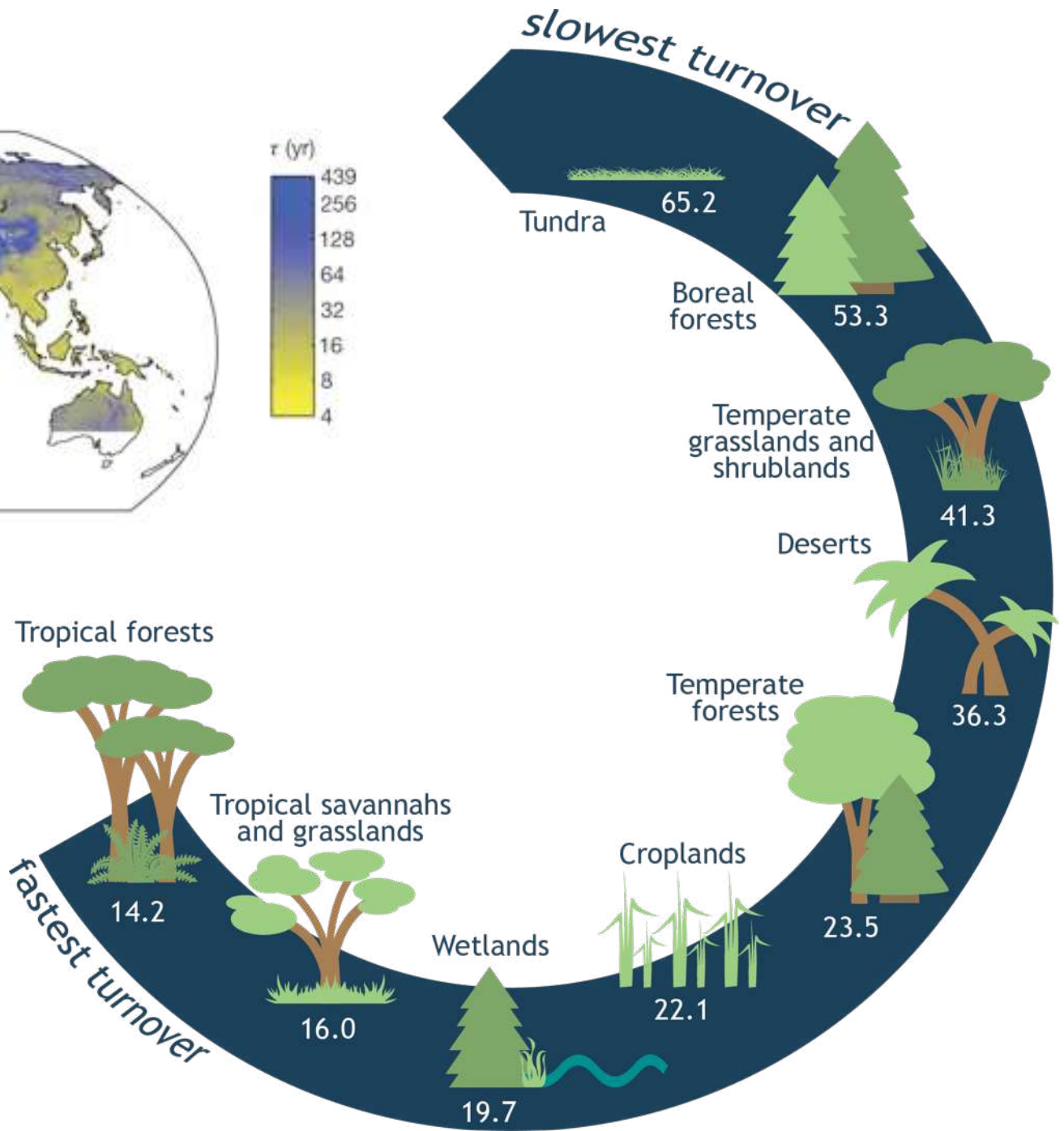
Fonte: Global Carbon Project



Carbon turnover



Carvalhais et al. 2014, Nature



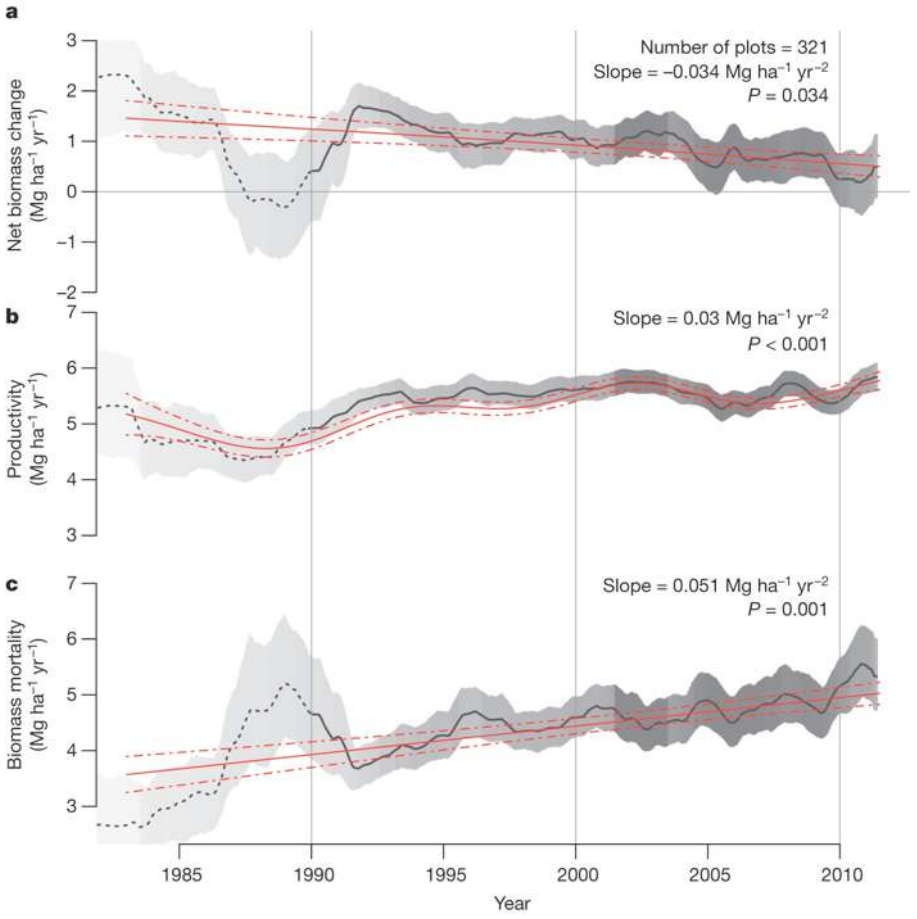
Deforestation emissions

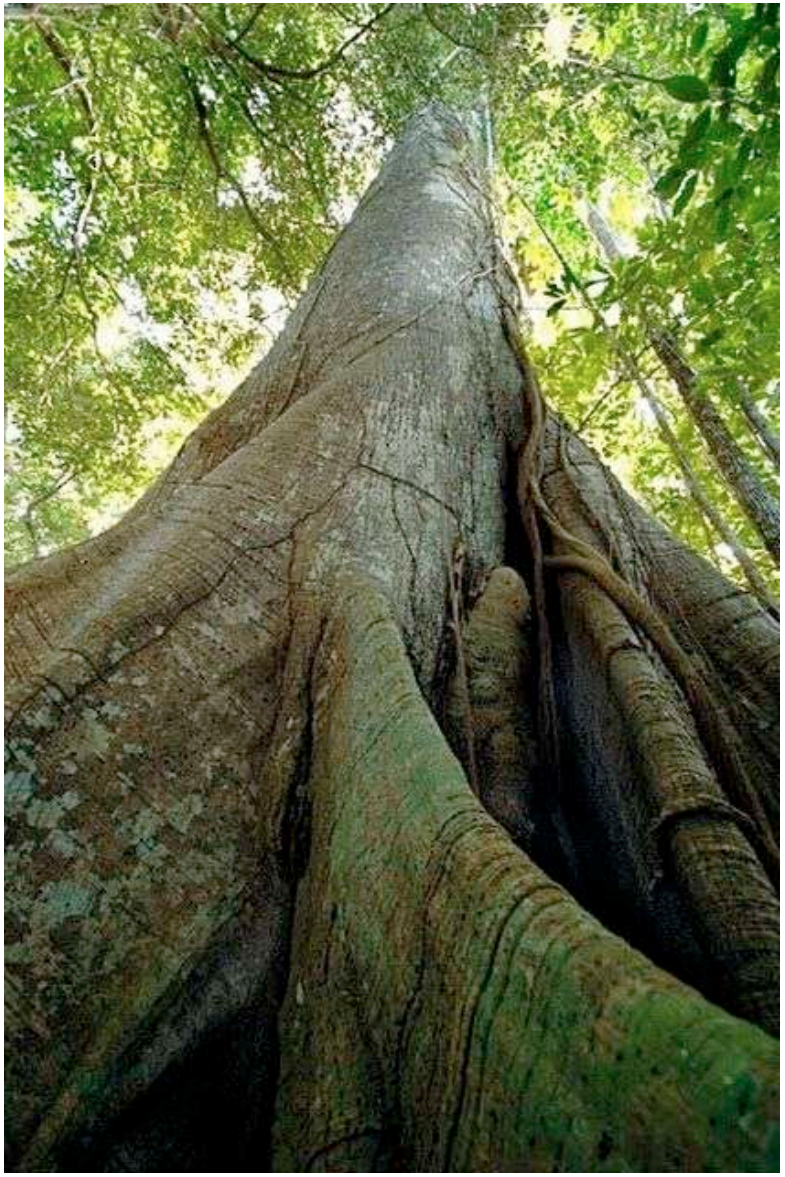
2.9 Gt CO_2 $year^{-1}$

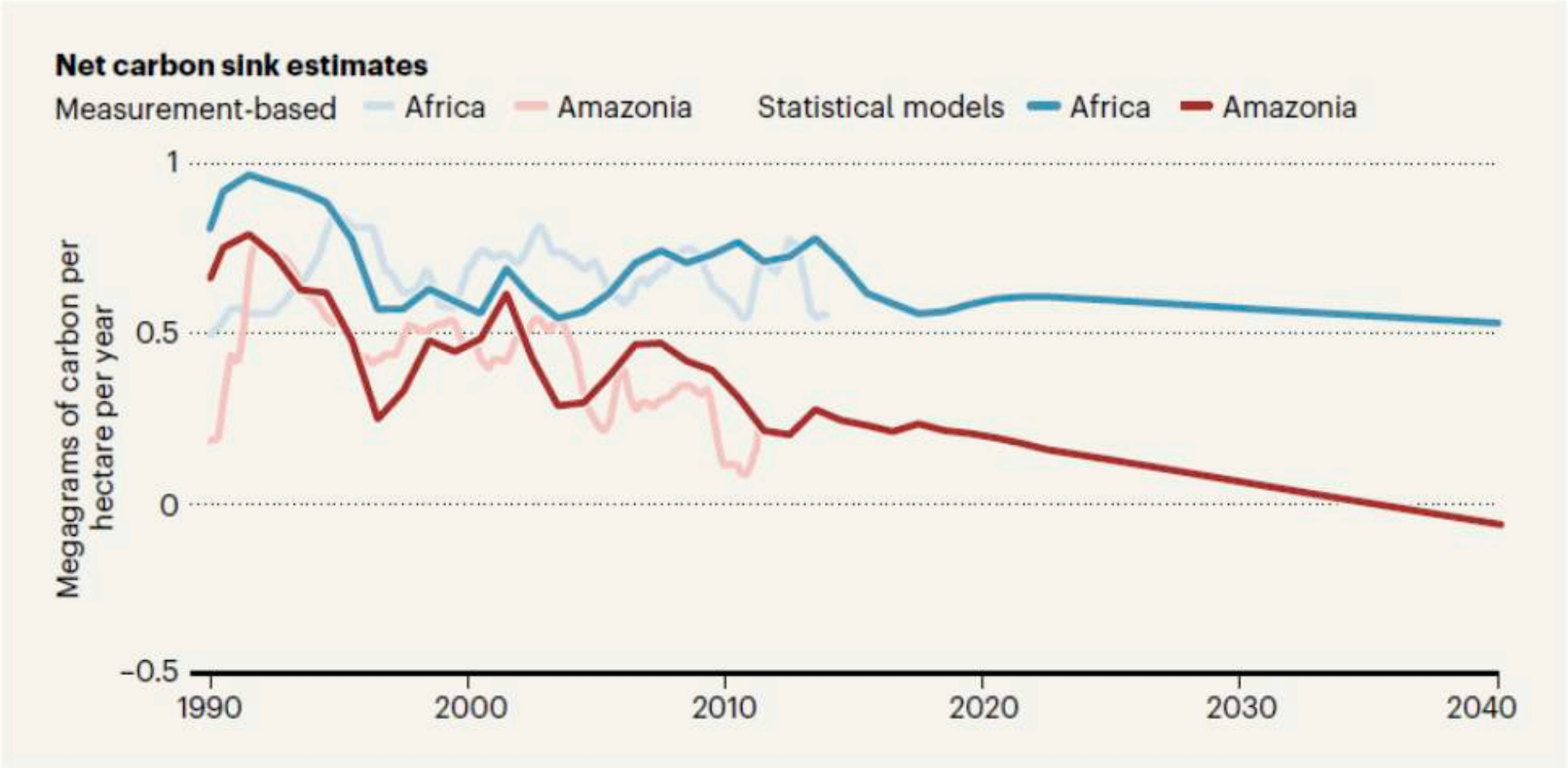
Of which 29-39% for internationally traded goods

Pendrill et al. 2019, Glob Env Change


Fire emissions
7.3 Gt CO_2 year^{-1}
Van der Werf et al. 2010, Atmos Chem Phys


a
Number of plots = 321
Slope = –0.034 Mg ha⁻¹ yr⁻²
P = 0.034
Net biomass change (Mg ha⁻¹ yr⁻¹)
b
Slope = 0.03 Mg ha⁻¹ yr⁻²
P < 0.001
Productivity (Mg ha⁻¹ yr⁻¹)
c
Slope = 0.051 Mg ha⁻¹ yr⁻²
P = 0.001
Biomass mortality (Mg ha⁻¹ yr⁻¹)
1985
1990
1995
2000
2005
2010
Year



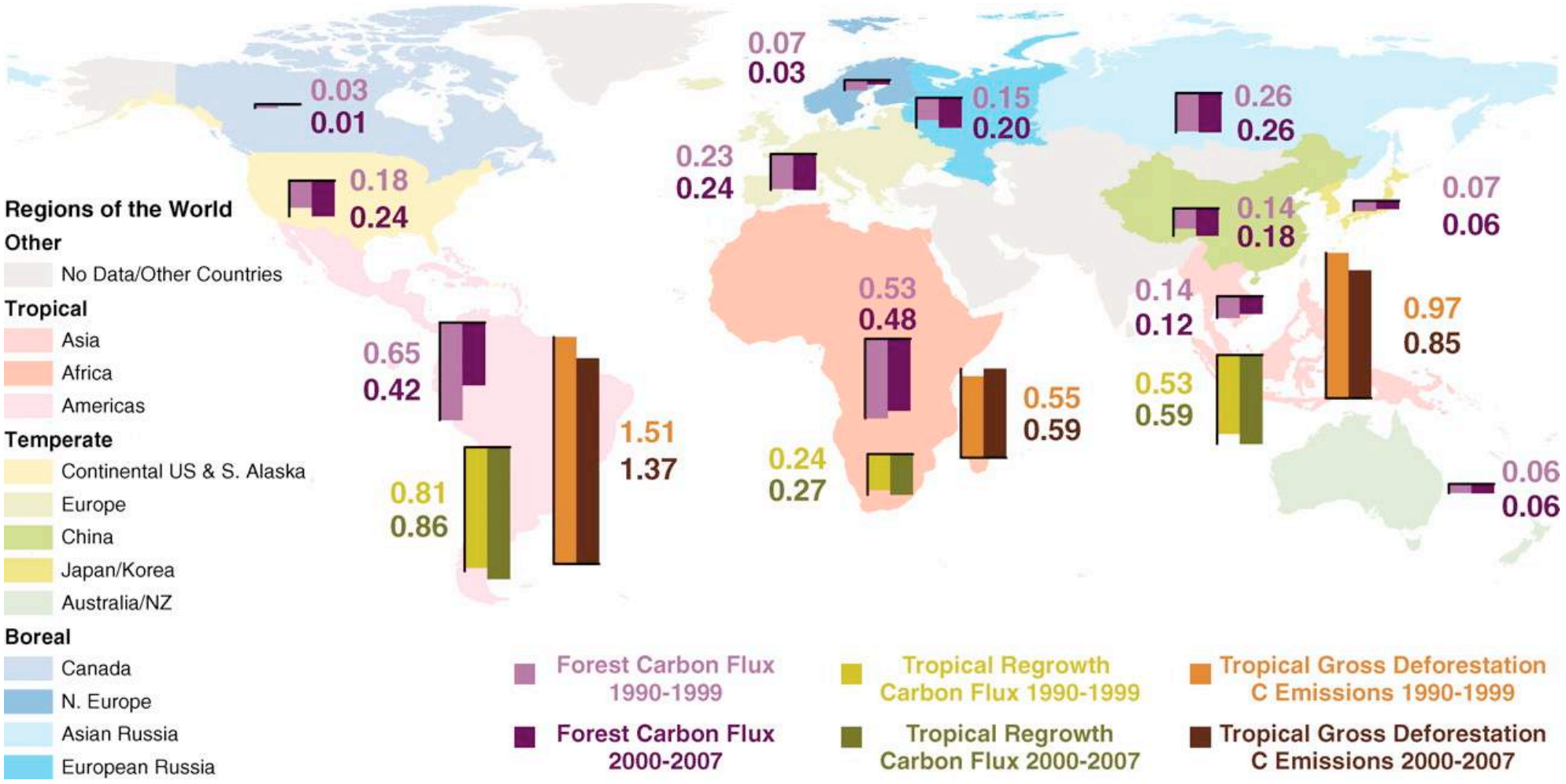


Amazon C sink in strongest decline, continued throughout 2010s and predicted to reach zero by 2030 – But net C sink reductions are mainly due to increases in turnover/mortality, not lowering off productivity.

CO_2 fluxes (Gt) in Earth's forests

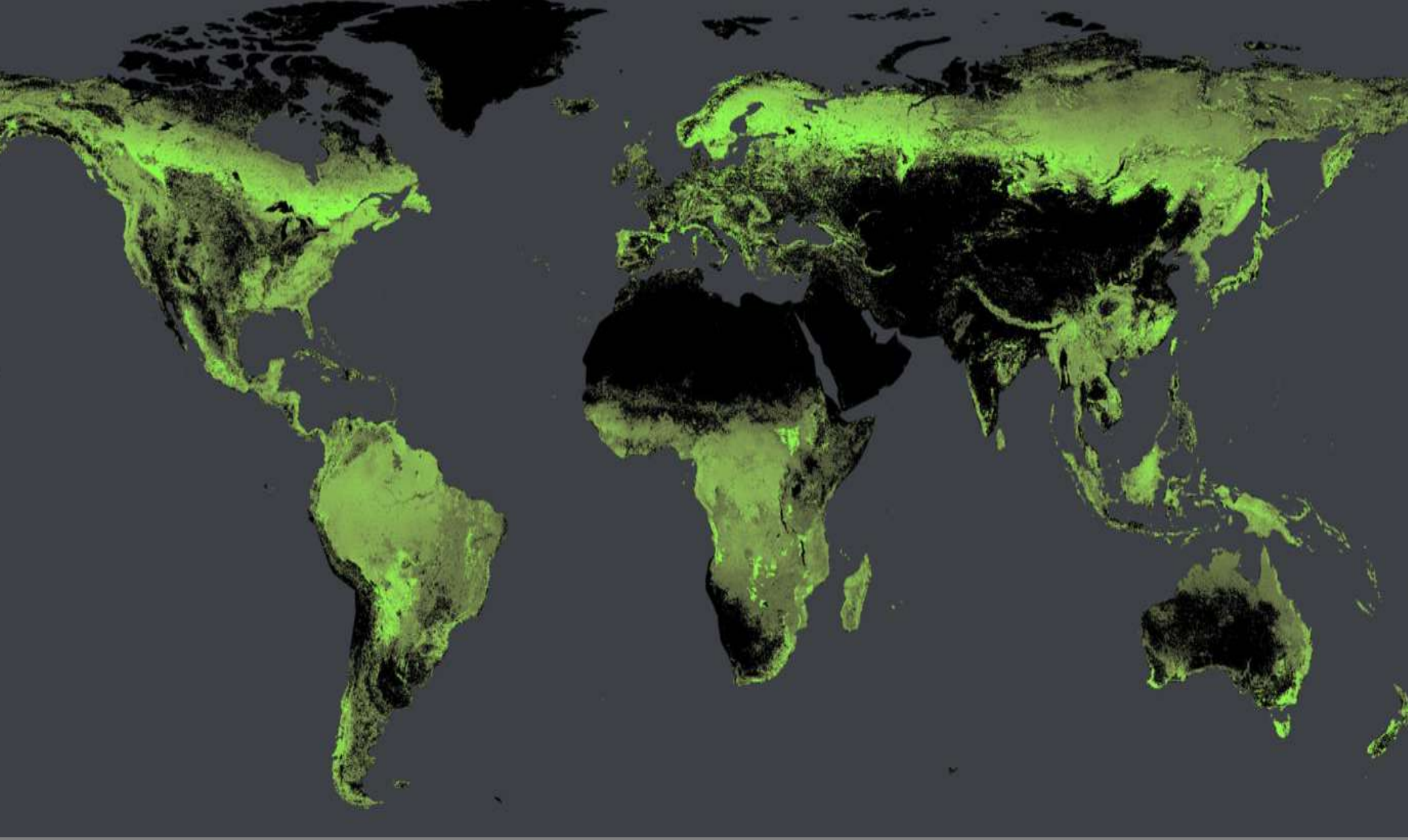
Net sequestration = 4.0 ± 2.0 Gt CO_2 $year^{-1}$

Net mean sequestration (without deforestation) = 2.9 t CO_2/ha $year^{-1}$



Pan et al. 2011, Nature

Photo: Pixabay

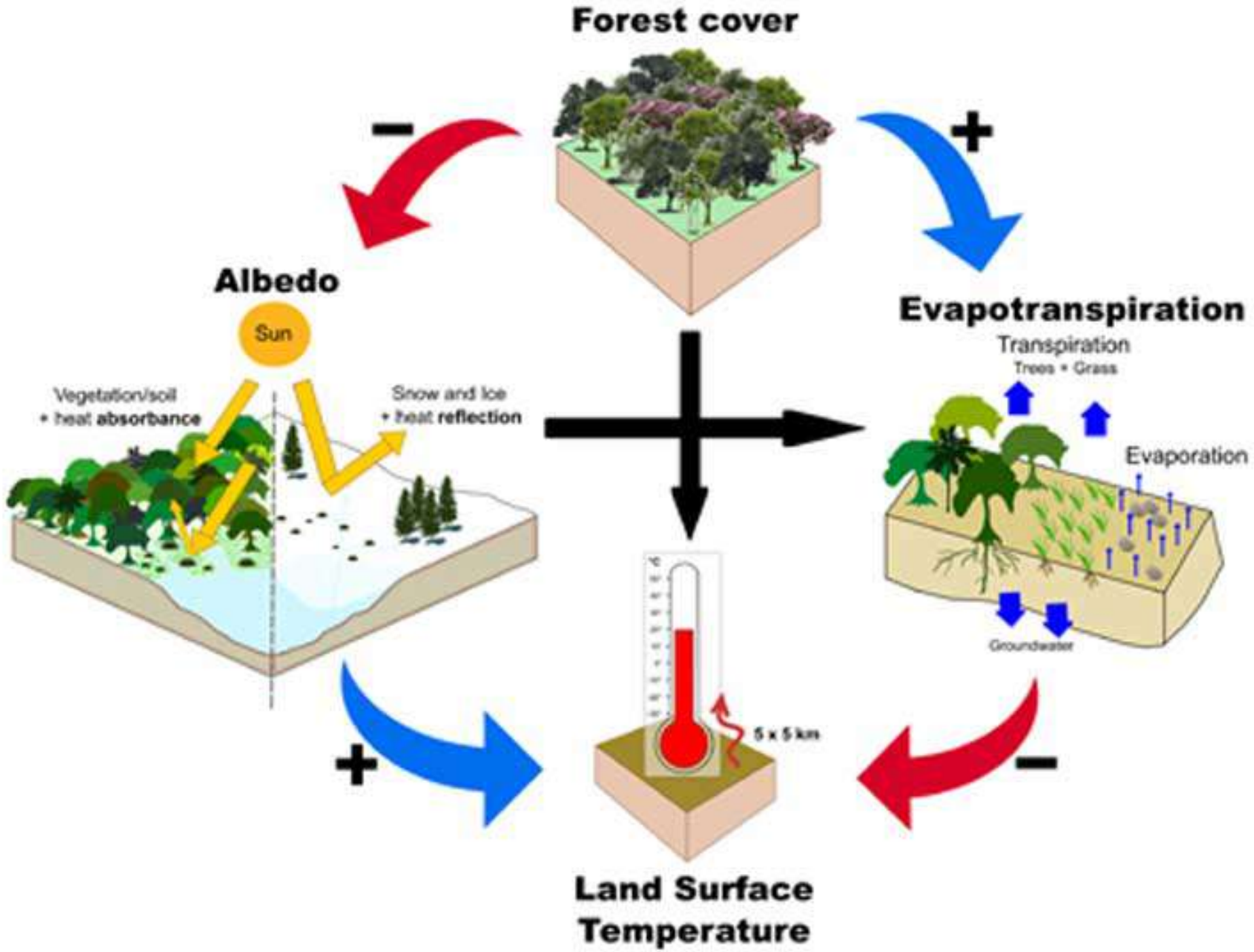


Area available for tree planting

Source: Bastin et al. 2019 (Science)

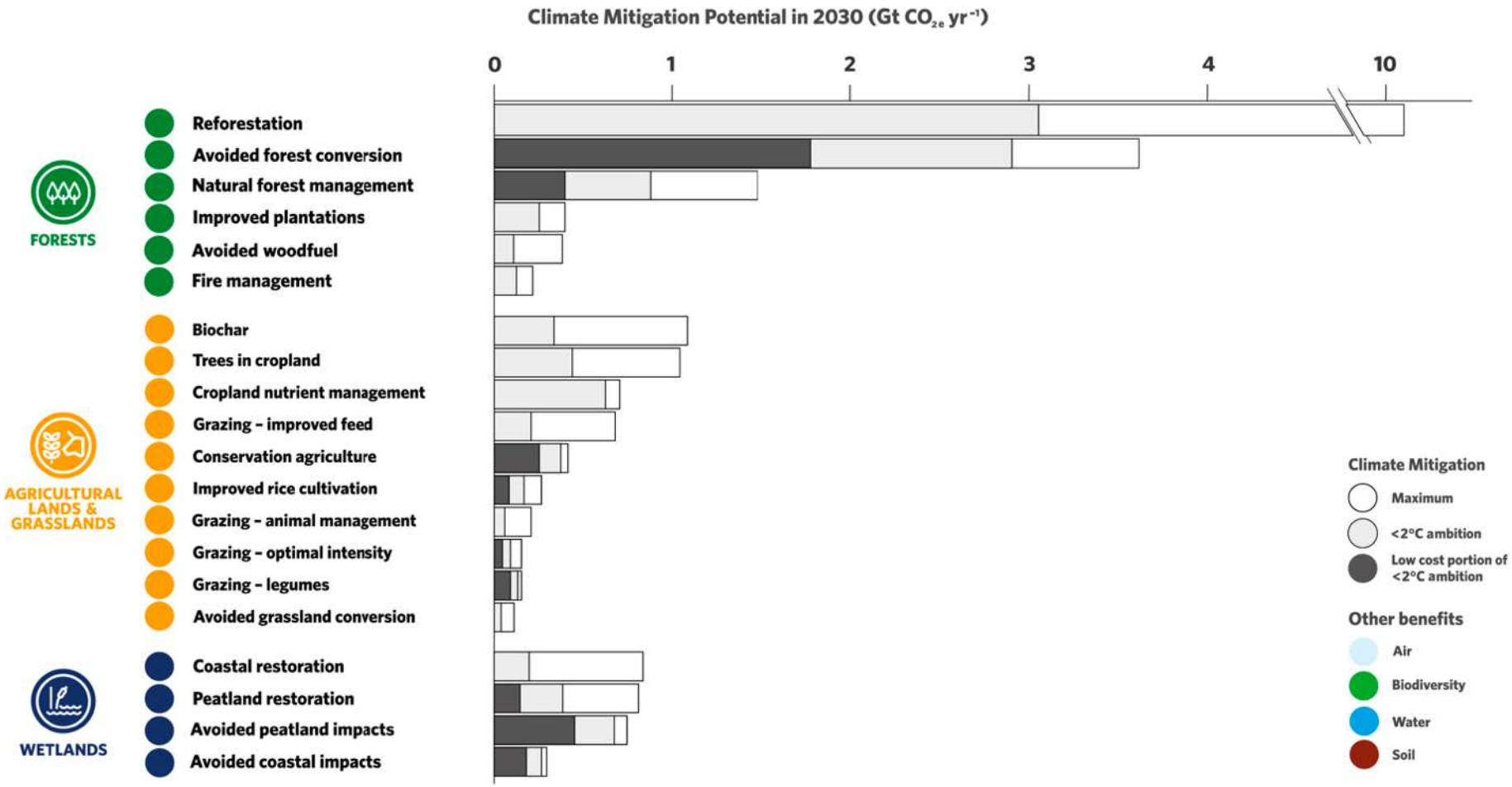
1 000 000 000 000 trees

730 000 000 000 tons CO_2 ???

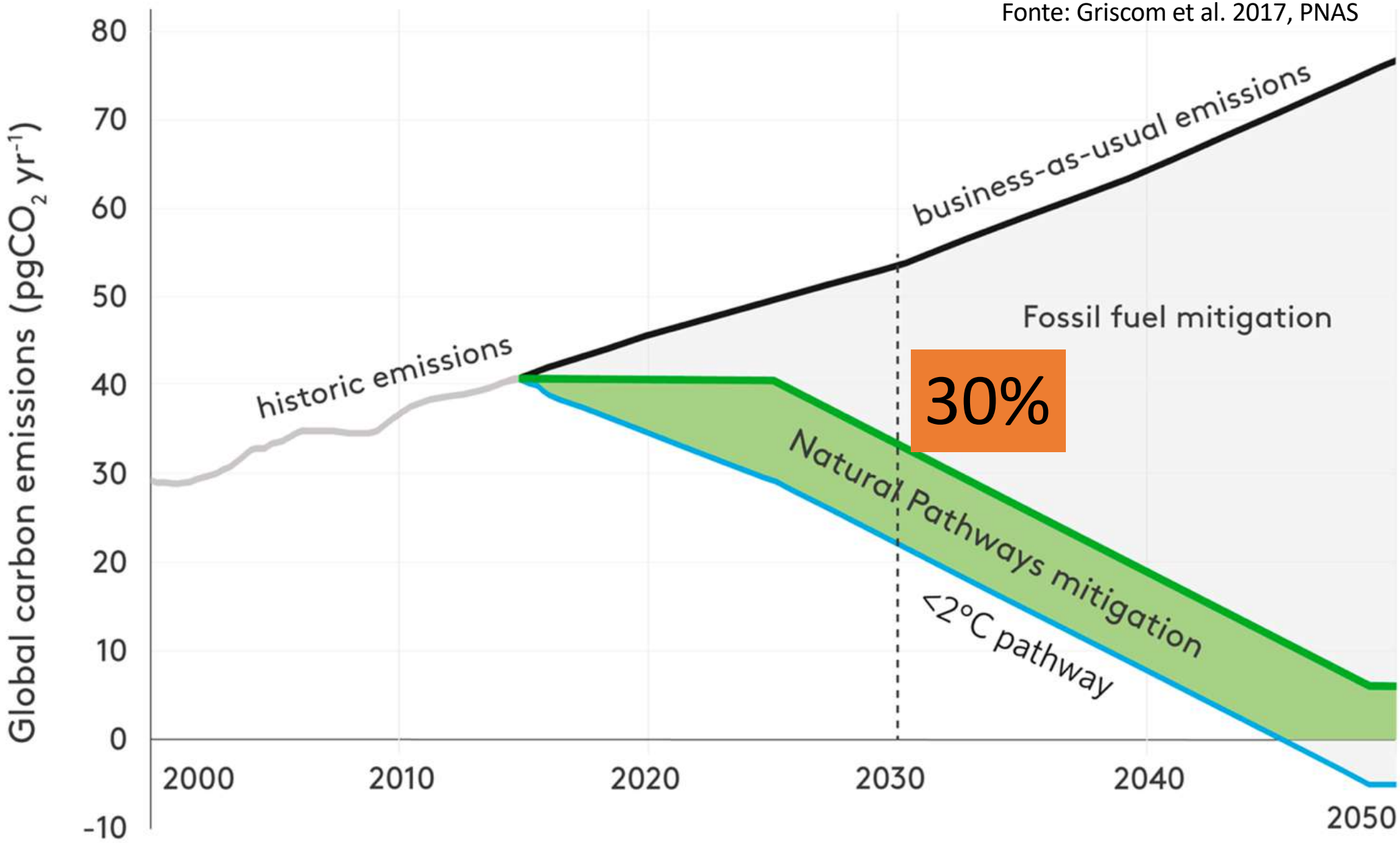

Forest cover
−
+
Albedo
Sun
Vegetation/soil
+ heat absorbance
Snow and Ice
+ heat reflection
Evapotranspiration
Transpiration
Trees + Grass
Evaporation
Groundwater
+
−
5 x 5 km
Land Surface
Temperature

Fonte: Griscom et al. 2017, PNAS

20 Pathways of Natural Climate Solutions



Fonte: Griscom et al. 2017, PNAS



CO_2 accounting Italy 1990-2017

GHG categories	1990	1995	2000	2005	2010	2015	2016	2017
				Gg CO_2 equivalent				
1. Energy	425,233	439,358	459,095	479,675	418,615	352,832	350,284	345,852
2. Industrial Processes and Product Use	40,472	38,368	39,178	47,152	36,748	32,576	32,556	32,827
3. Agriculture	34,739	34,701	33,946	31,893	30,012	30,065	31,000	30,780
4. LULUCF	-3,283	-21,919	-16,229	-28,377	-34,674	-39,608	-36,558	-18,379
5. Waste	17,302	19,993	21,887	21,880	20,399	18,571	18,278	18,249
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (including LULUCF)	**514,462**	**510,500**	**537,877**	**552,223**	**471,099**	**394,436**	**395,561**	**409,329**

Source: ISPRA, National Inventory Report 2019

CO_2 fluxes in LULUCF sector in Italy, 1990-2017

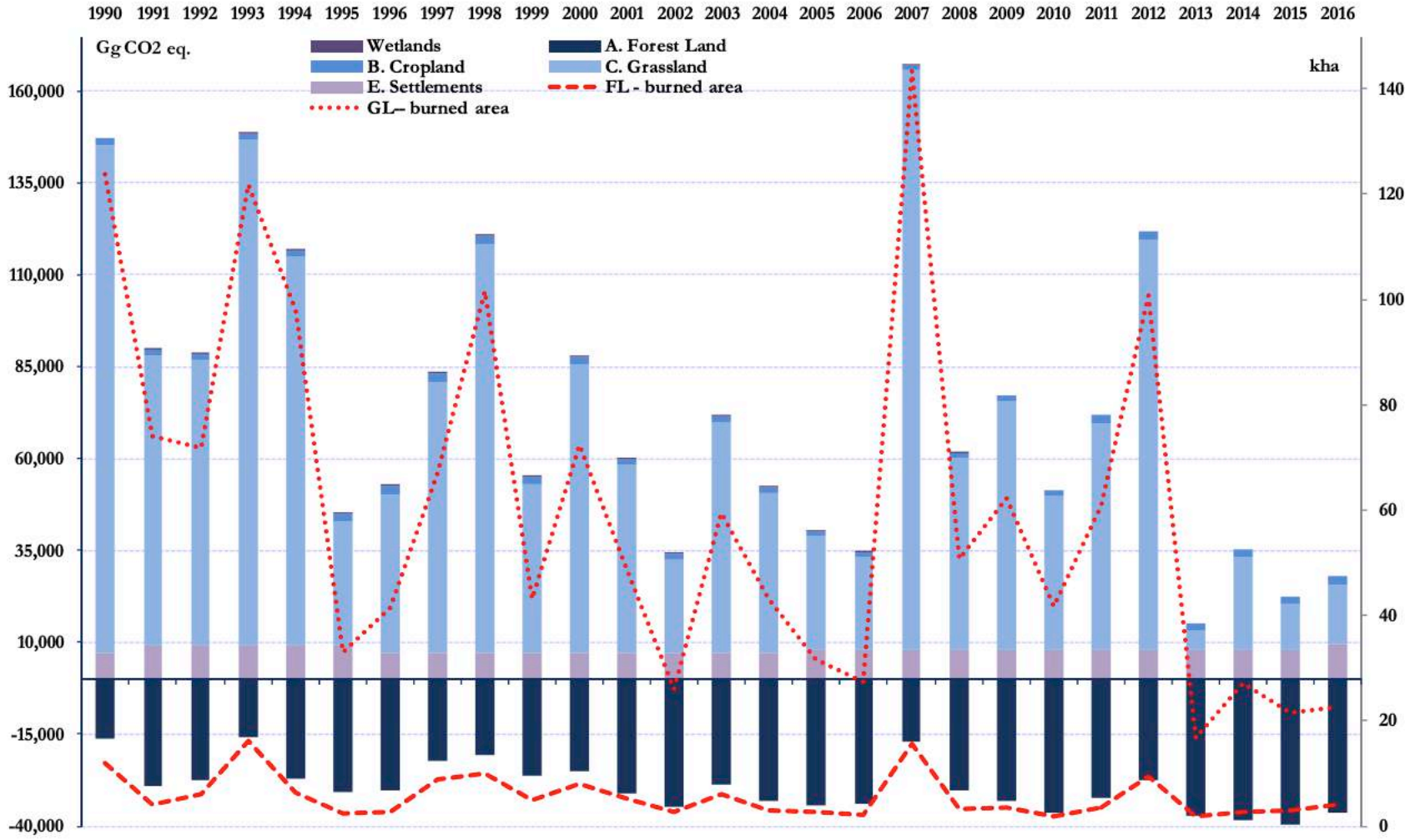
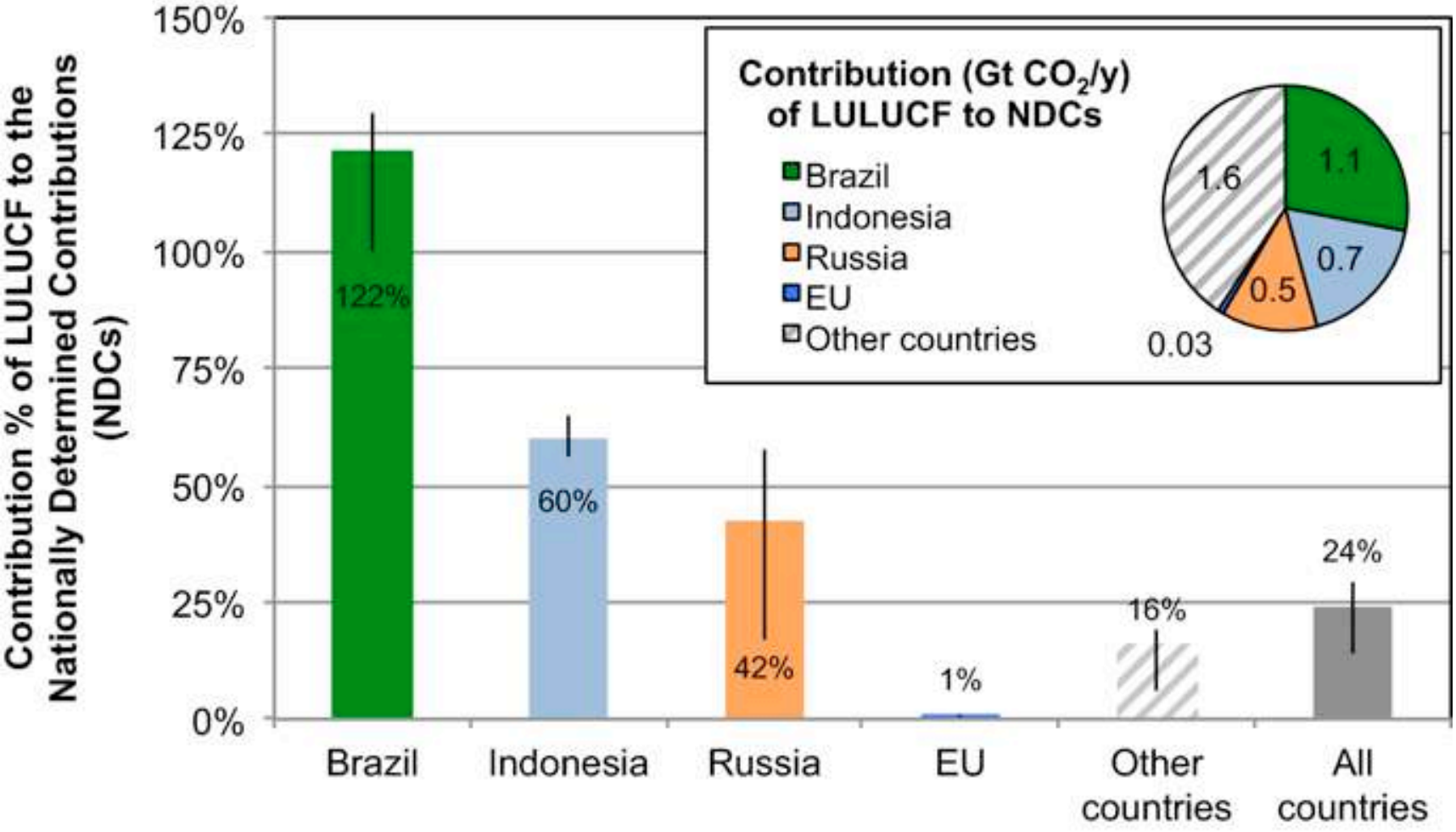


Figure 6 GHG emission/removal from the LULUCF 1990-2016

National Forest Accounting Program 2019

LULUCF contribution to NDCs



Grassi et al. 2019, Carbon Balance and Management


Photo: Pixabay

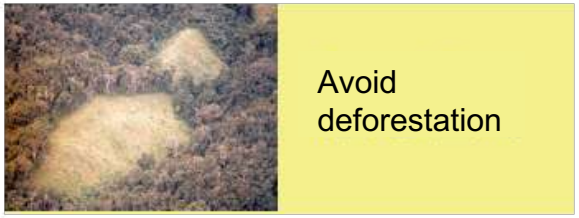
Photo: Pixabay

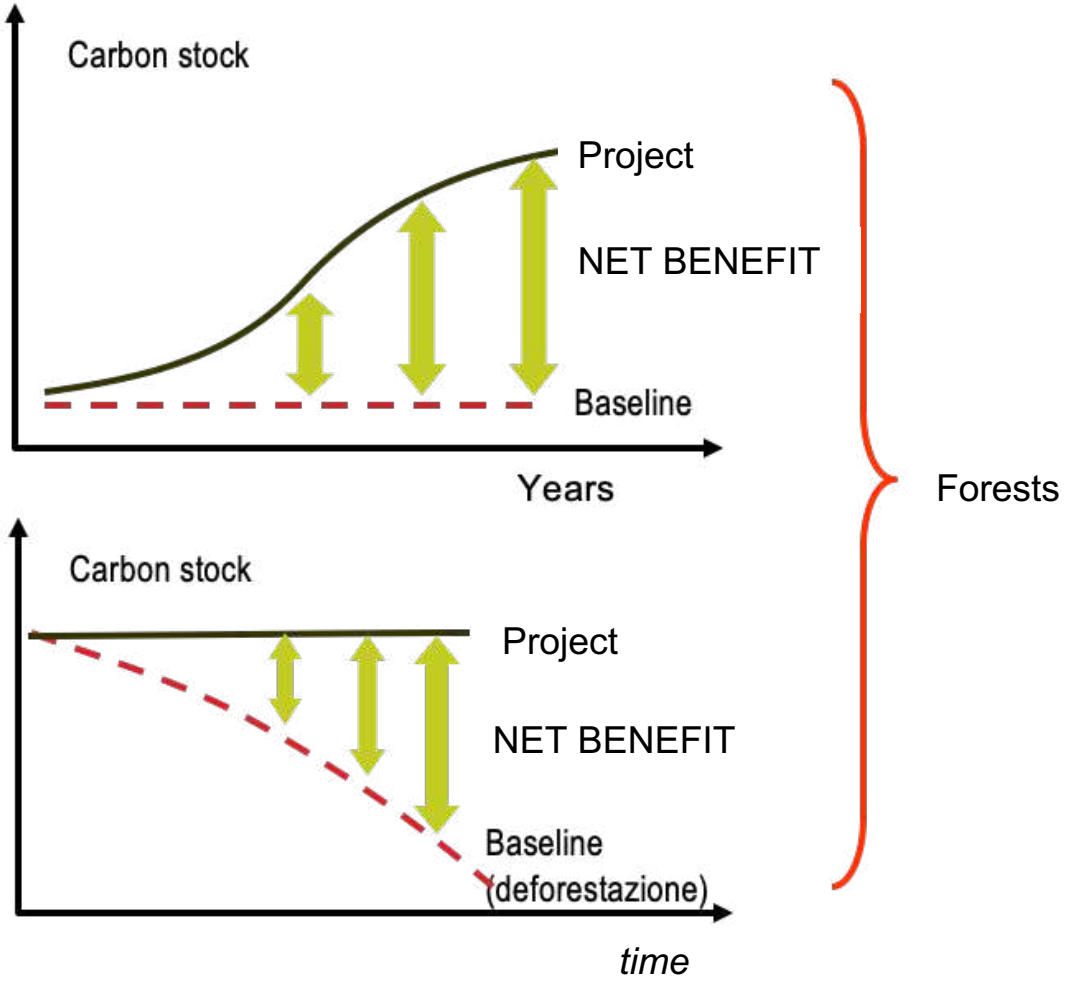
Mitigation in the forest sector

Must account only “human contribution”

- Increase stocks

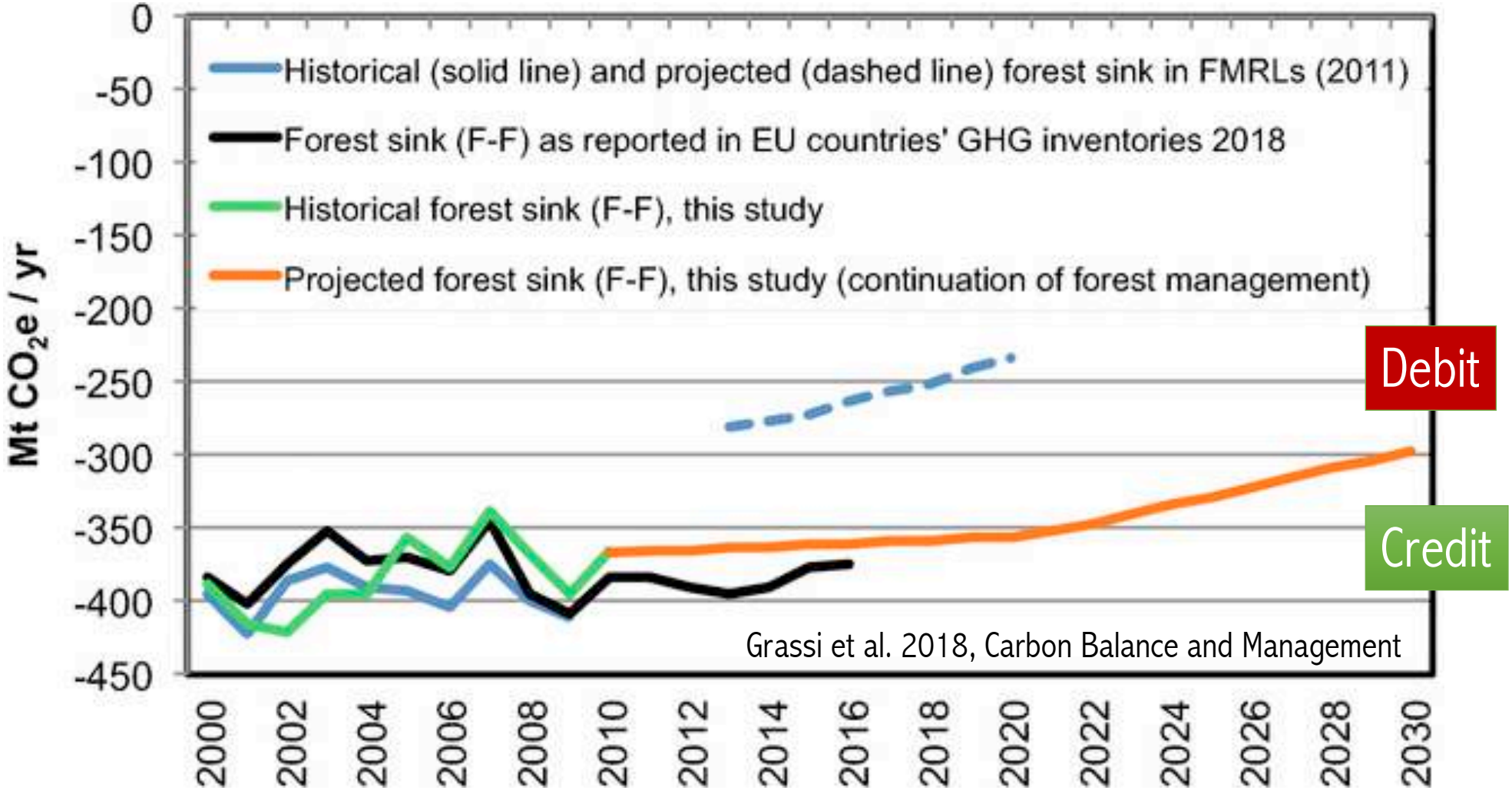
- Avoid losses

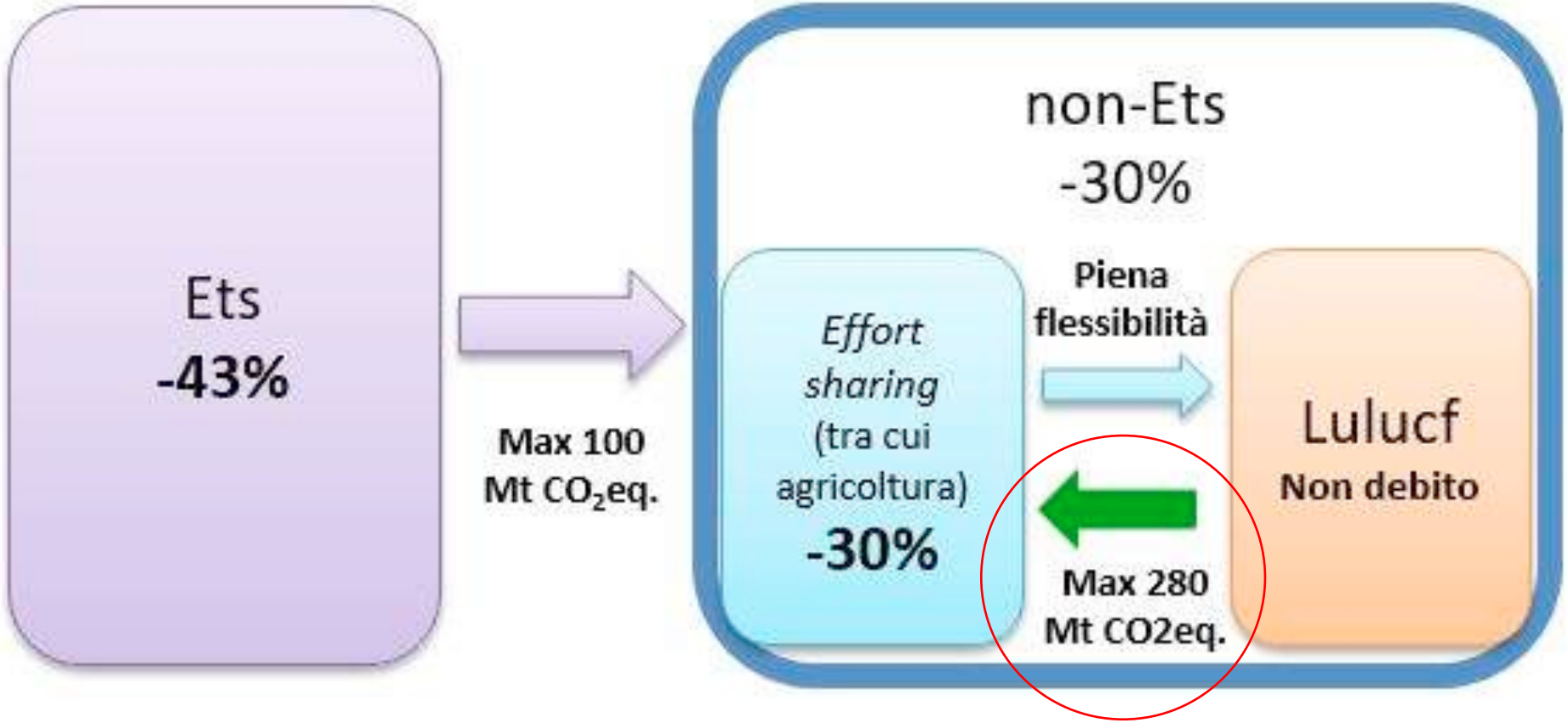




EU LULUCF Regulation

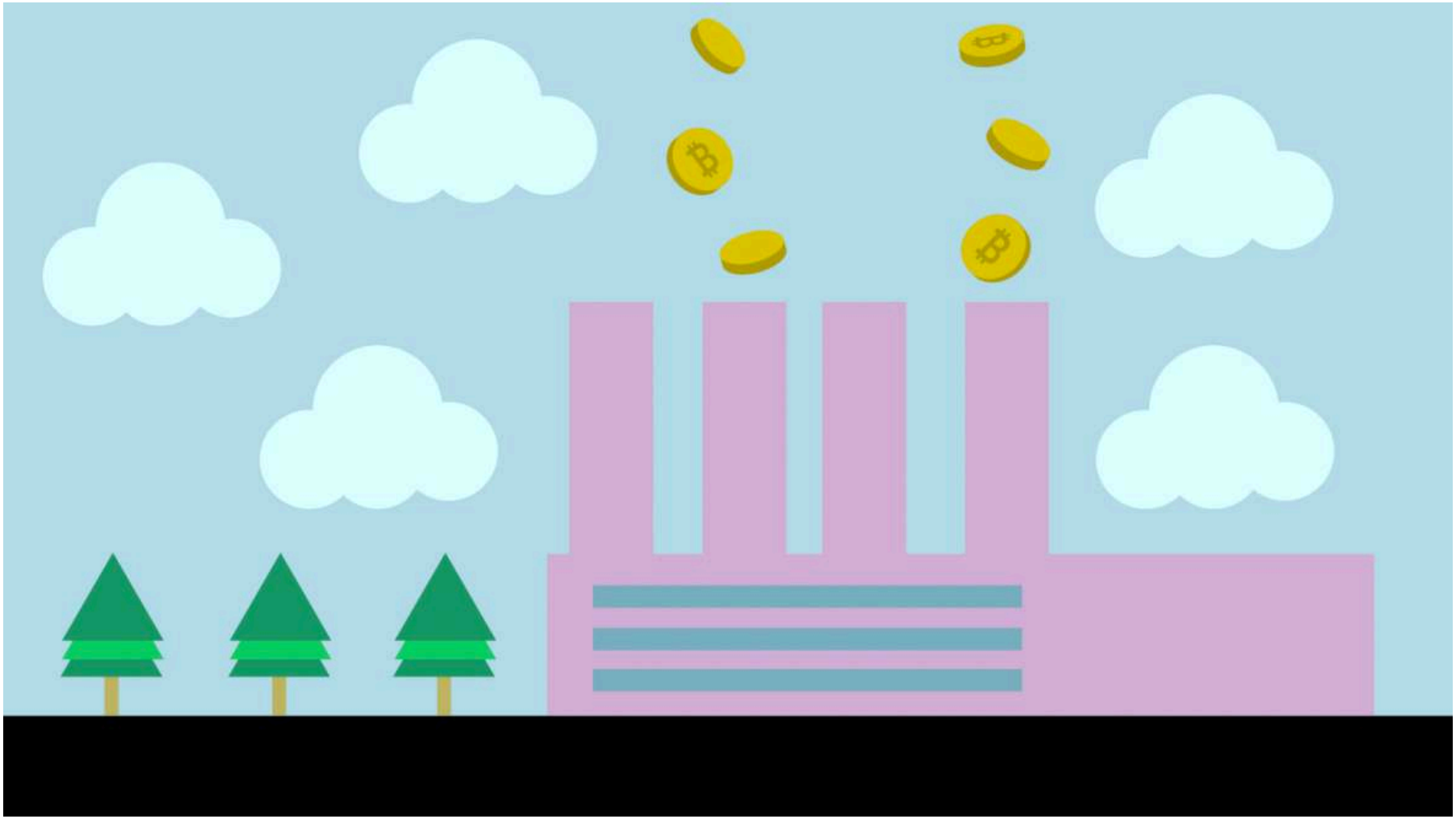
Forest Reference Level





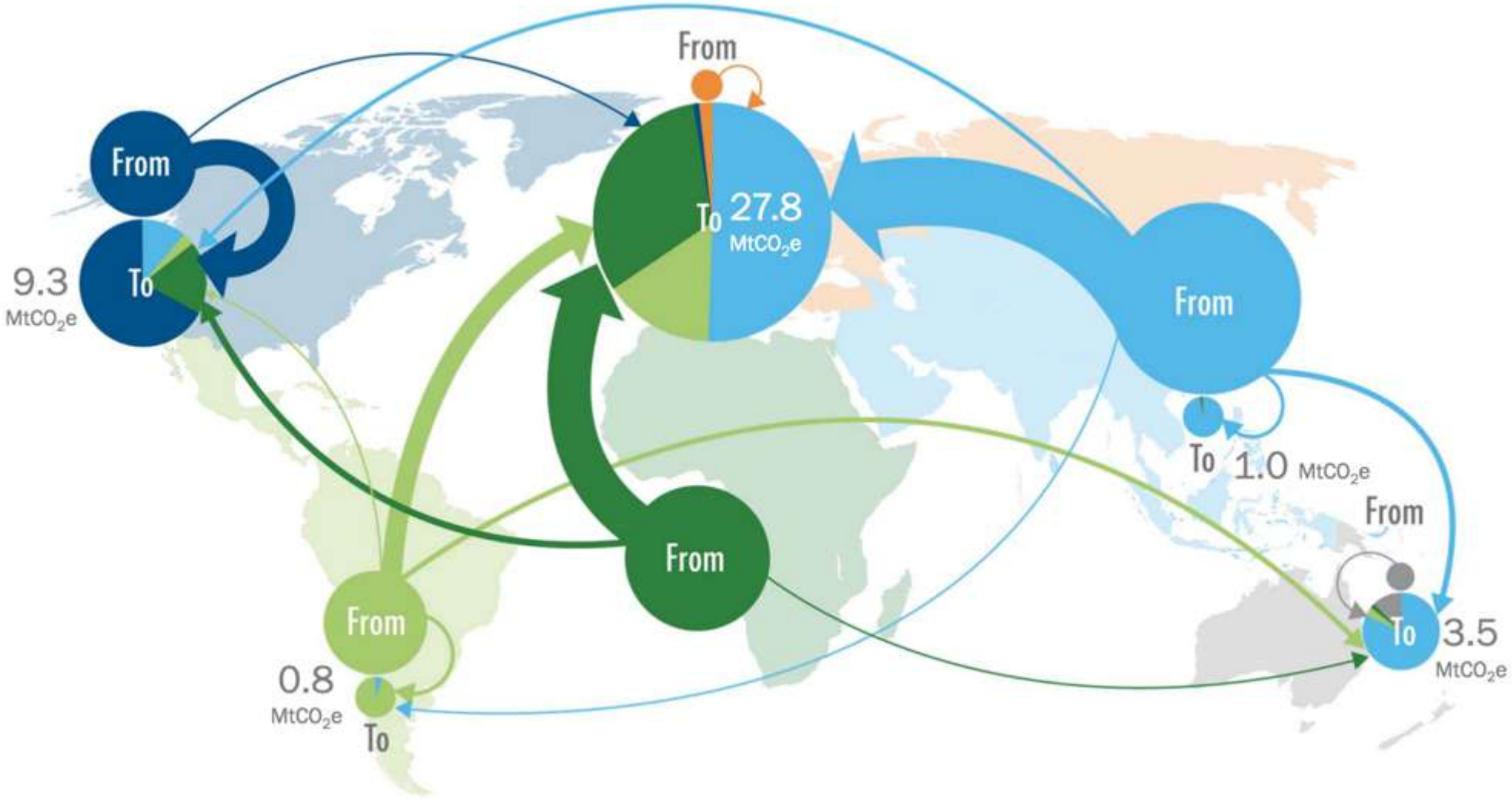
In EU LULUCF regulation (2018forest carbon credits may be transferred to other sectors up to a given cap. For Italy the cap is **11.5 Mt CO_2 in 10 years.**

Voluntary carbon markets

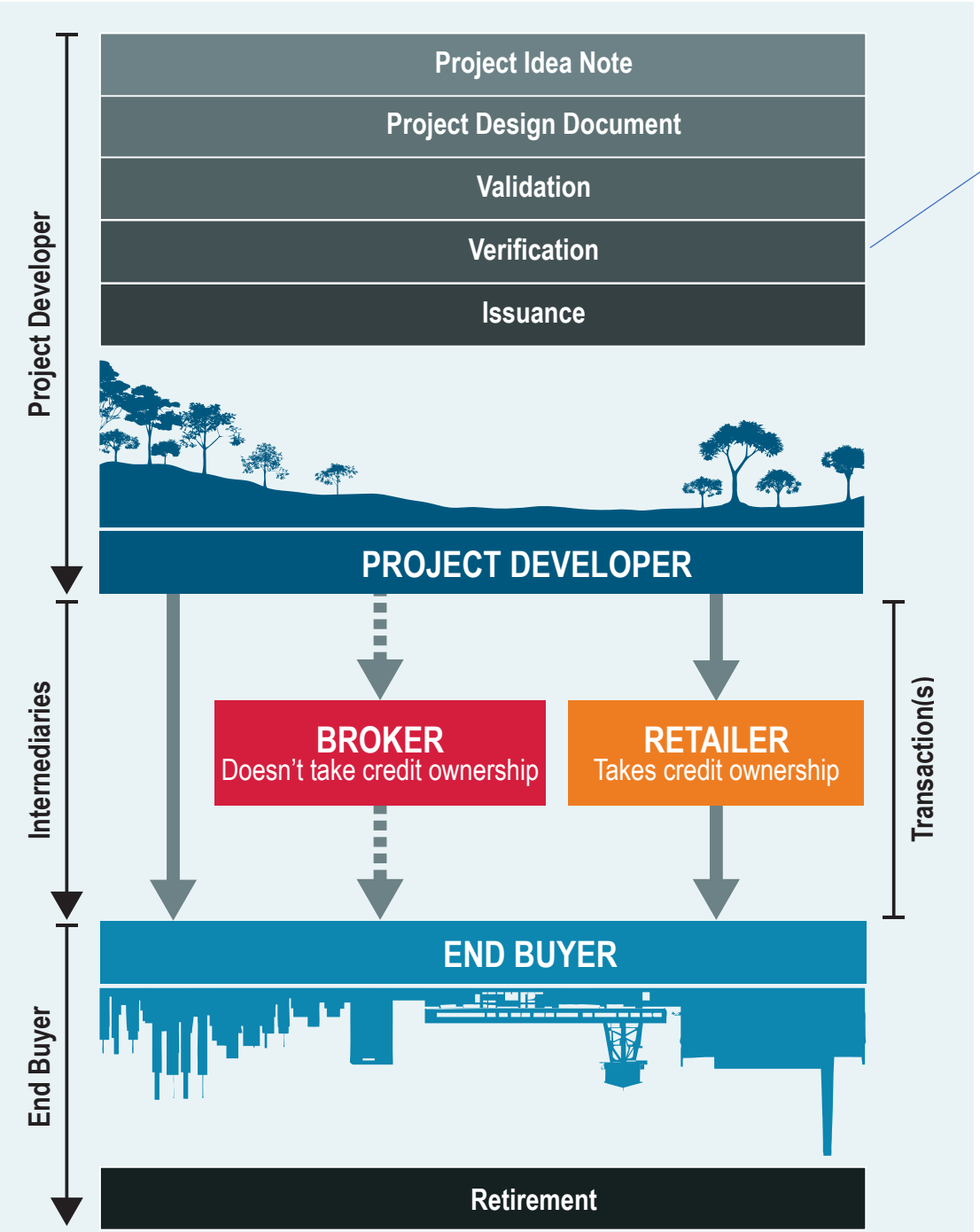


	VOLUME	AVERAGE PRICE	VALUE
RENEWABLES	18.3 $MtCO_2e$	$1.4	$25M
FORESTRY AND LAND USE	13.1 $MtCO_2e$	$5.1	$67M
METHANE	5.6 $MtCO_2e$	$1.8	$10M
EFFICIENCY AND FUEL SWITCHING	4.5 $MtCO_2e$	$2.9	$13M
HOUSEHOLD DEVICE	3.4 $MtCO_2e$	$5.2	$18M
TRANSPORTATION	1.9 $MtCO_2e$	$0.3	$1M
GASES	1.4 $MtCO_2e$	$5.7	$8M
OTHER	0.5 $MtCO_2e$	$4.0	$2M

Notes: Based on 717 transactions representing 48.8 $MtCO_2e$ in 2016.

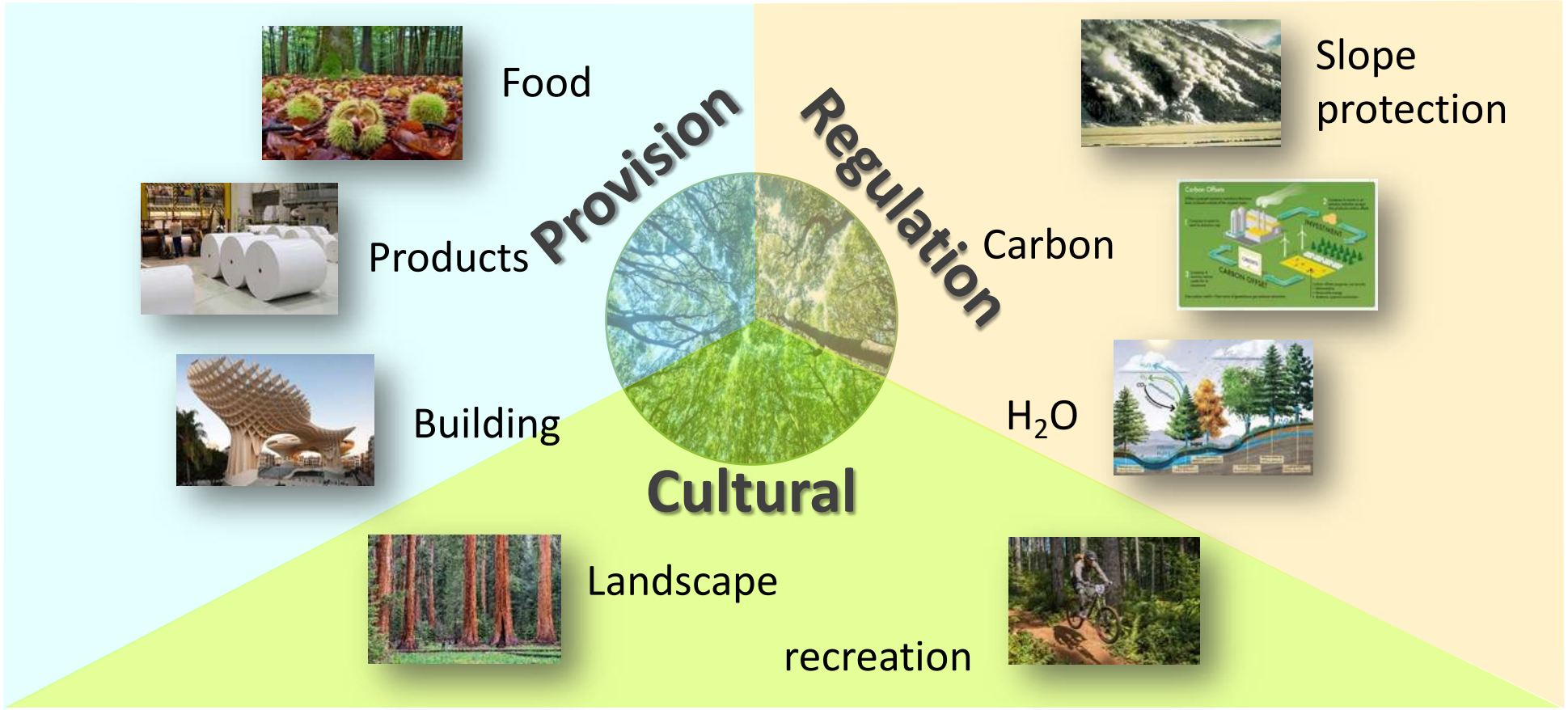


SOURCE: Forest Trends' Ecosystem Marketplace. State of the Voluntary Carbon Markets 2014.



Criteria for third-party verification:

- **Additionality**
- **Permanence**
- **Voluntarity**

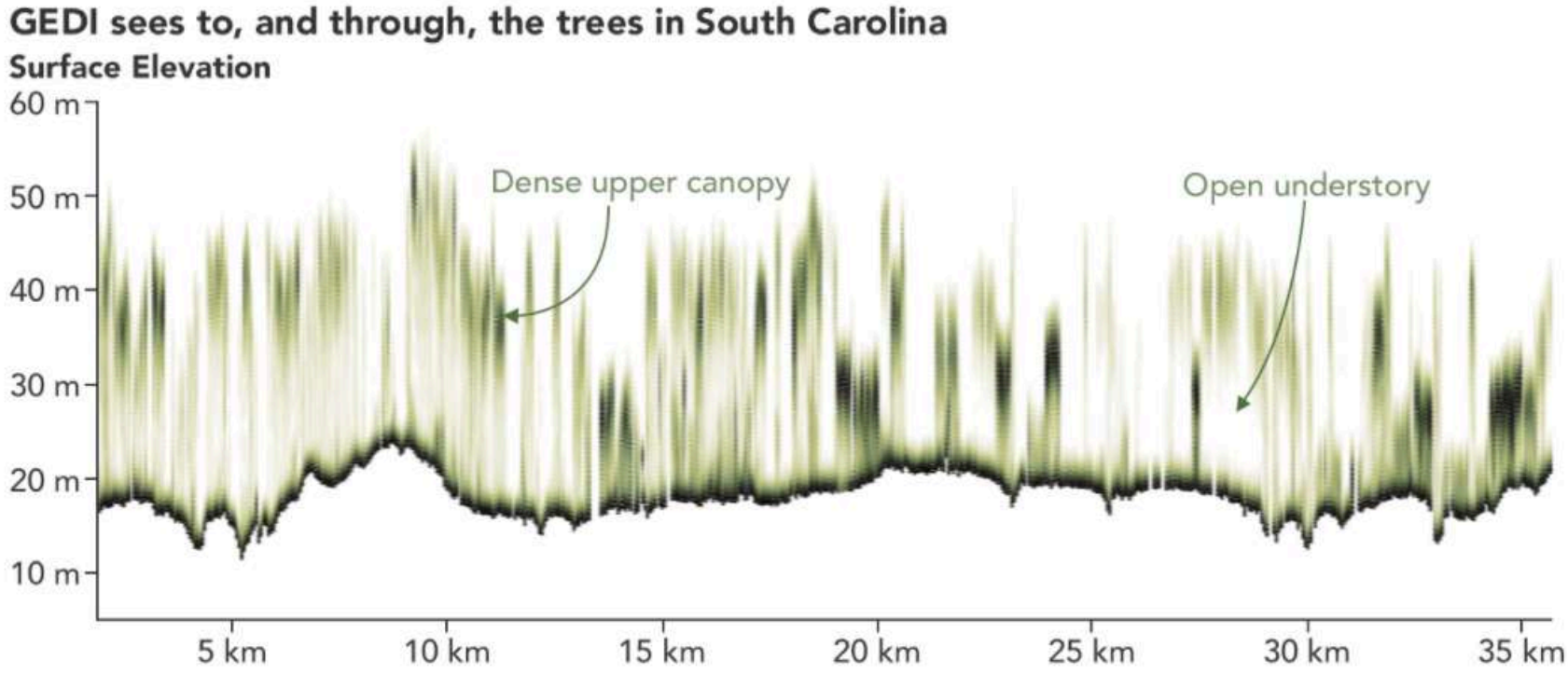

Food
Provision
Regulation
Slope protection
Products
Carbon
Building
H_2O
Cultural
Landscape
recreation

One forest, many services

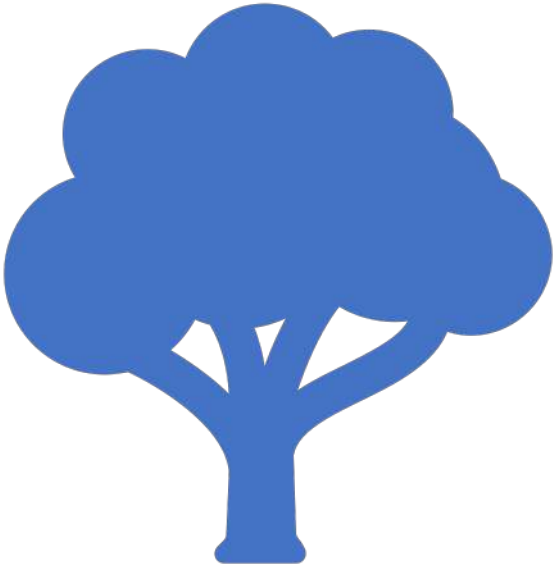

Sustainable forest management

Forest planning

Remote sensing of forest structure



NASA's Global Ecosystem Dynamics Investigation (GEDI) mission created this image of a South Carolina woodland. Darker green colors show where the leaves and branches are denser, while the lighter areas show where the canopy is less dense. Credit: Joshua Stevens / NASA Earth Observatory, Bryan Blair / NASA Goddard Space Flight Center, Michelle Hofton and Ralph Dubayah / University of Maryland

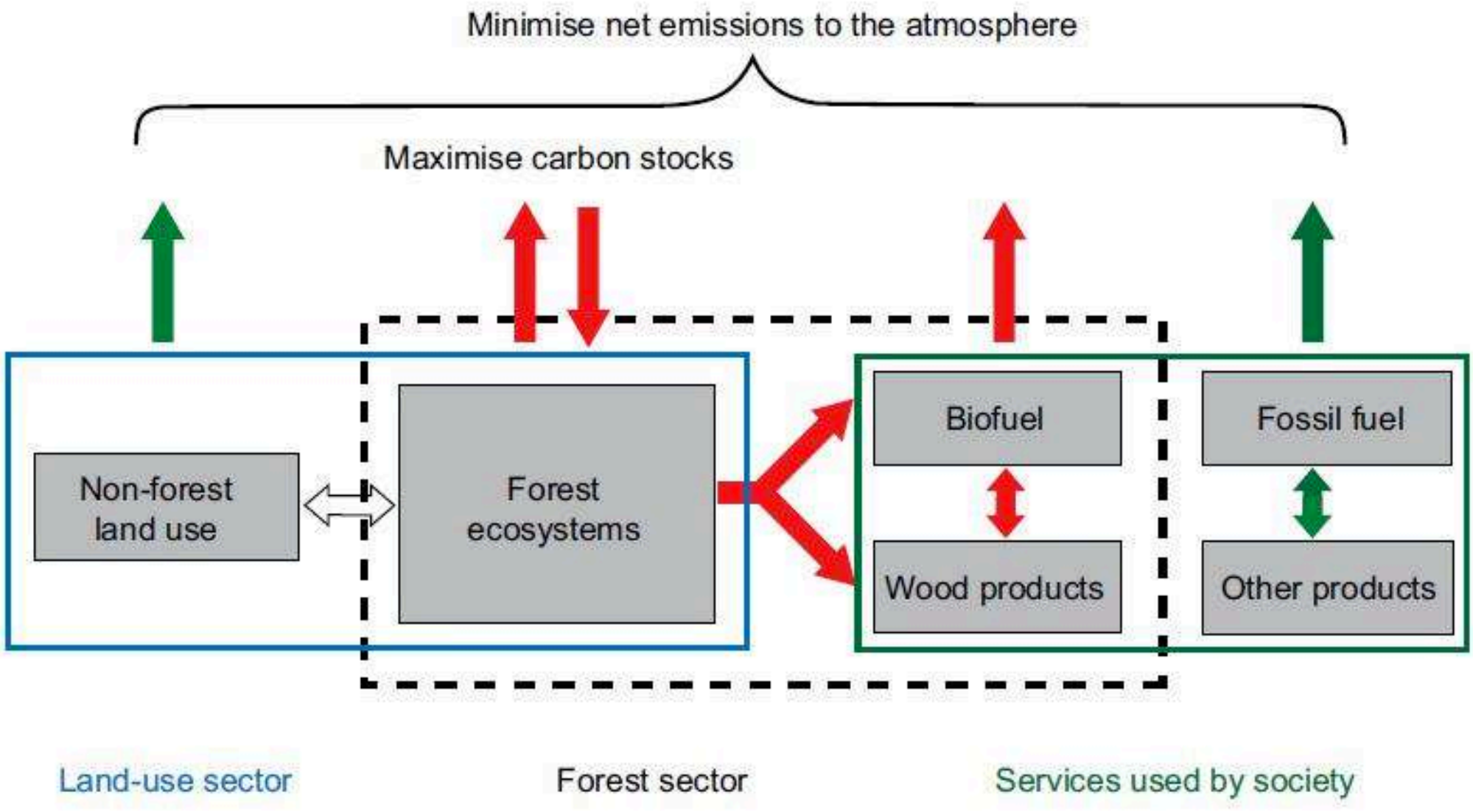


Climate-smart forestry

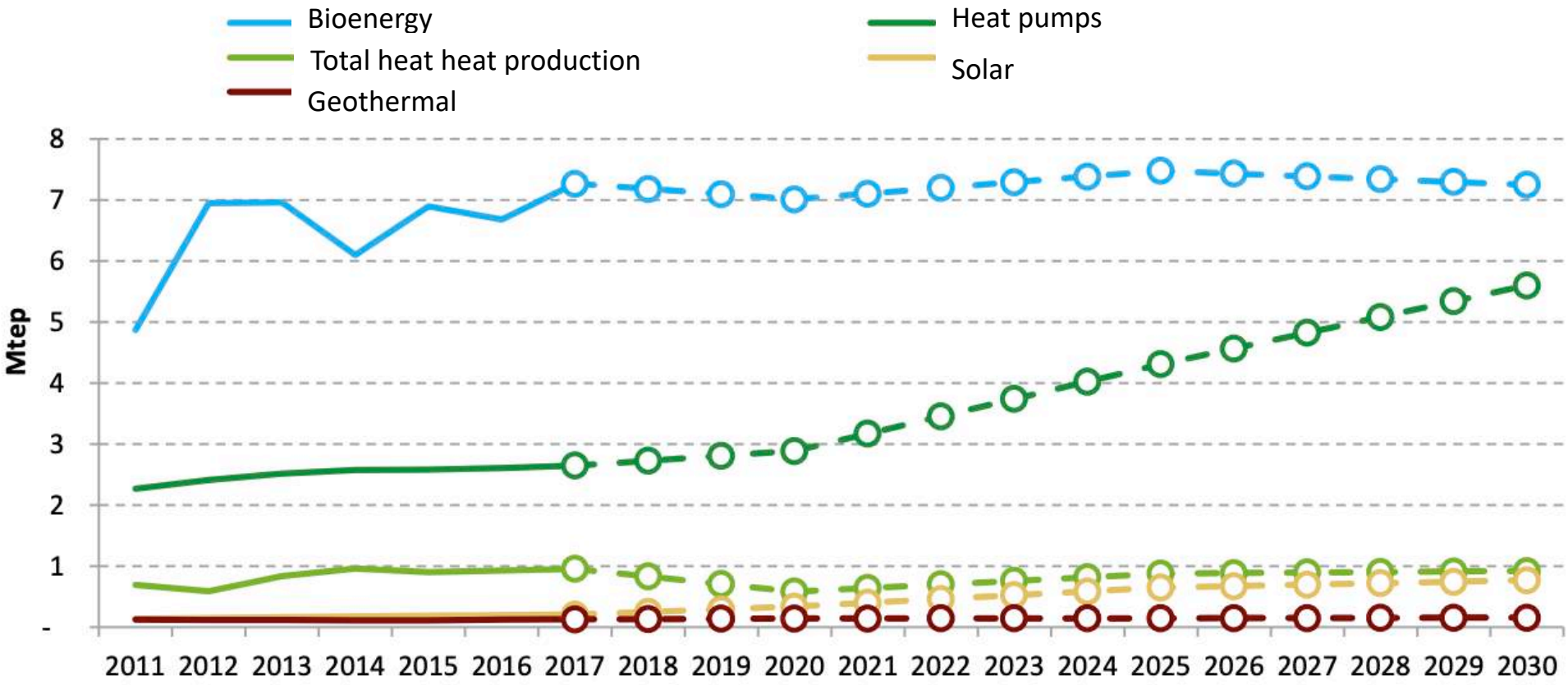
Forest management that acknowledges sinergies between climate mitigation needs and other forest ecosystem services.

Optimizes efficacy and efficiency of forest contributions to climate mitigation.

Carbon mitigation must have a comprehensive perspective

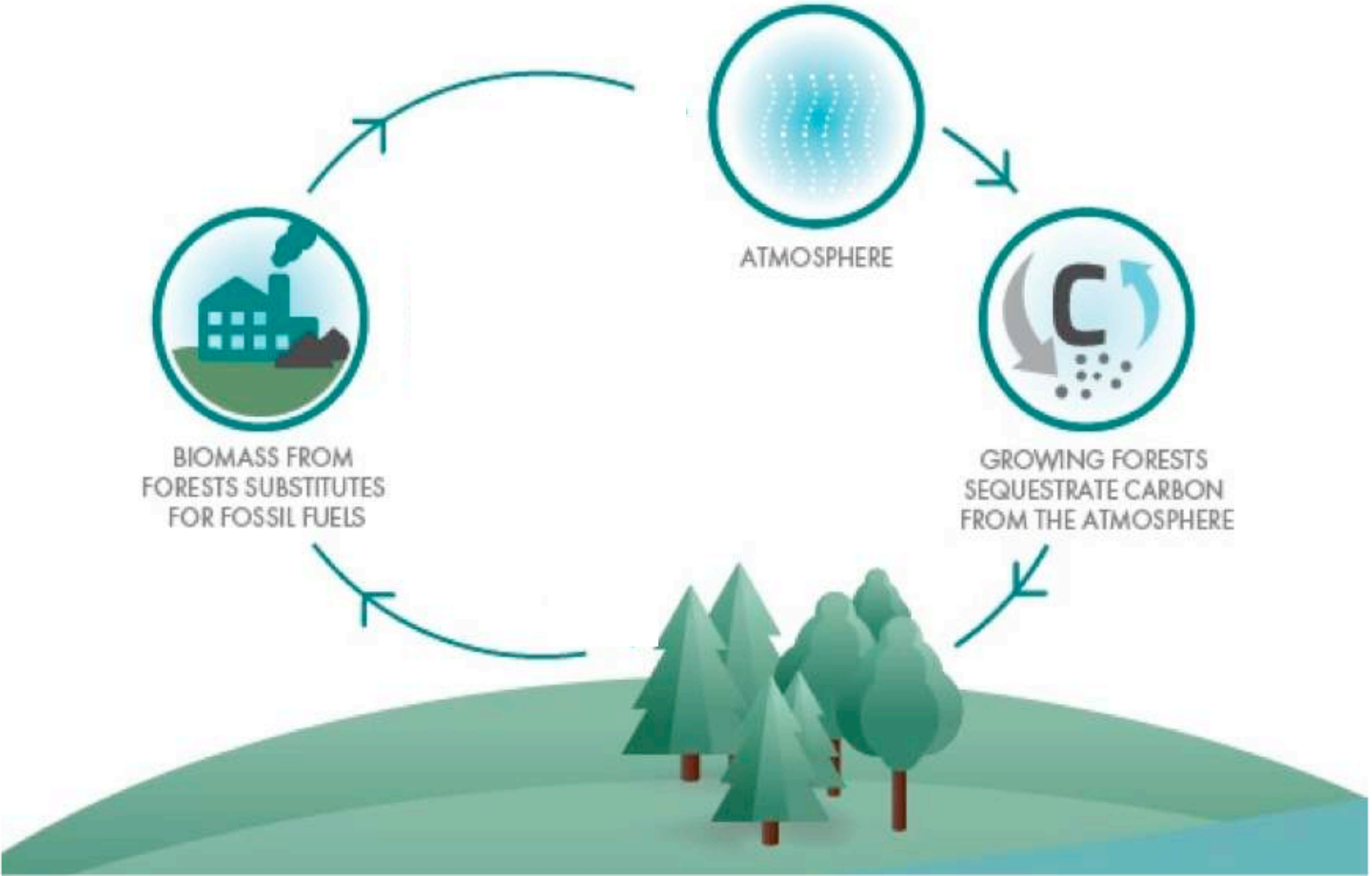


Renewable energy production scenarios in Italy
Heating sector

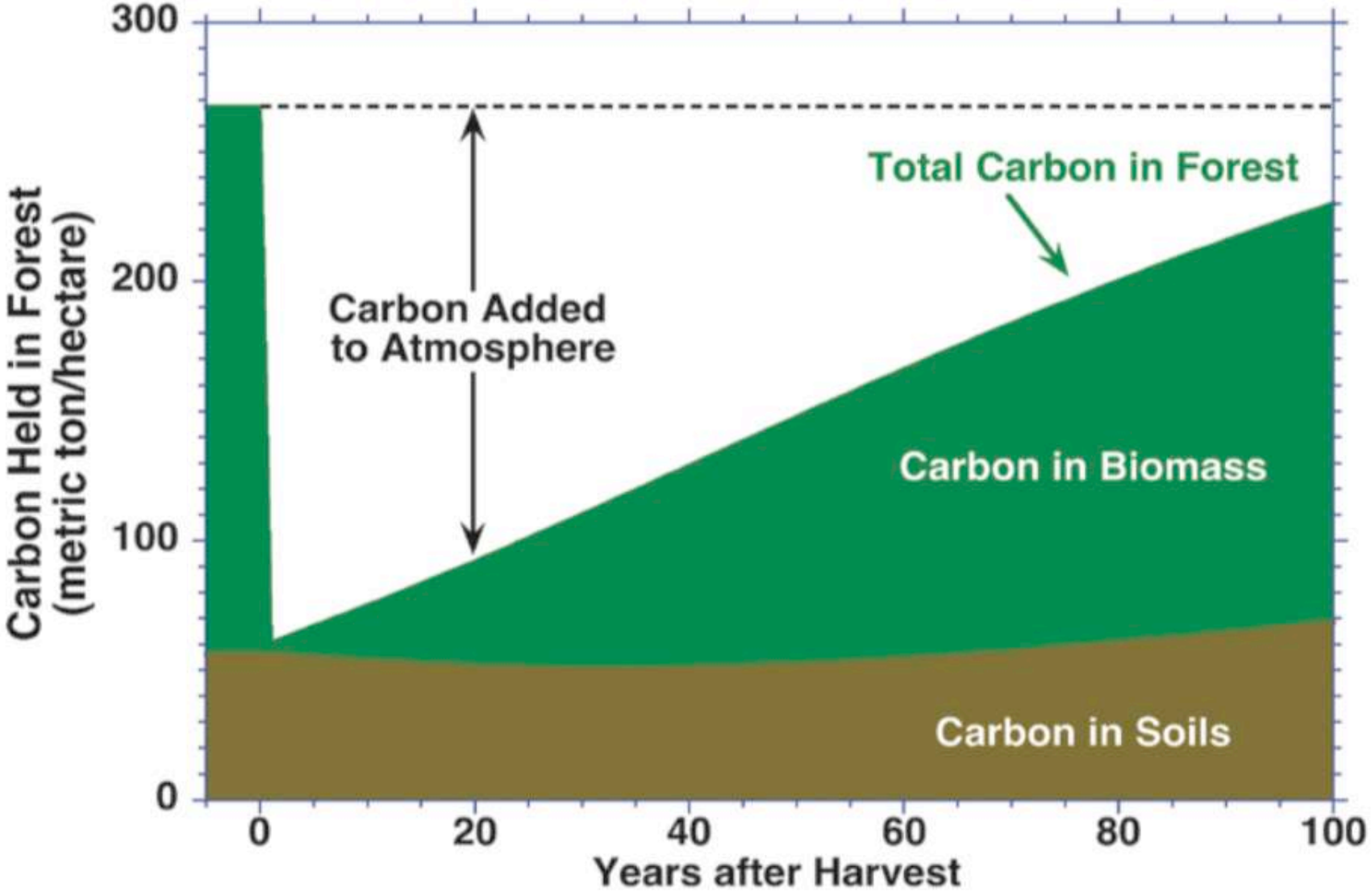


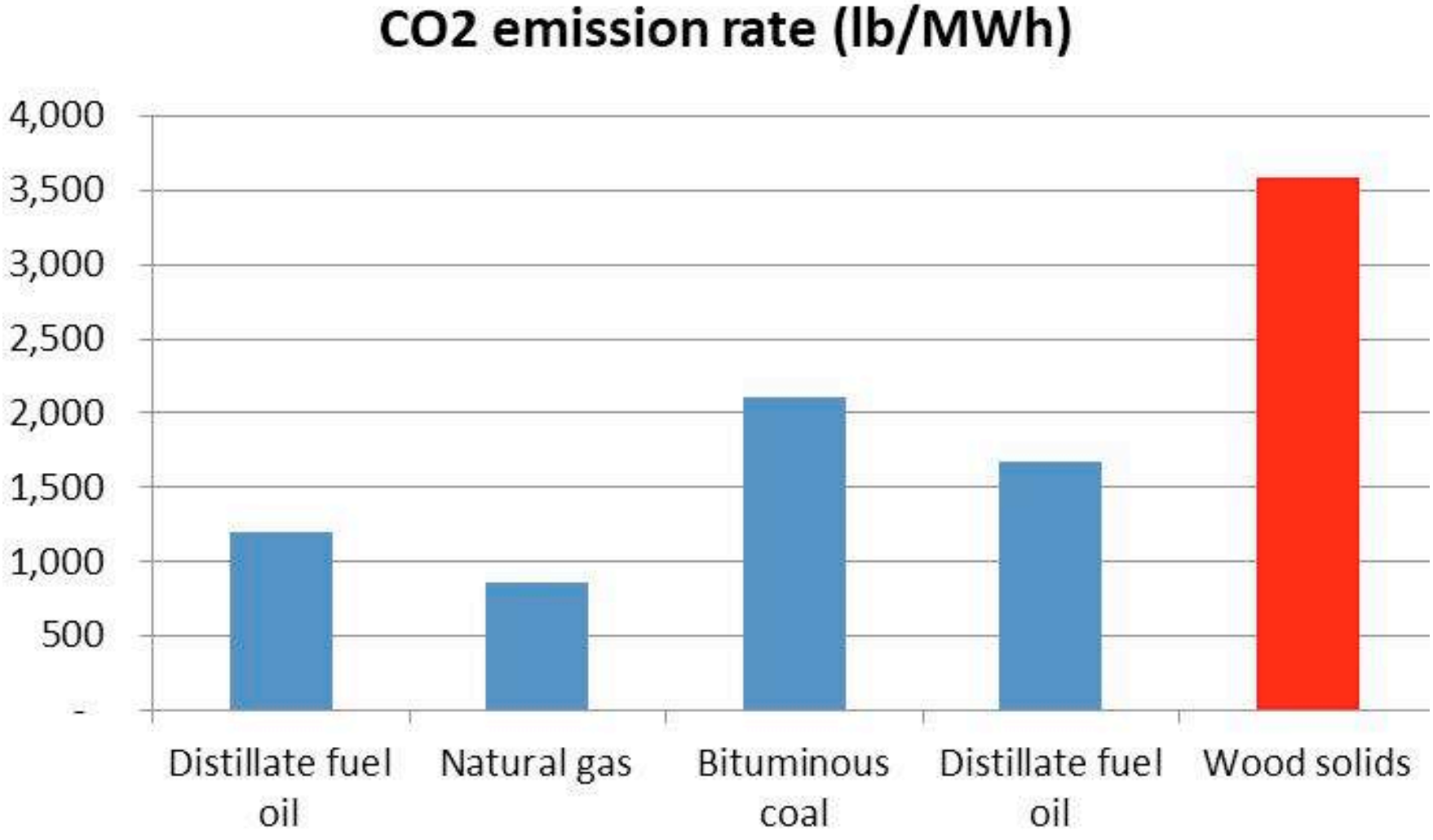
Substitution effects

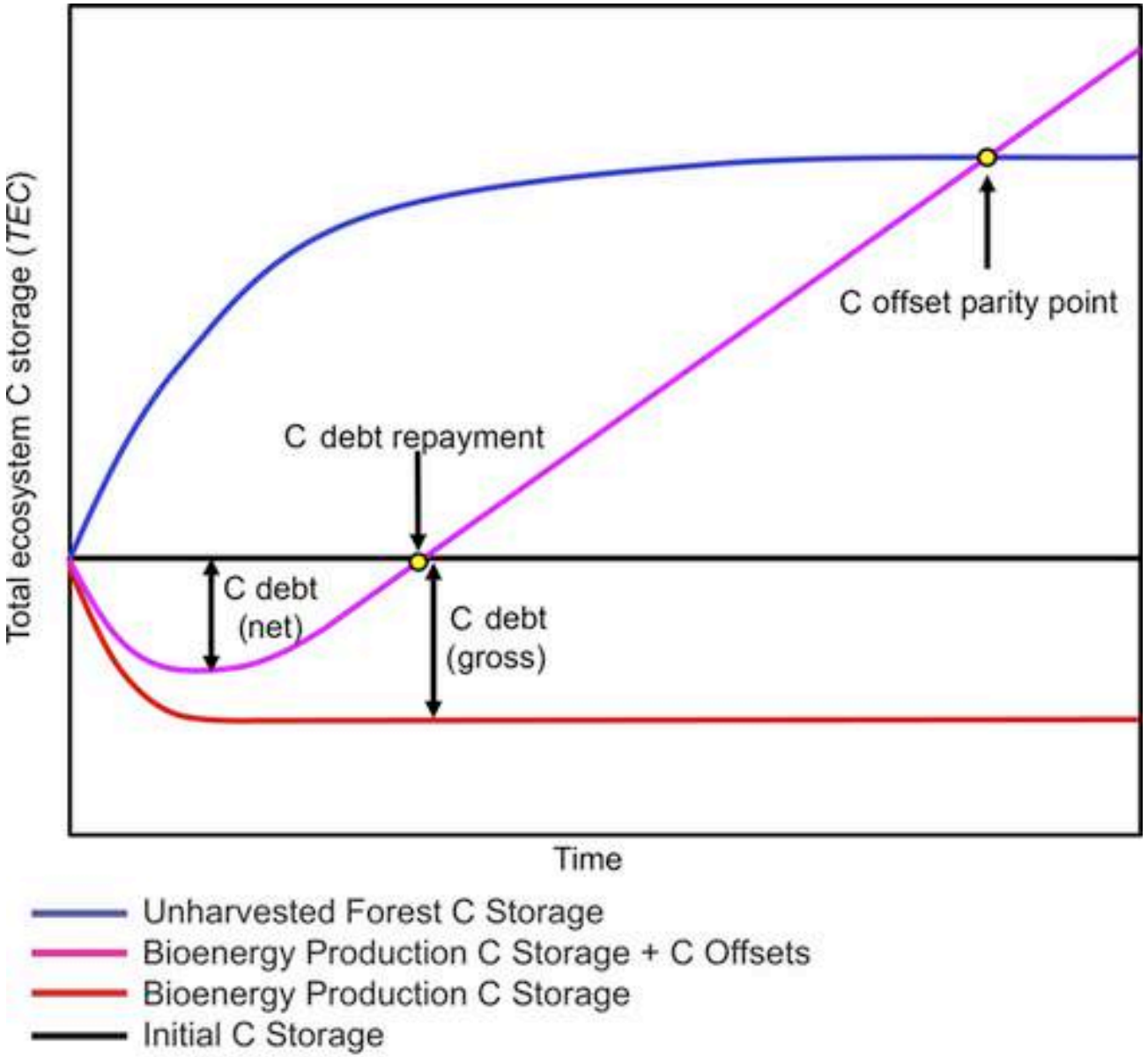
Energy


ATMOSPHERE
C
GROWING FORESTS
SEQUESTRATE CARBON
FROM THE ATMOSPHERE
BIOMASS FROM
FORESTS SUBSTITUTES
FOR FOSSIL FUELS

Is burning wood climate neutral?




CO2 emission rate (lb/MWh)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
Distillate fuel oil
Natural gas
Bituminous coal
Distillate fuel oil
Wood solids



Mitchell et al. 2012, Global Change Biology Bioenergy

Is burning wood climate neutral?

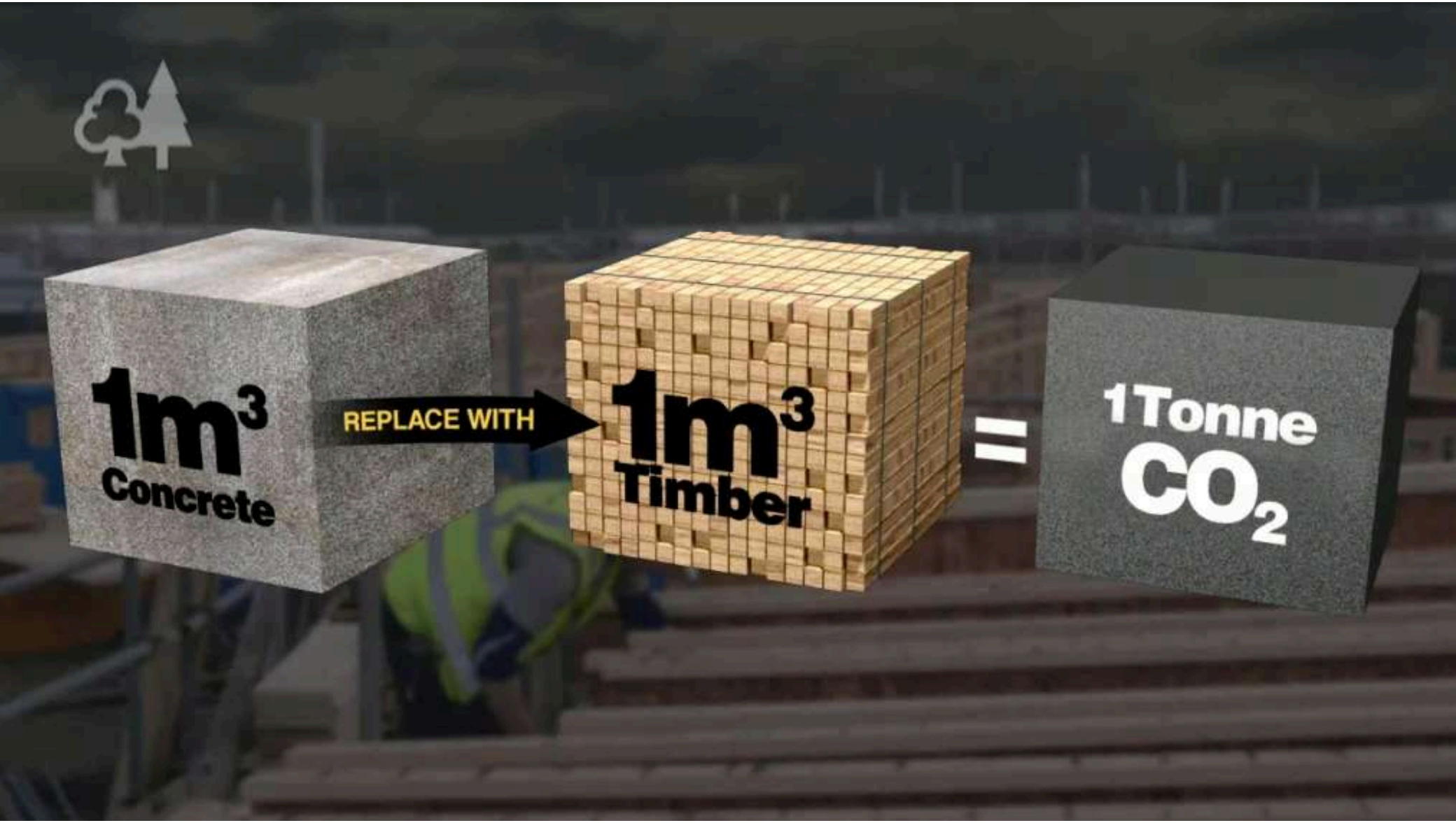
What it costs to generate electricity

Biomass, coal and nuclear power are more expensive than wind, natural gas and utility-scale solar energy.

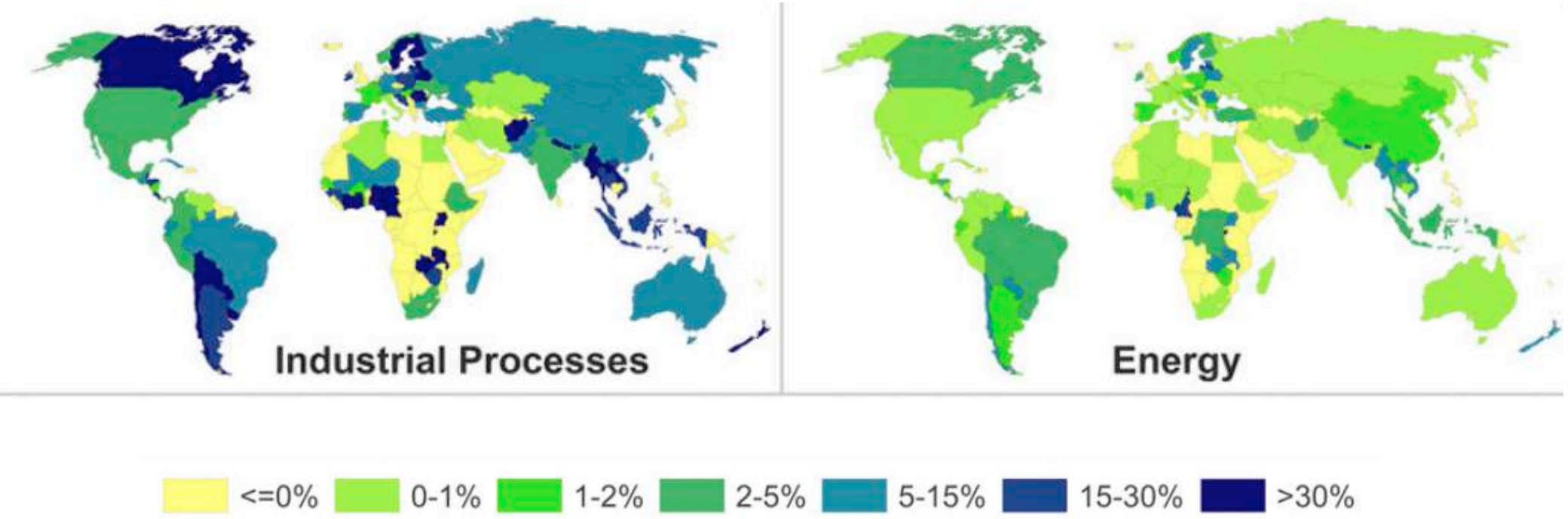
Costs are expressed in terms of dollars per megawatt hour.

Substitution effects

Materials

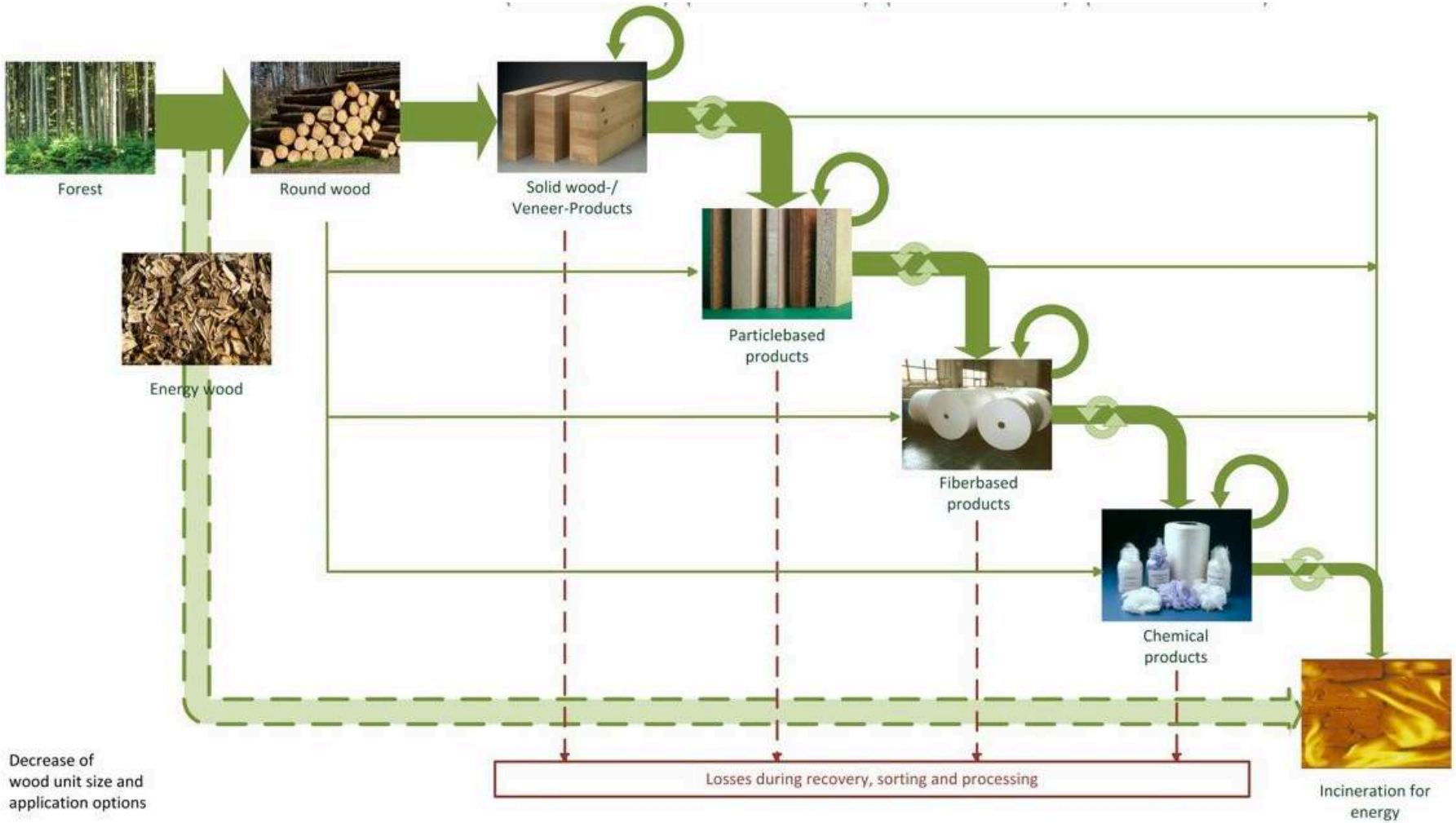

1m³
Concrete
REPLACE WITH
1m³
Timber
=
1Tonne
CO2

% of national sector CO_2 emissions potentially offset by wood-based substitution effects



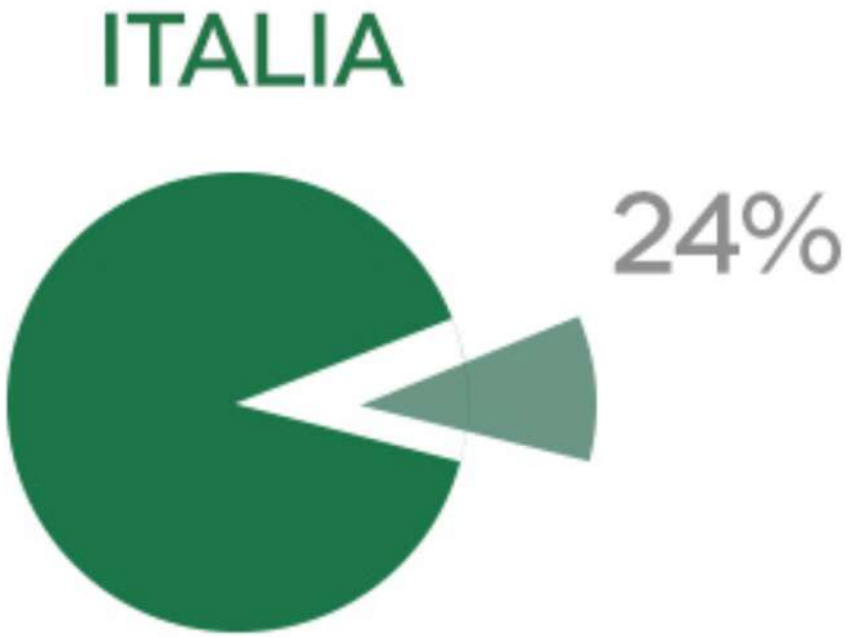
Johnston and Radeloff 2019, PNAS

Cascading use of wood (EU Forest strategy)

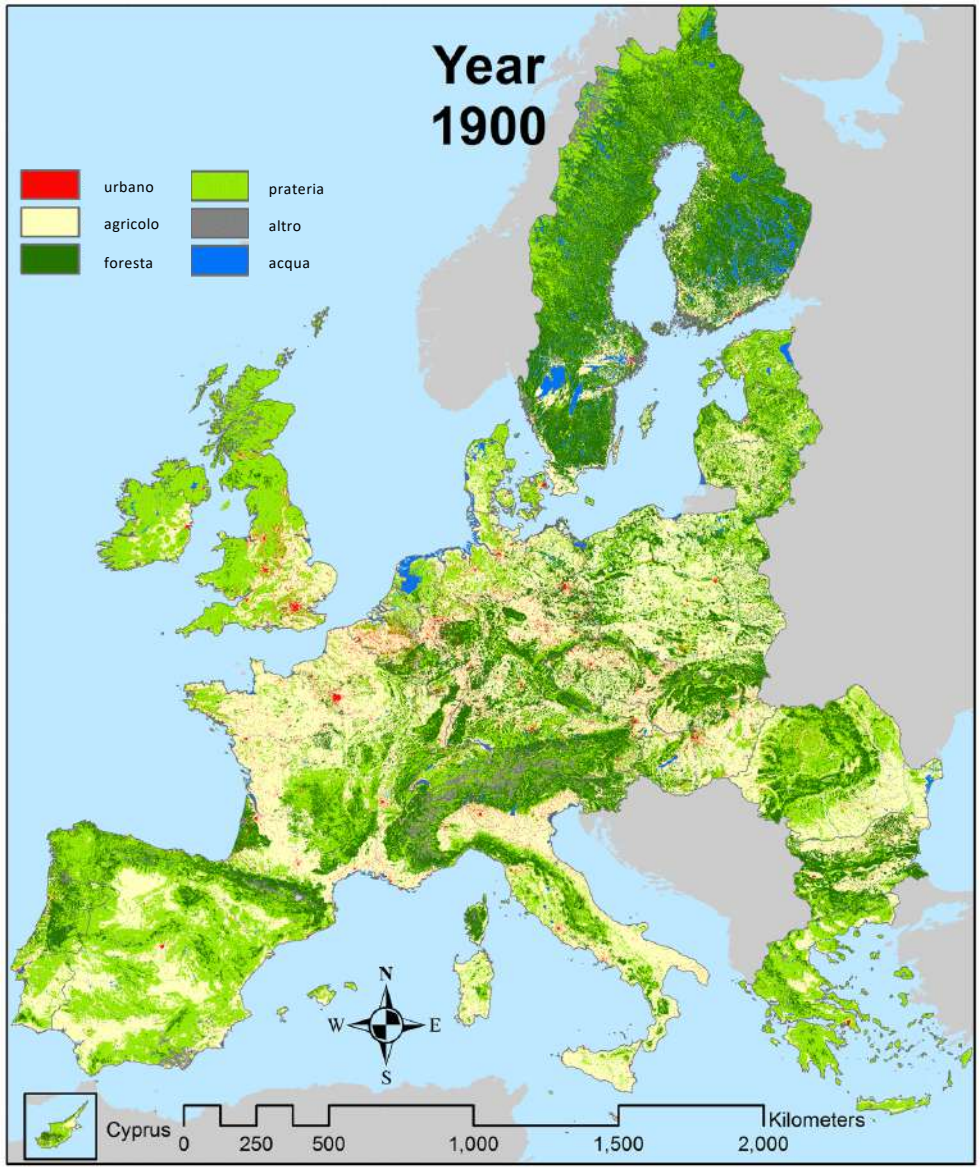


Is harvest sustainable ?

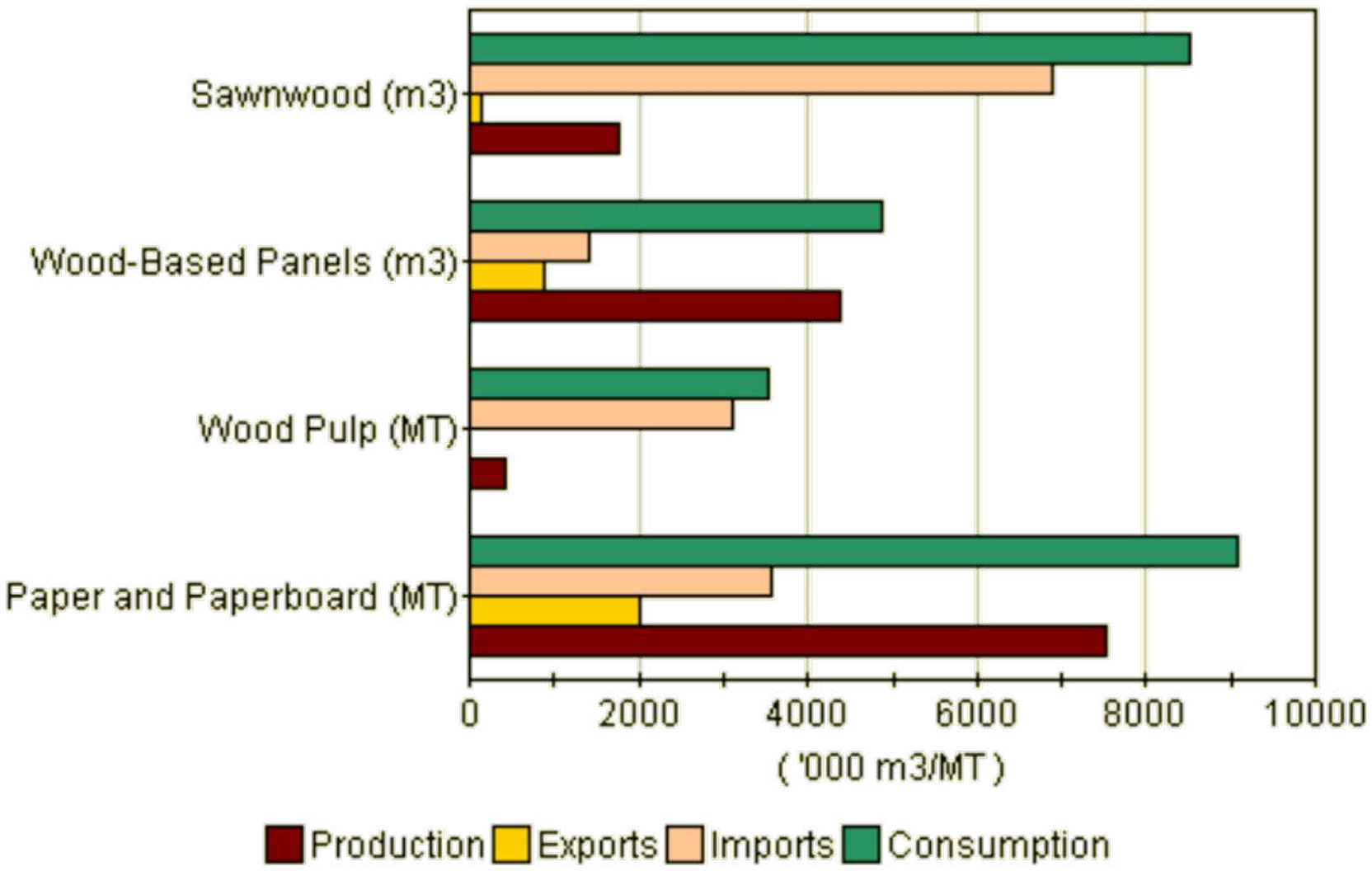
Ratio to yearly forest growth:




European forests increase
800,00 new hectares
every year

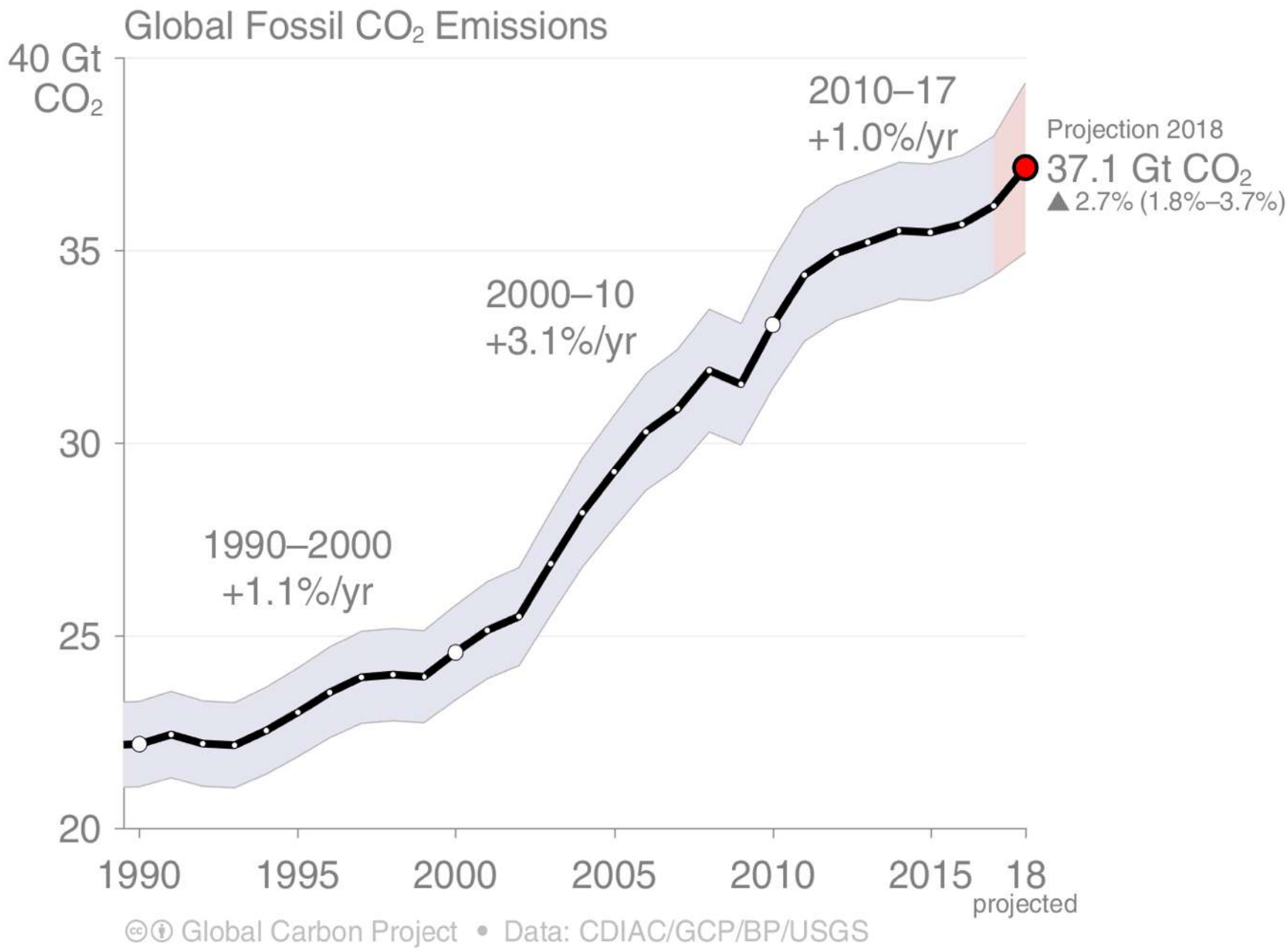

Year
1900
urbano
agricolo
foresta
prateria
altro
acqua
N
W
E
S
Cyprus
0
250
500
1,000
1,500
2,000
Kilometers

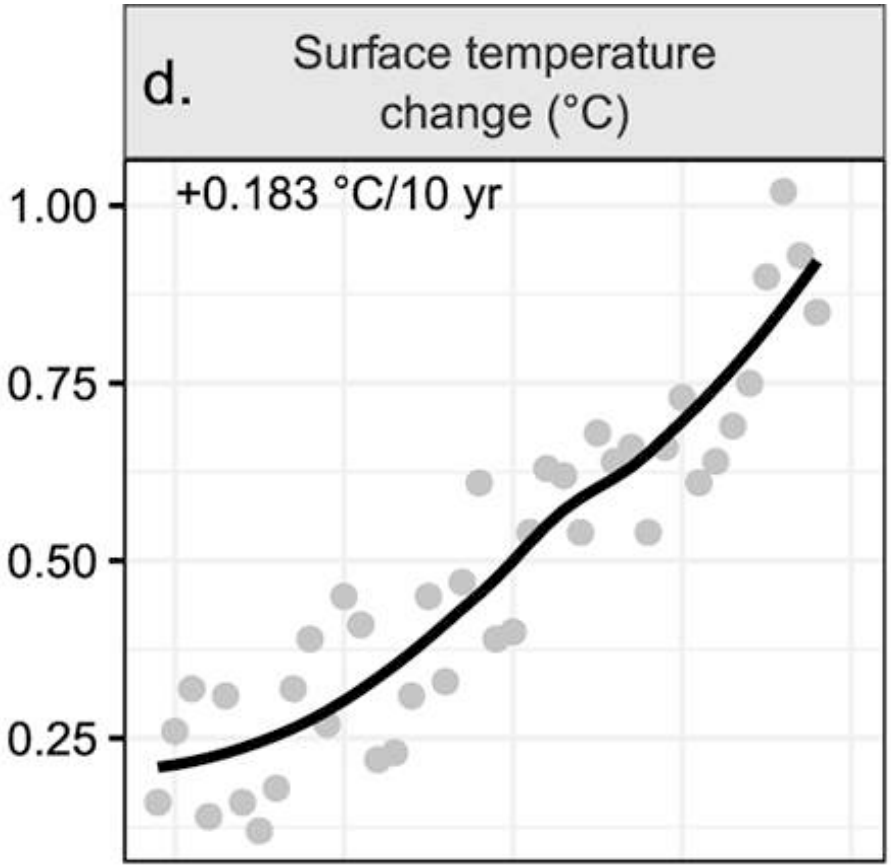
Wood use in Italy

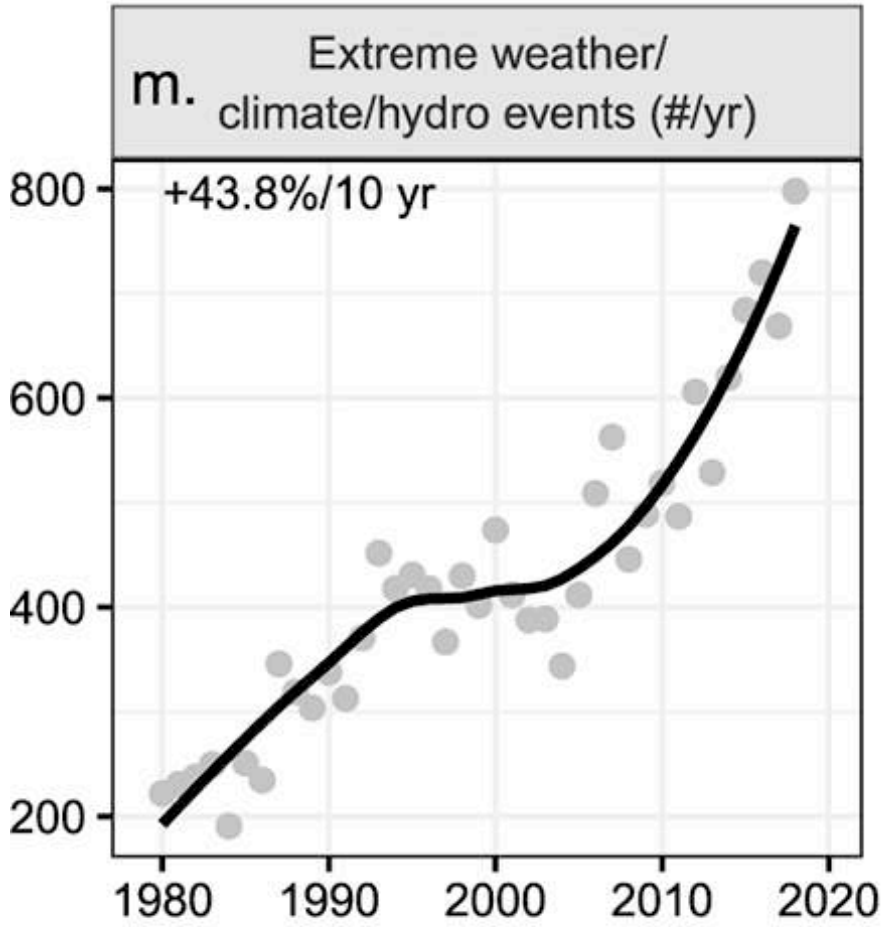


Source: FAO-ECE Timber Committee


“Embedded deforestation”
EU Timber Regulation
EU Green Deal
Photo: Pixabay

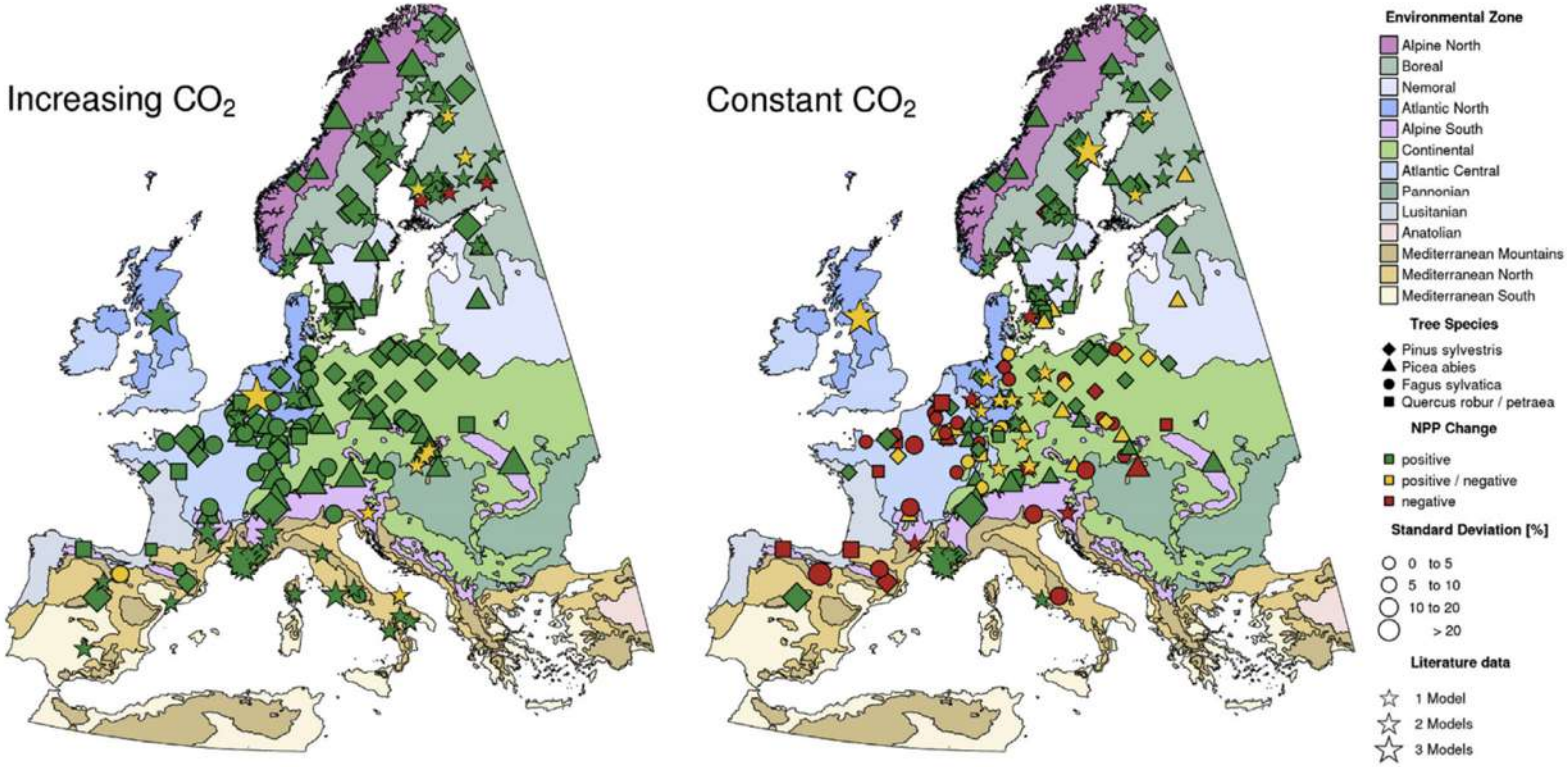

Global Fossil CO_2 Emissions
40 Gt CO_2
35
30
25
20
1990–2000
+1.1%/yr
2000–10
+3.1%/yr
2010–17
+1.0%/yr
Projection 2018
37.1 Gt CO_2
▲ 2.7% (1.8%–3.7%)
1990
1995
2000
2005
2010
2015
18
projected
Global Carbon Project • Data: CDIAC/GCP/BP/USGS





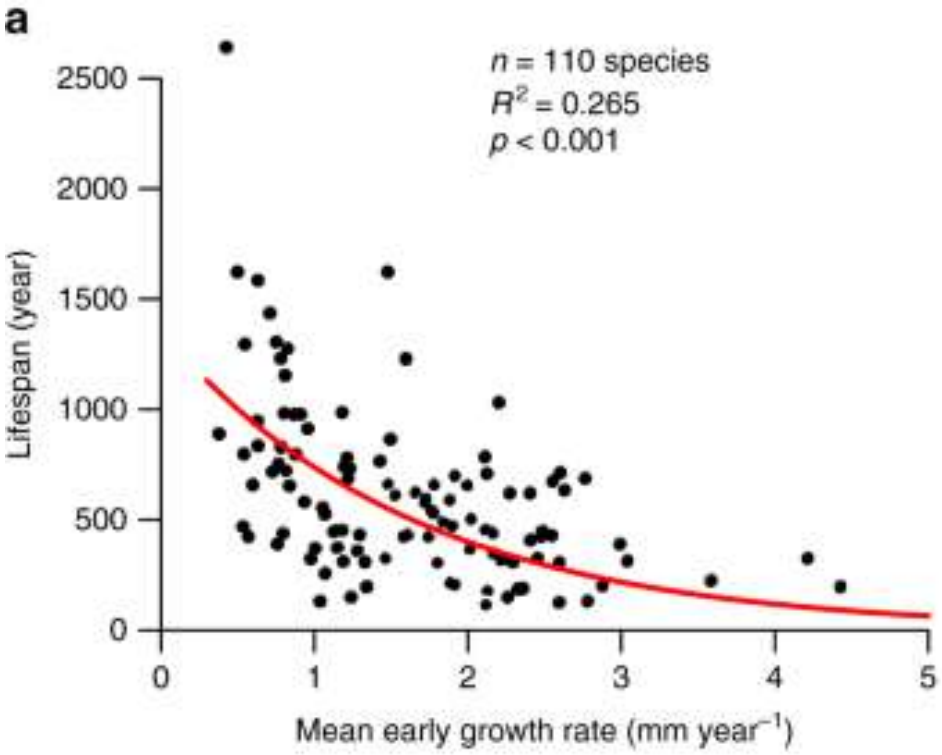
https://doi.org/10.1093/biosci/biz088

Effect on Net Primary Productivity



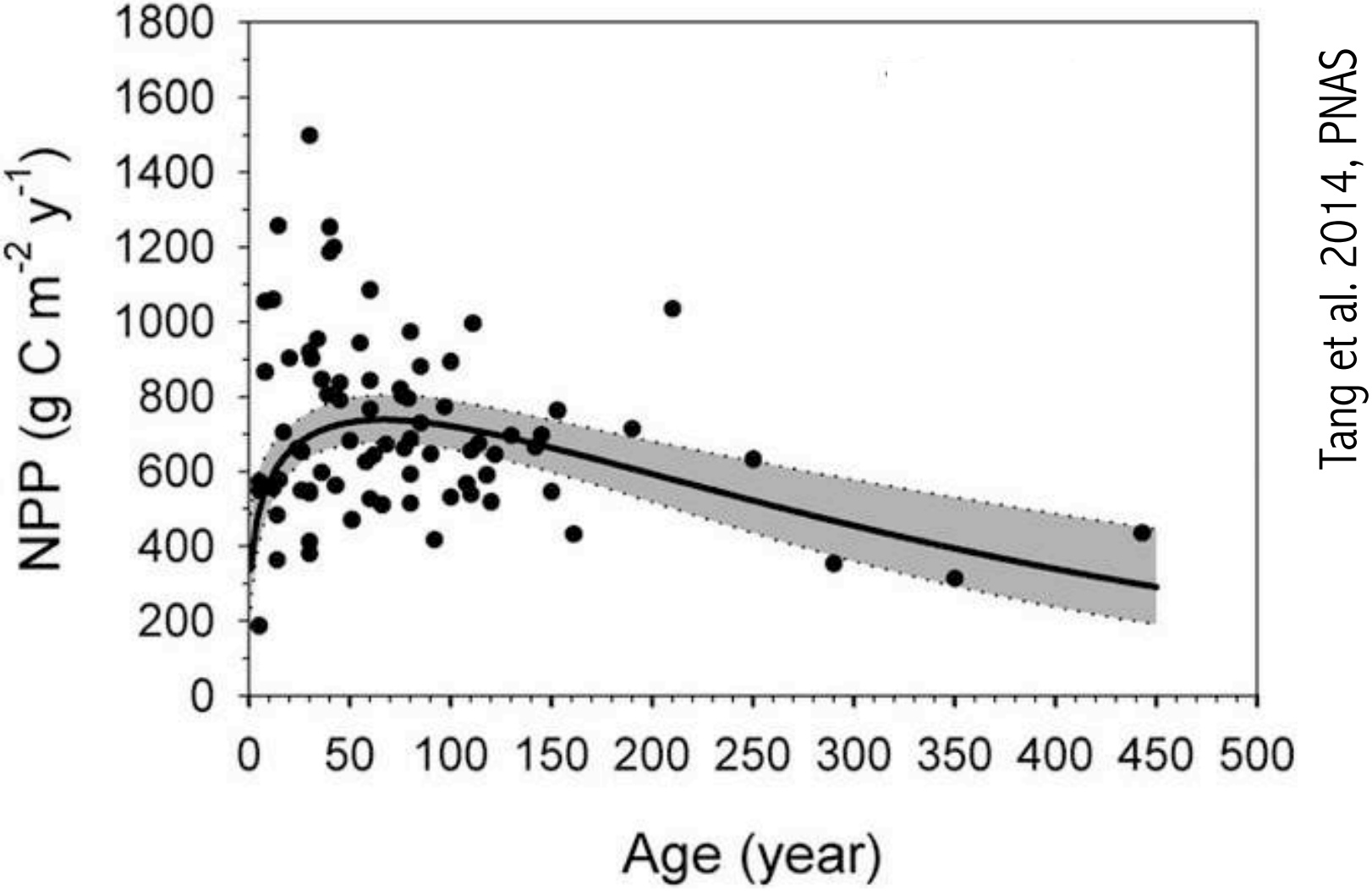
https://www.sciencedirect.com/science/article/pii/S030147971400379X

But: live fast, die young



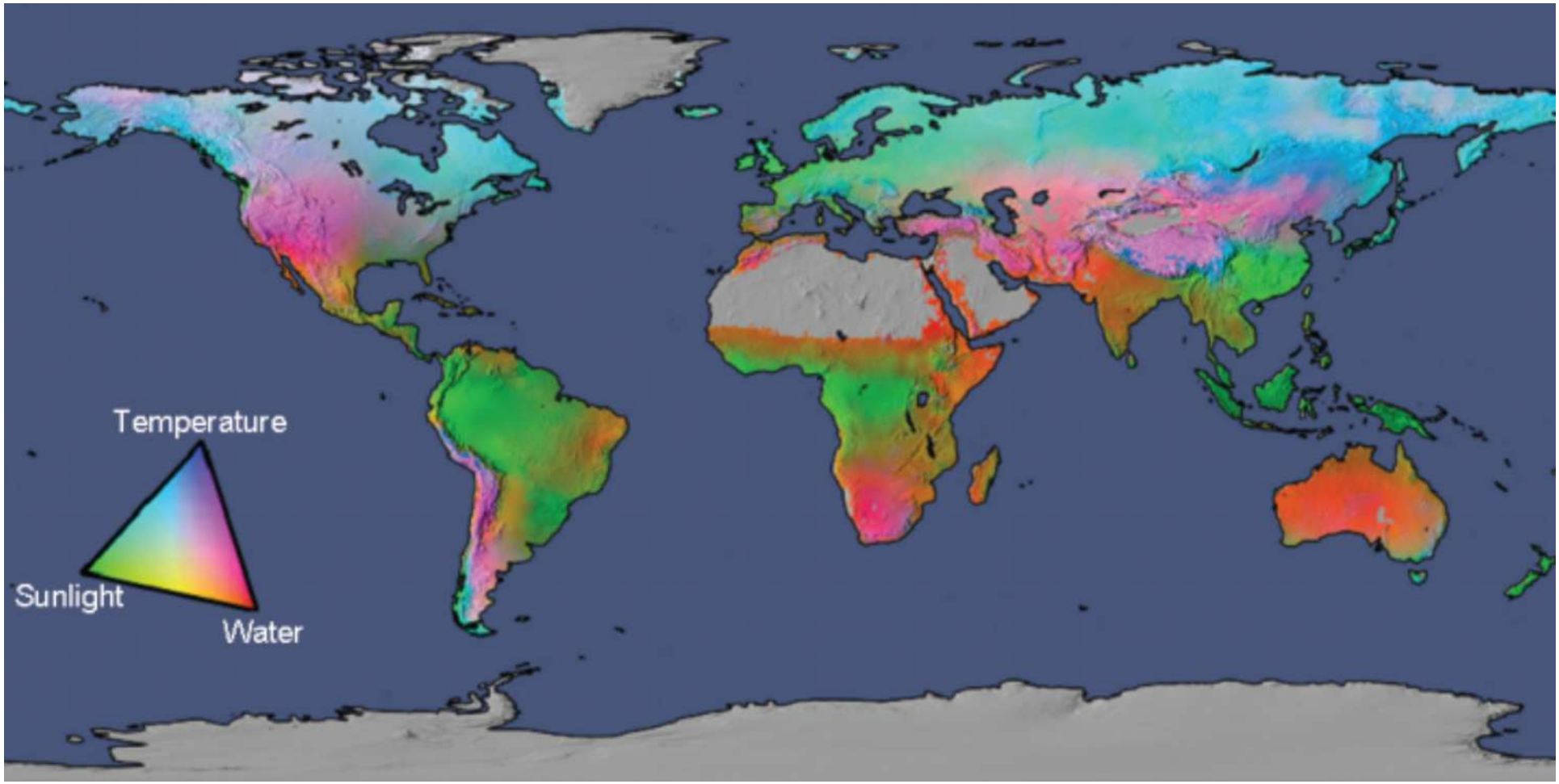
https://www.nature.com/articles/s41467-020-17966-z

Limits to carbon sink from forest age

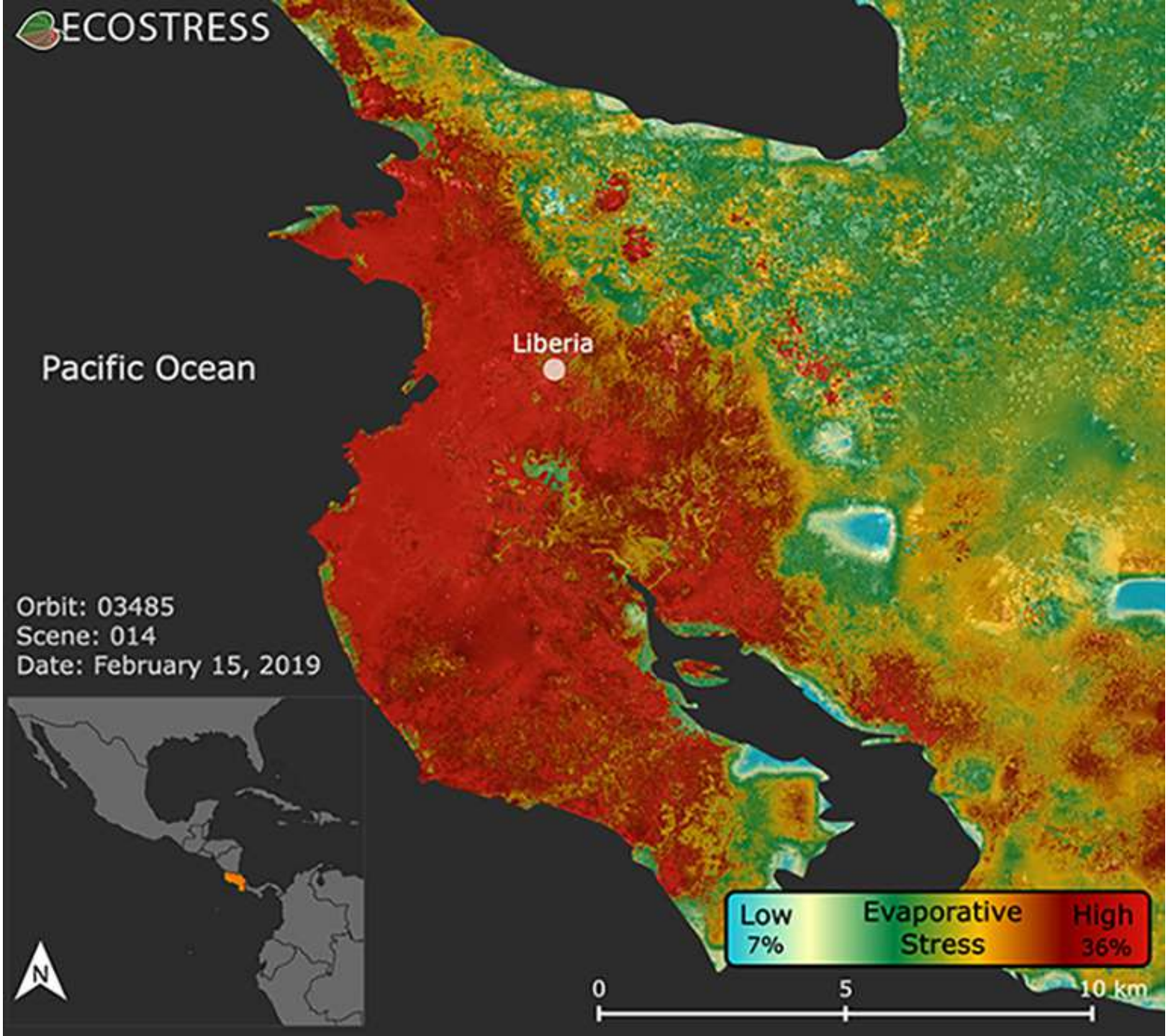


Tang et al. 2014, PNAS

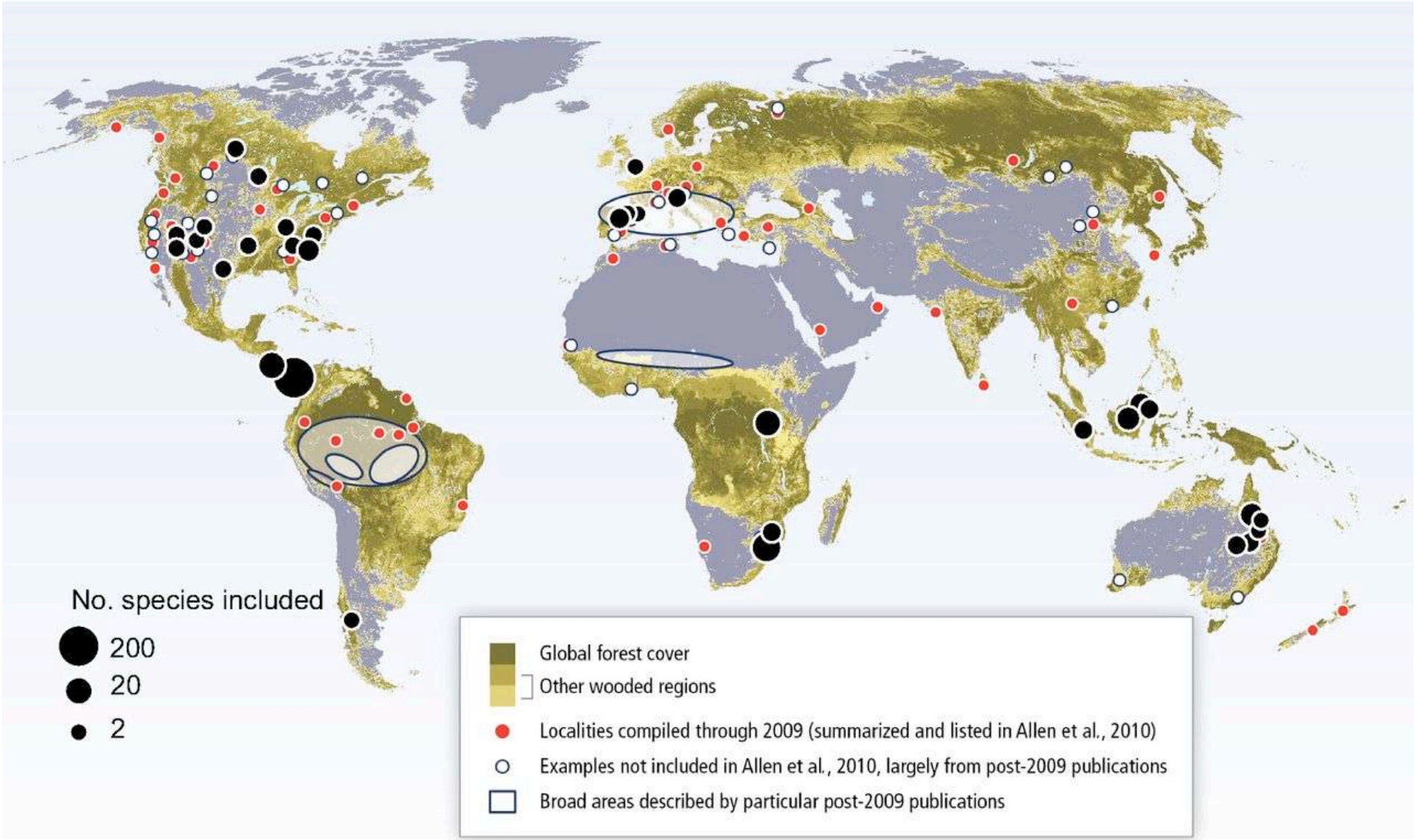
Potential limits to vegetation net primary production based on fundamental physiological limits



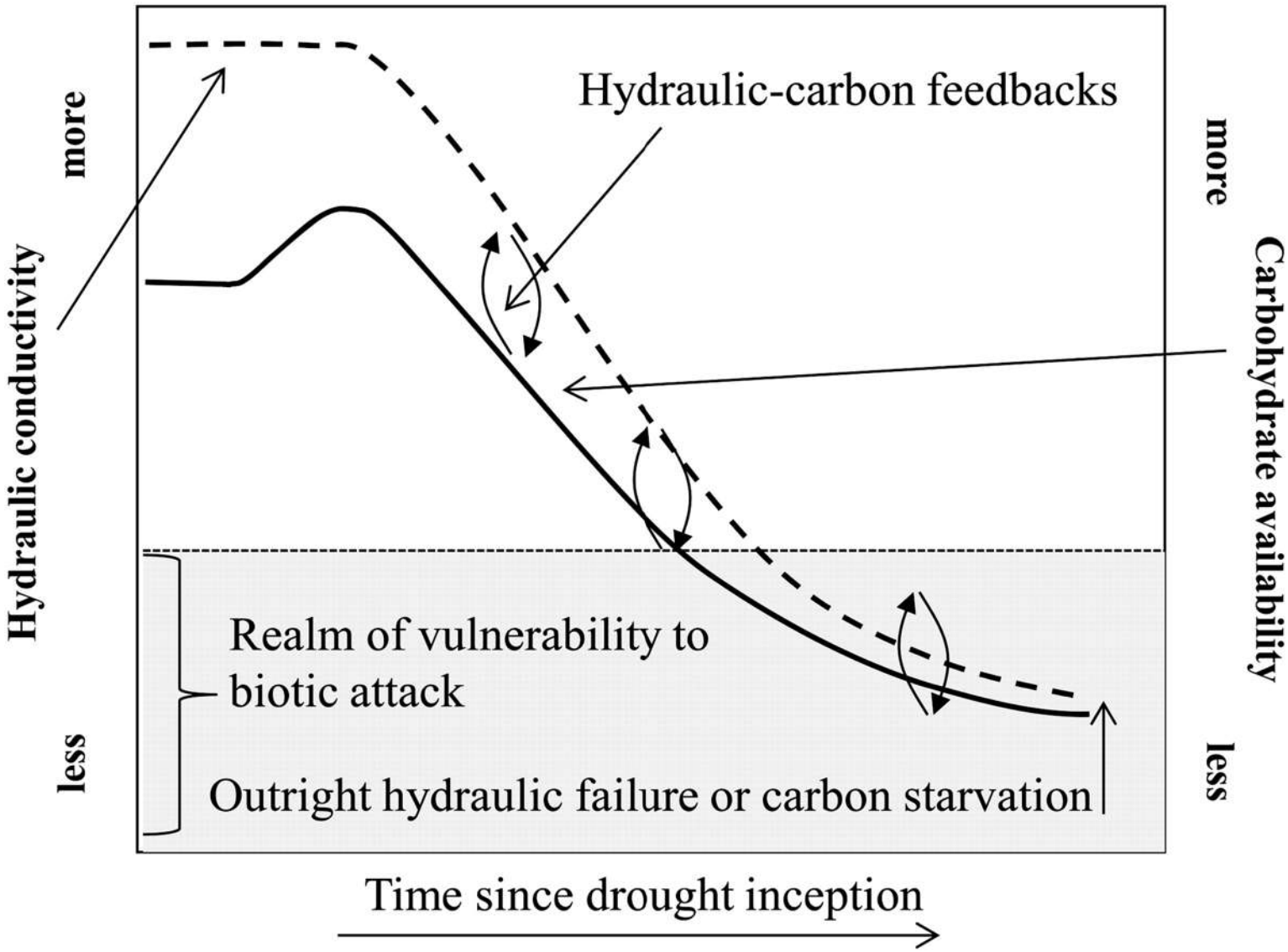
https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2006.01134.x


ECOSTRESS
Pacific Ocean
Liberia
Orbit: 03485
Scene: 014
Date: February 15, 2019
N
Low
7%
Evaporative
Stress
High
36%
0
5
10 km

Drought mortality events in global forests

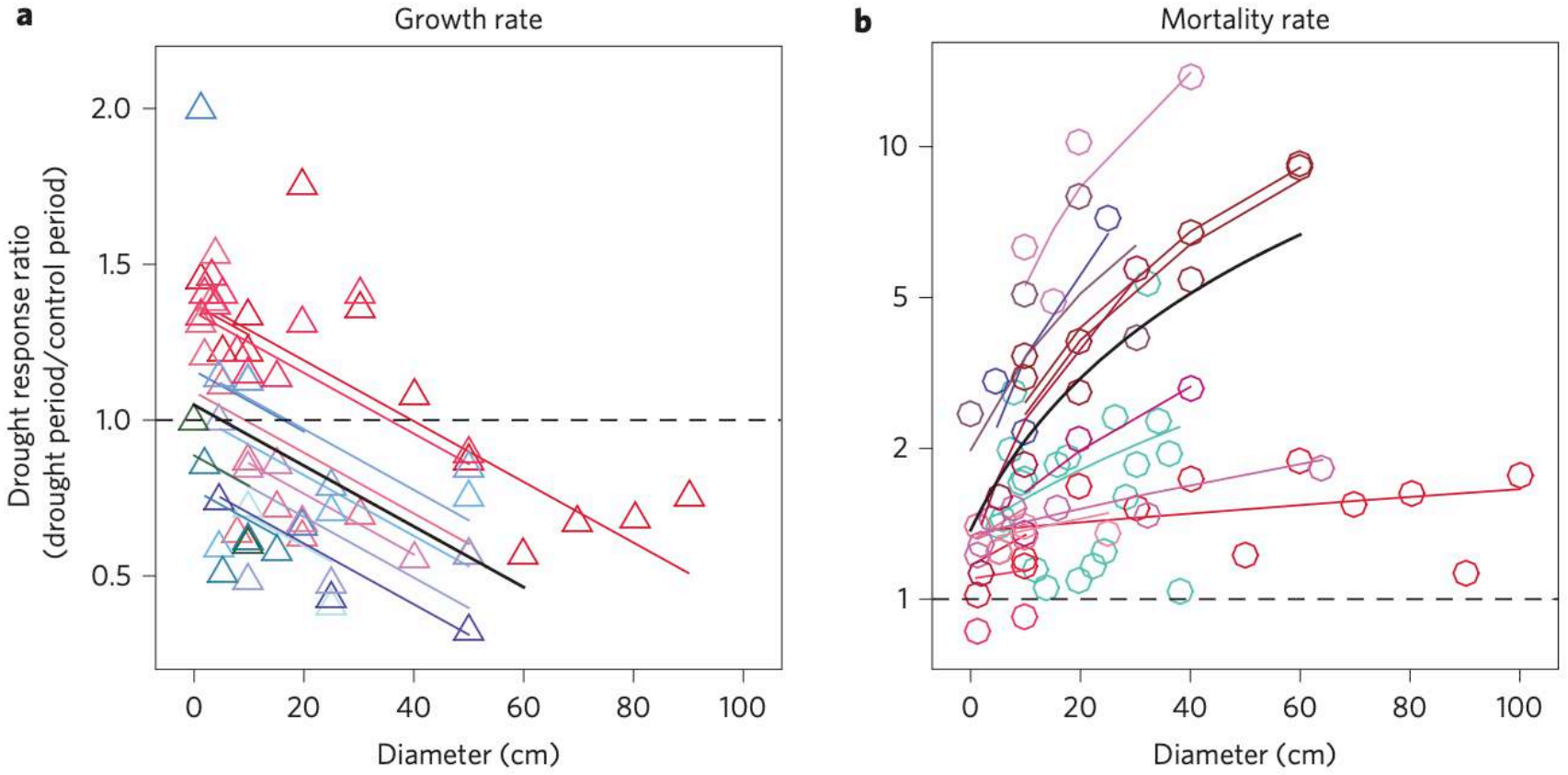


https://www.pnas.org/content/113/18/5024



http://www.plantphysiol.org/content/155/3/1051

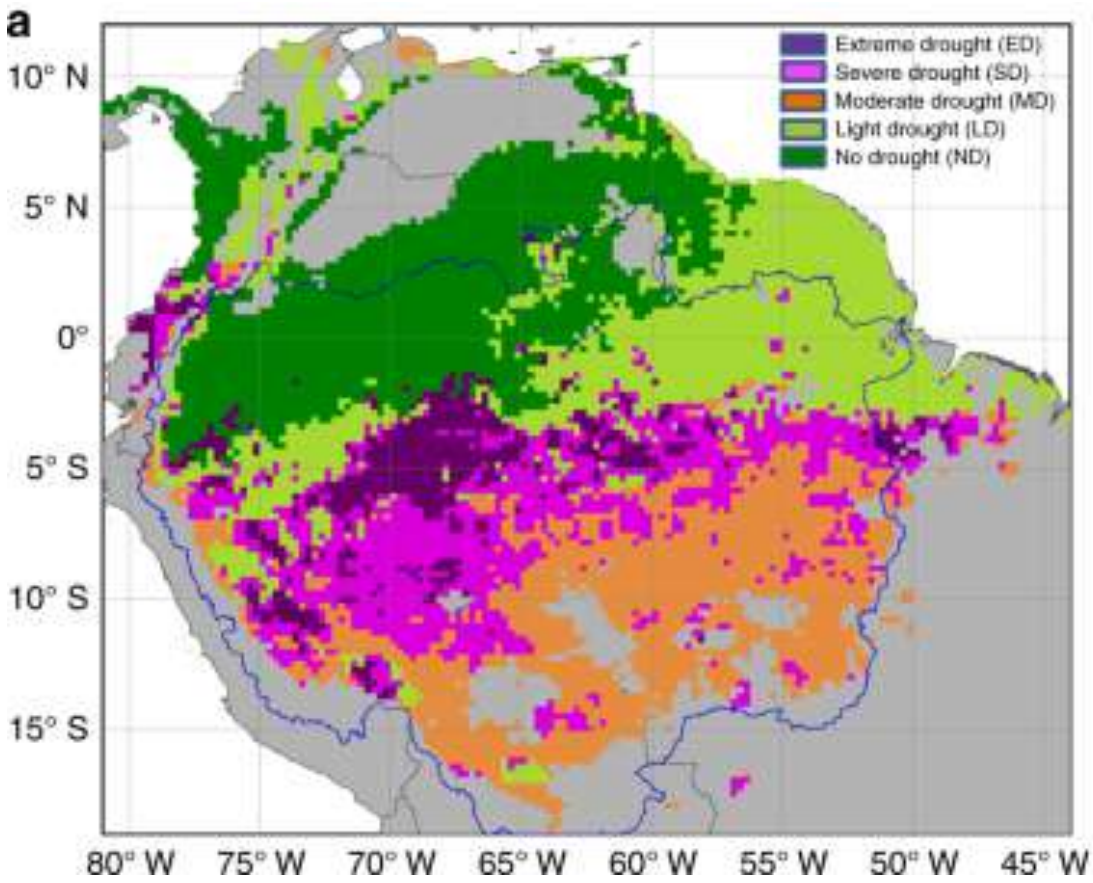
Larger trees are more impacted by drought

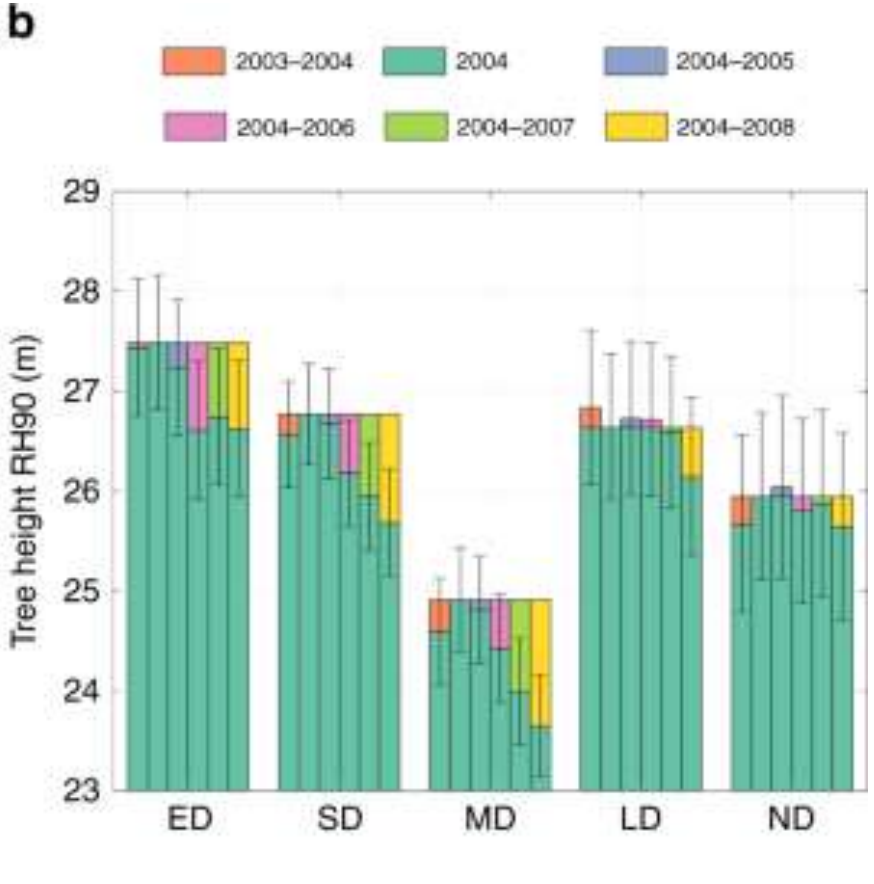


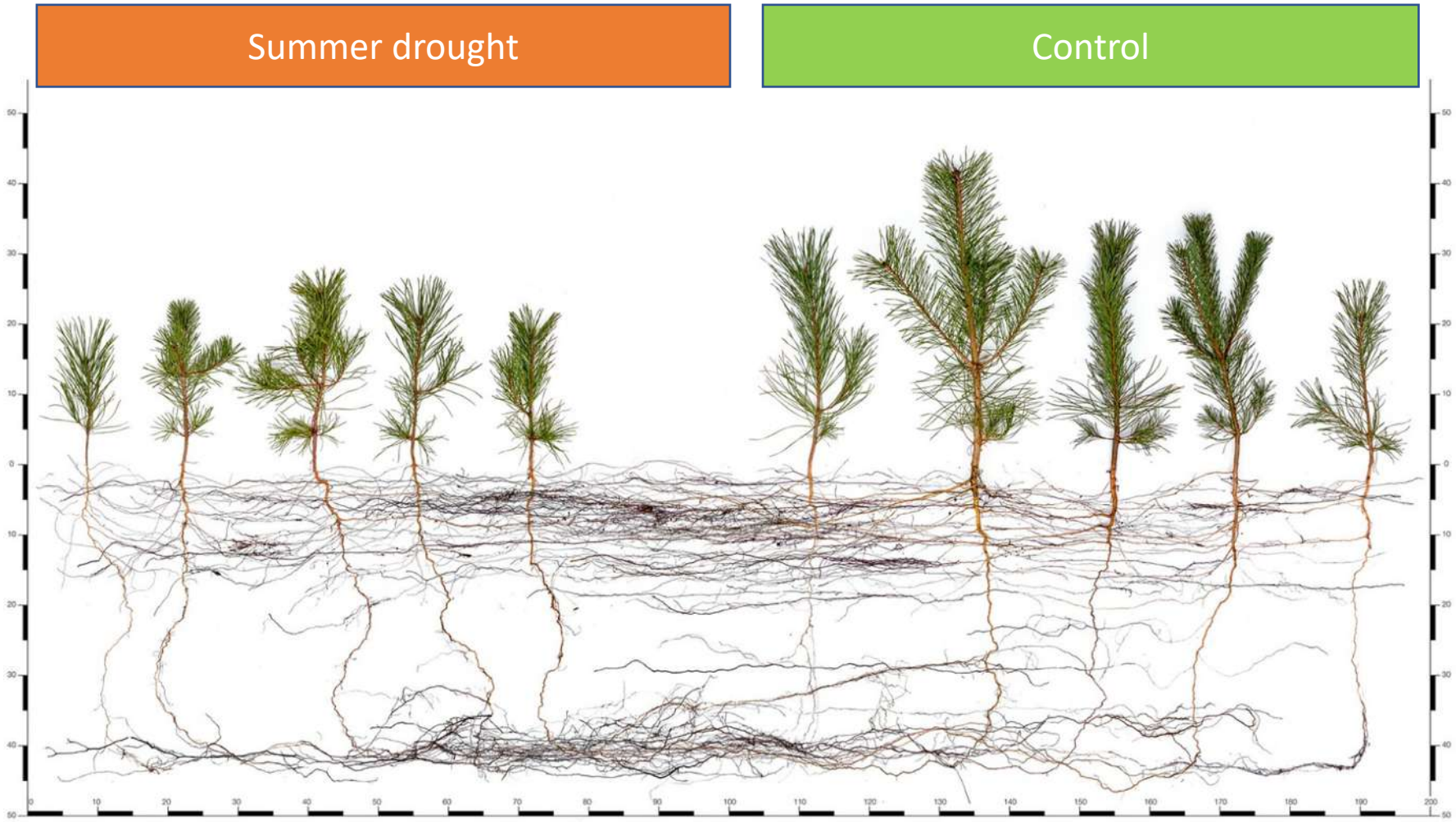
https://www.nature.com/articles/nplants2015139

Loss of canopy heght in the Amazon basin

https://www.nature.com/articles/s41467-018-05668-6







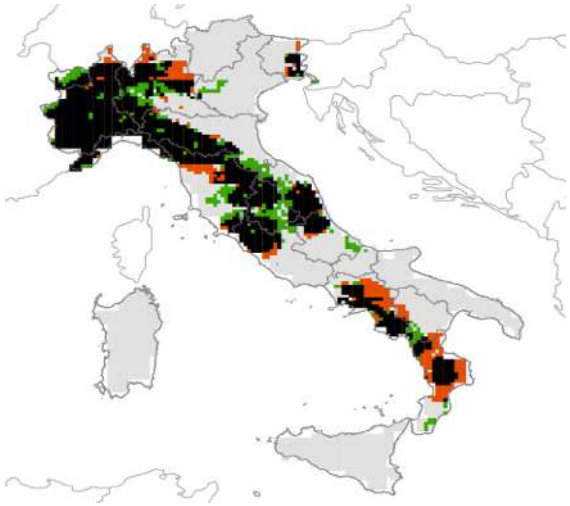
Pine regeneration during drought by Christoph Bachofen, WSL

https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs2.2108

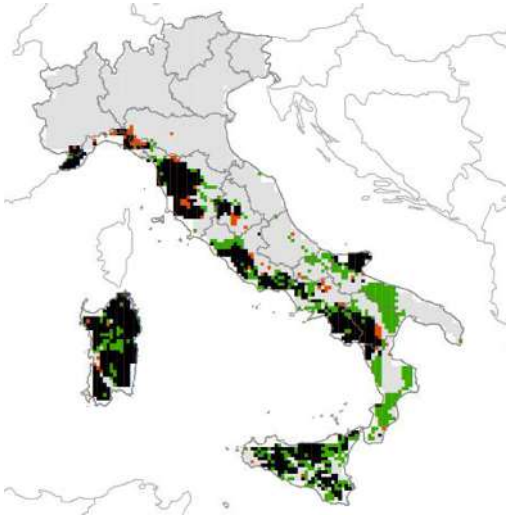
Forest cover unchanged
Increasing forest cover
Decreasing forest cover

Forest migrations

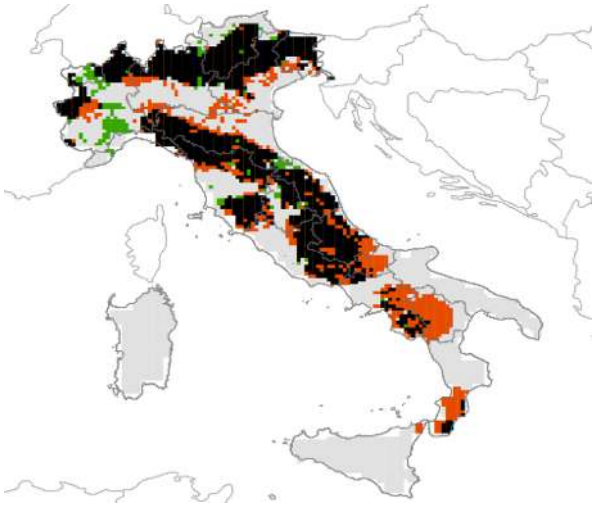
Castanea sativa



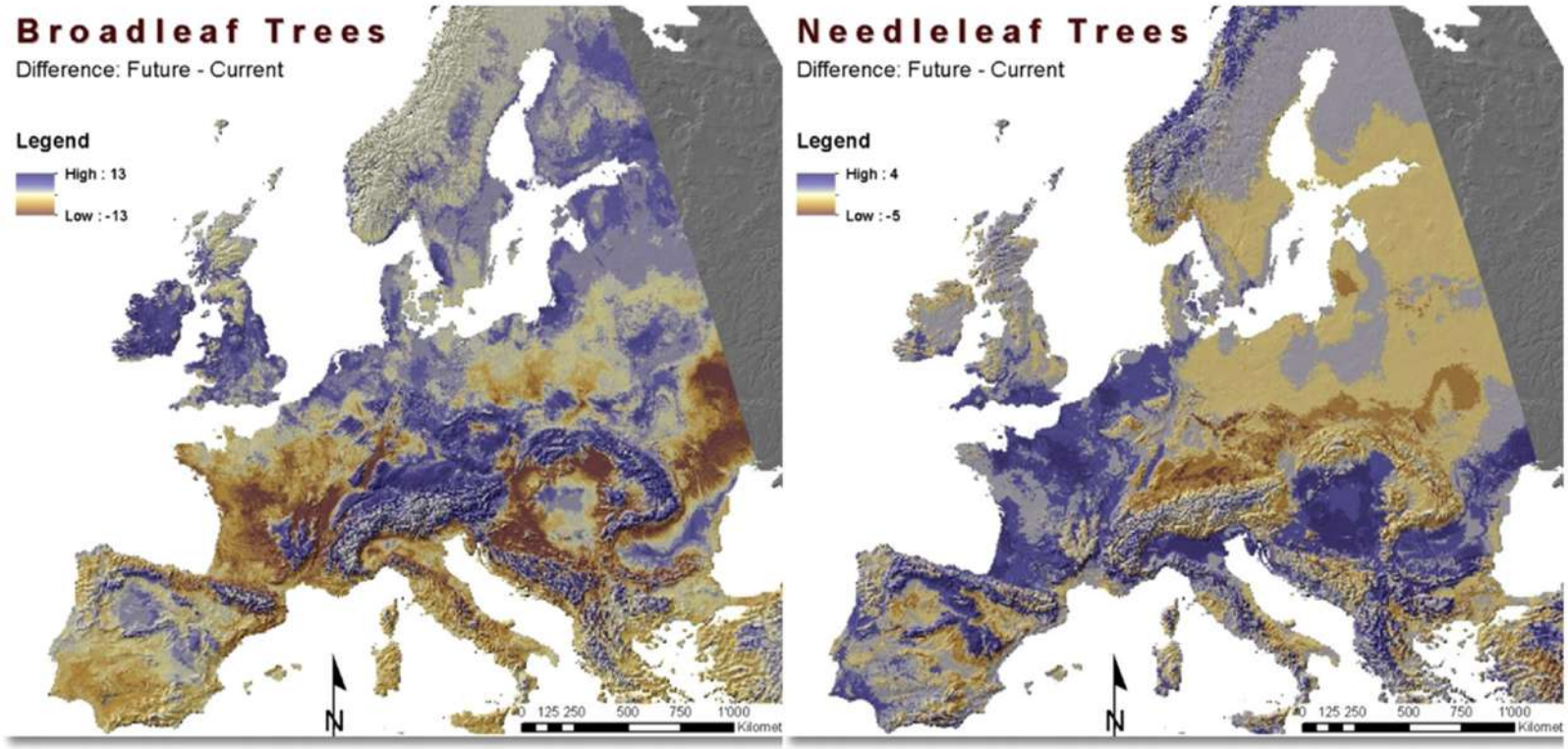
Mediterranean scrub



Fagus sylvatica

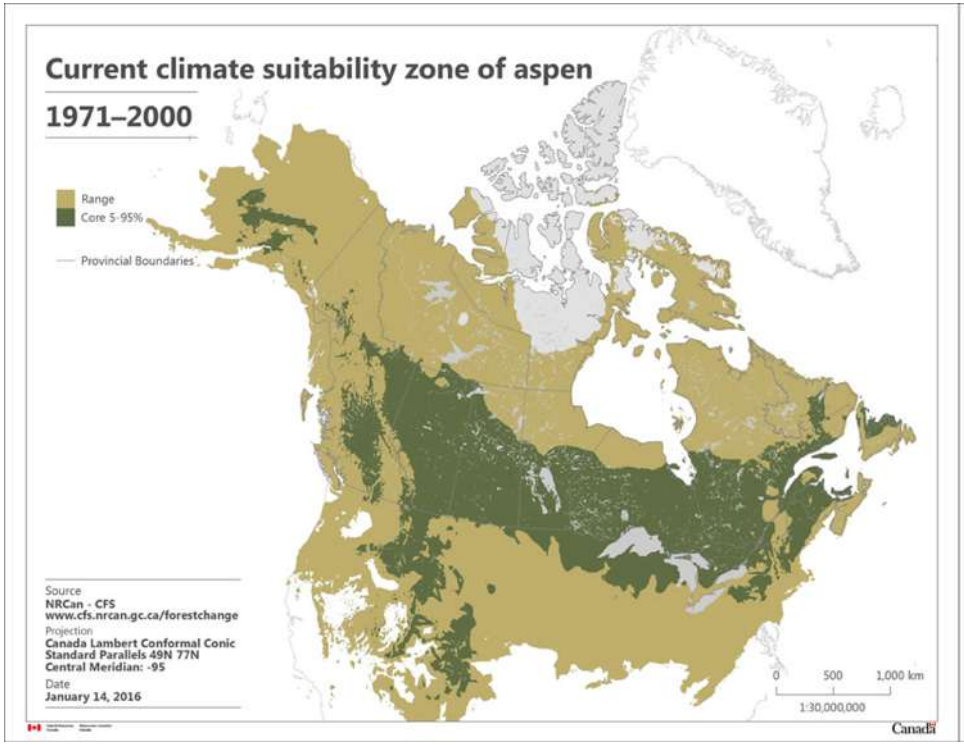


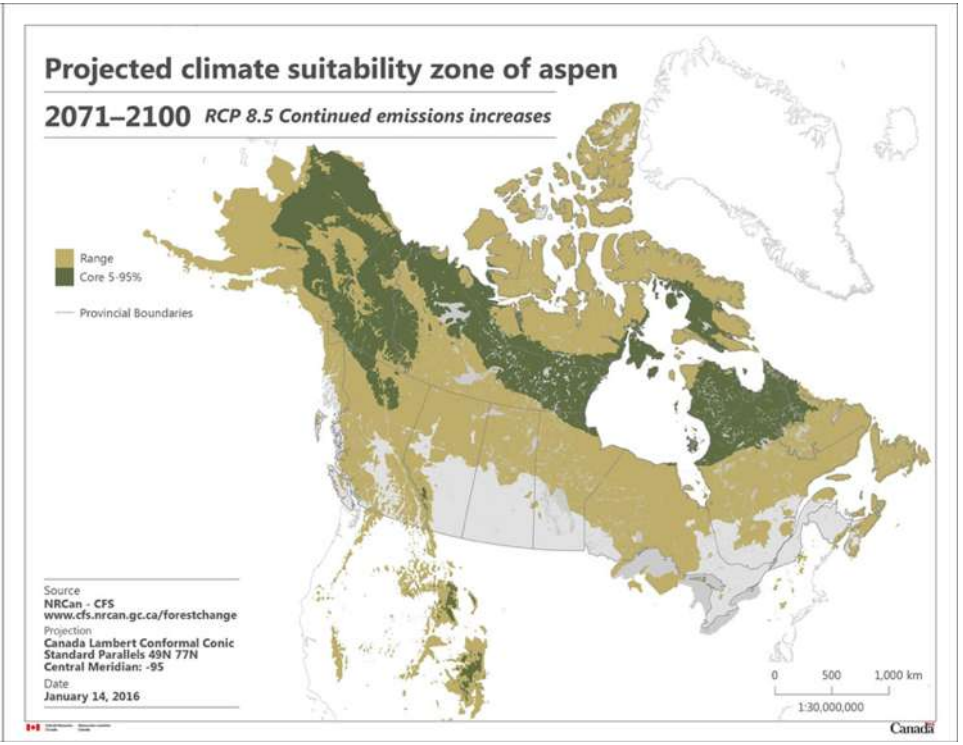
http://www.minambiente.it/comunicati/ambiente-parte-consultazione-su-piano-nazionale-adattamento-cambiamenti-climatici



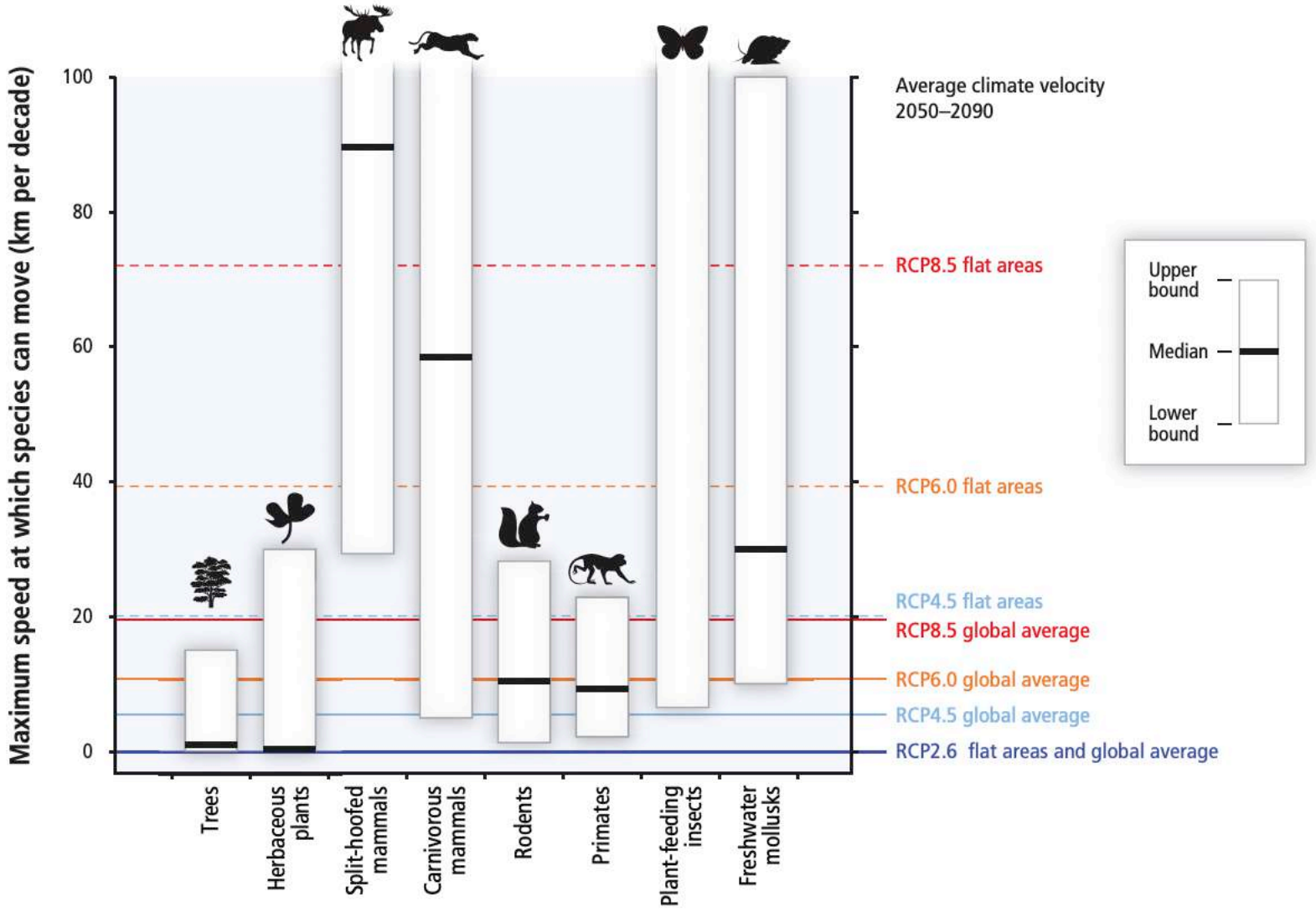
https://www.sciencedirect.com/science/article/pii/S030147971400379X

Forest migrations

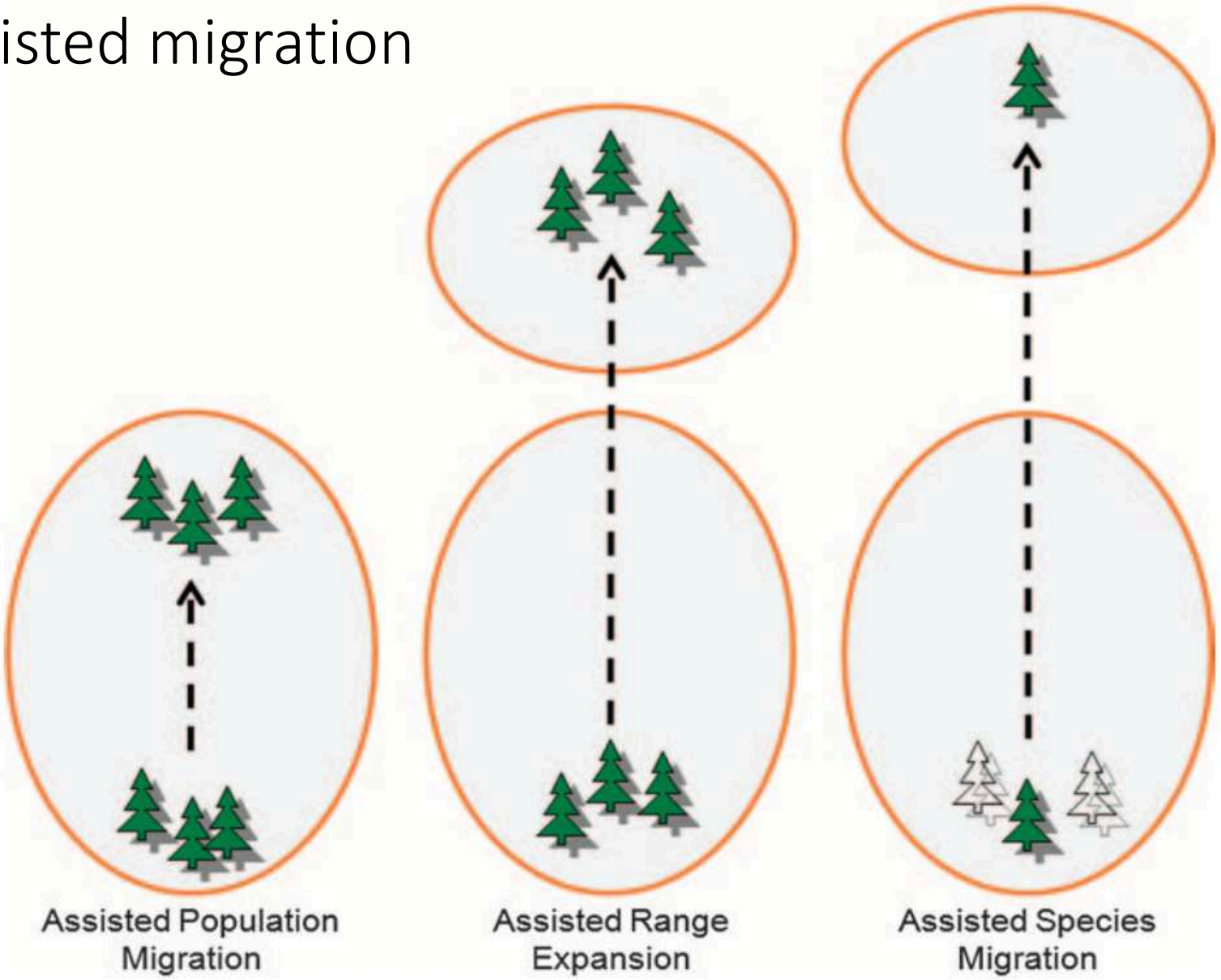




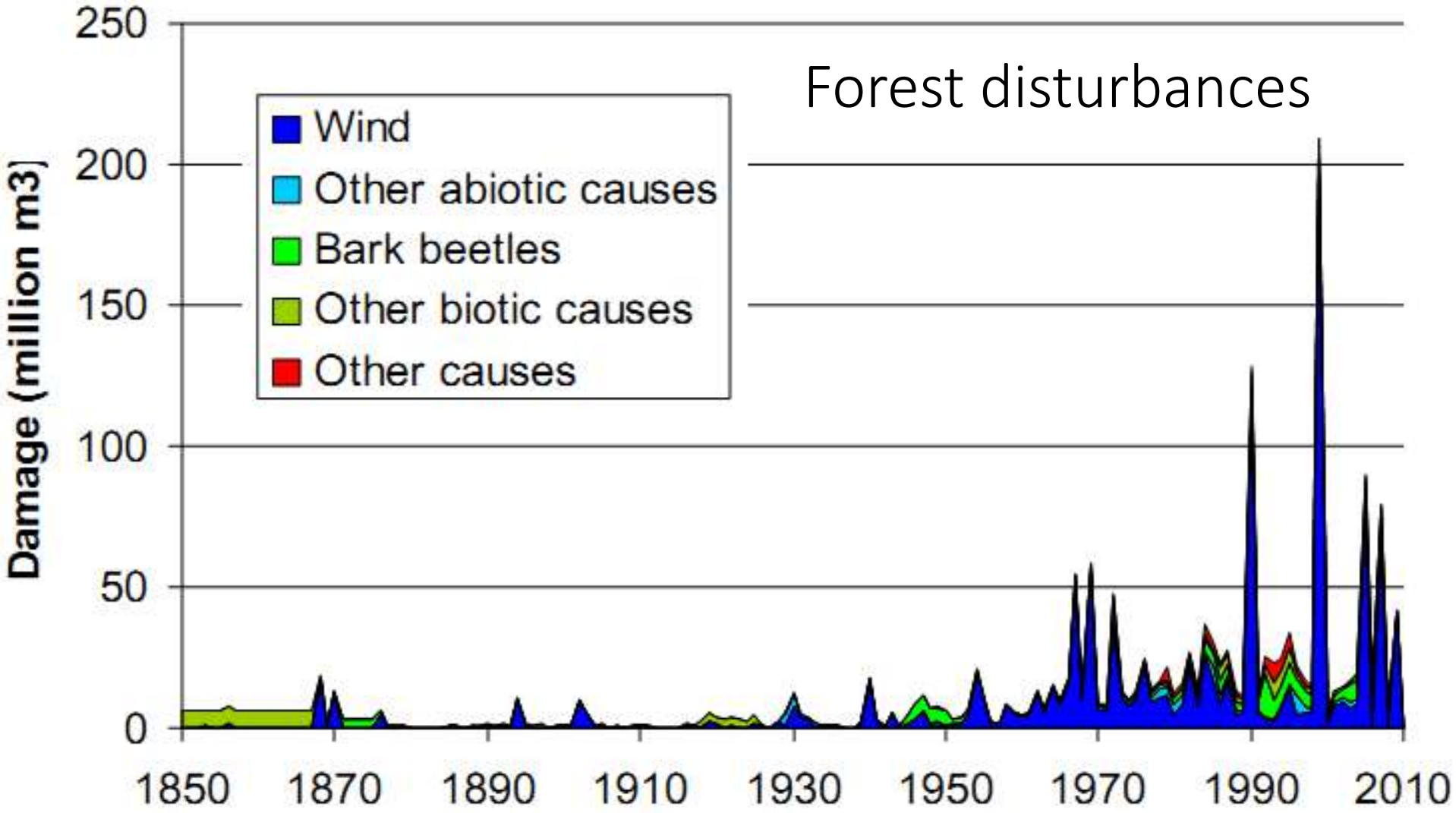
IPCC AR5 WG2 Figure SPM.5



Assisted migration

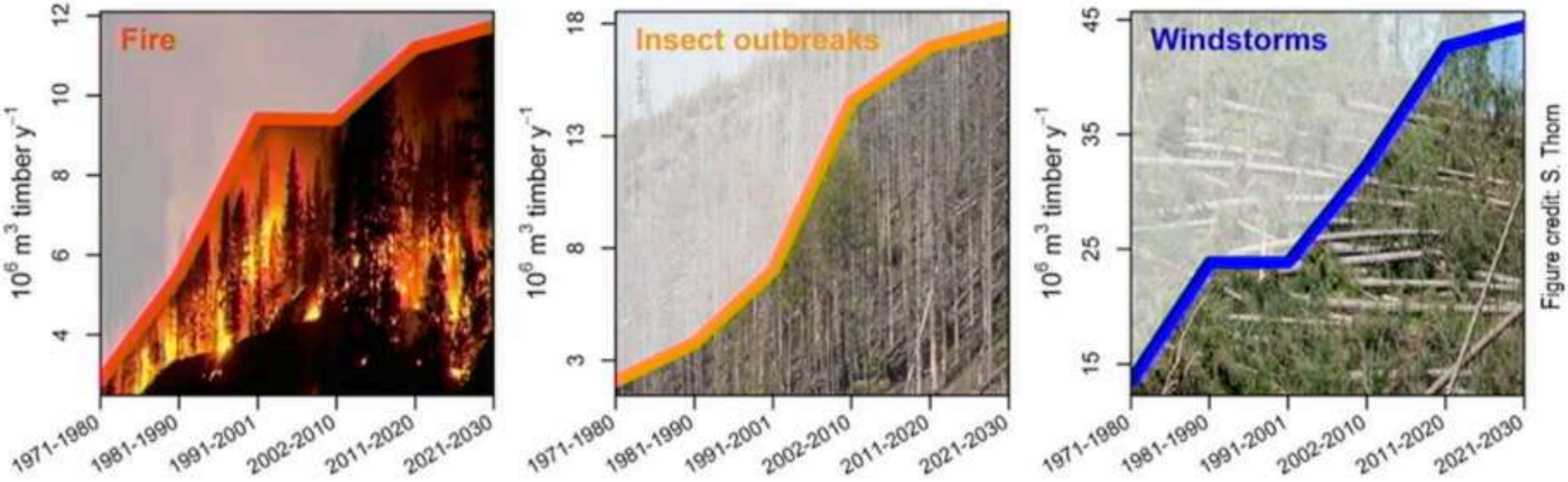


Forest disturbances

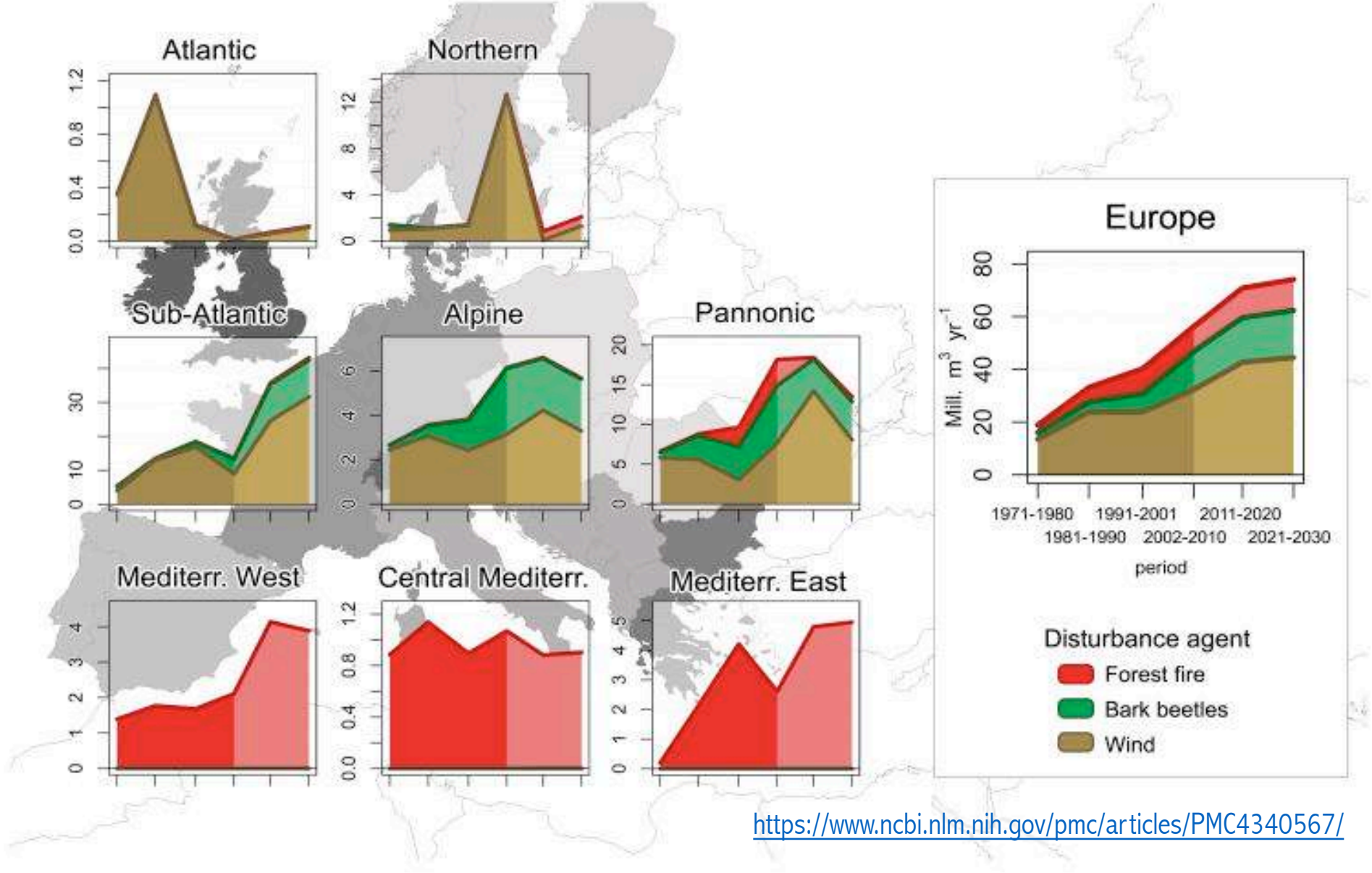


https://dissertationesforestales.fi/pdf/article1841.pdf

Estimated rate of increase: +1 Mill. m³ per year



Seidl et al. (2014, Nature Climate Change)

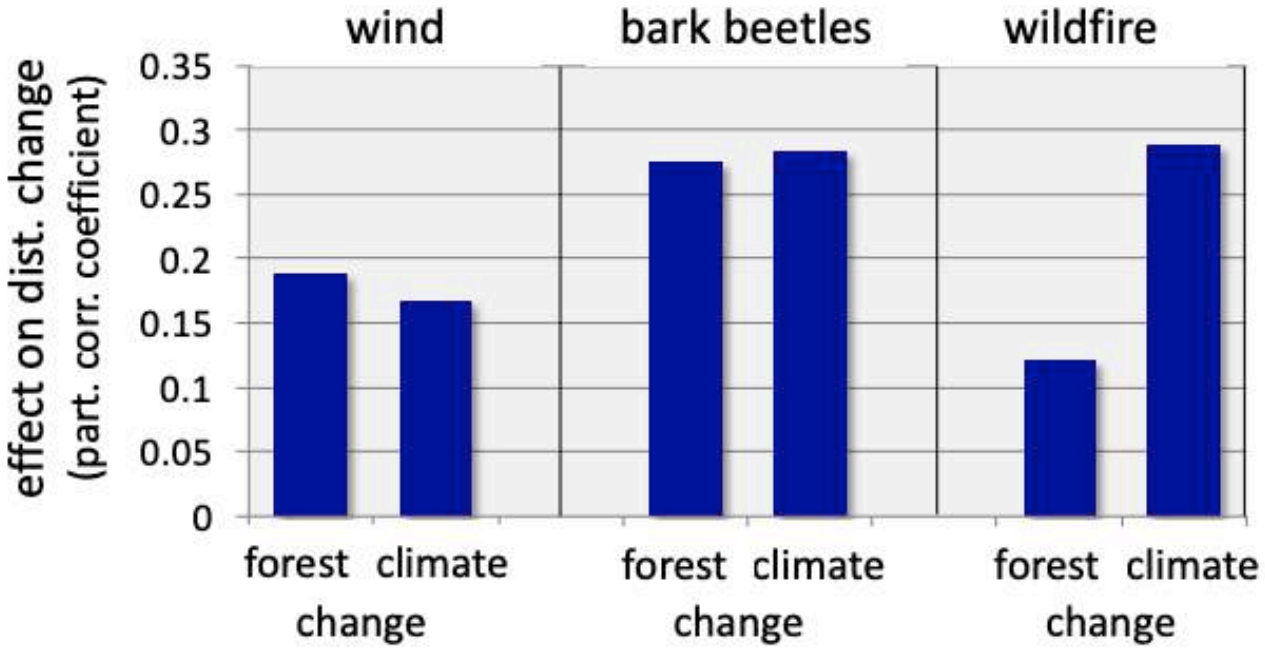


https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4340567/

Climate change is an important driver of increasing disturbances

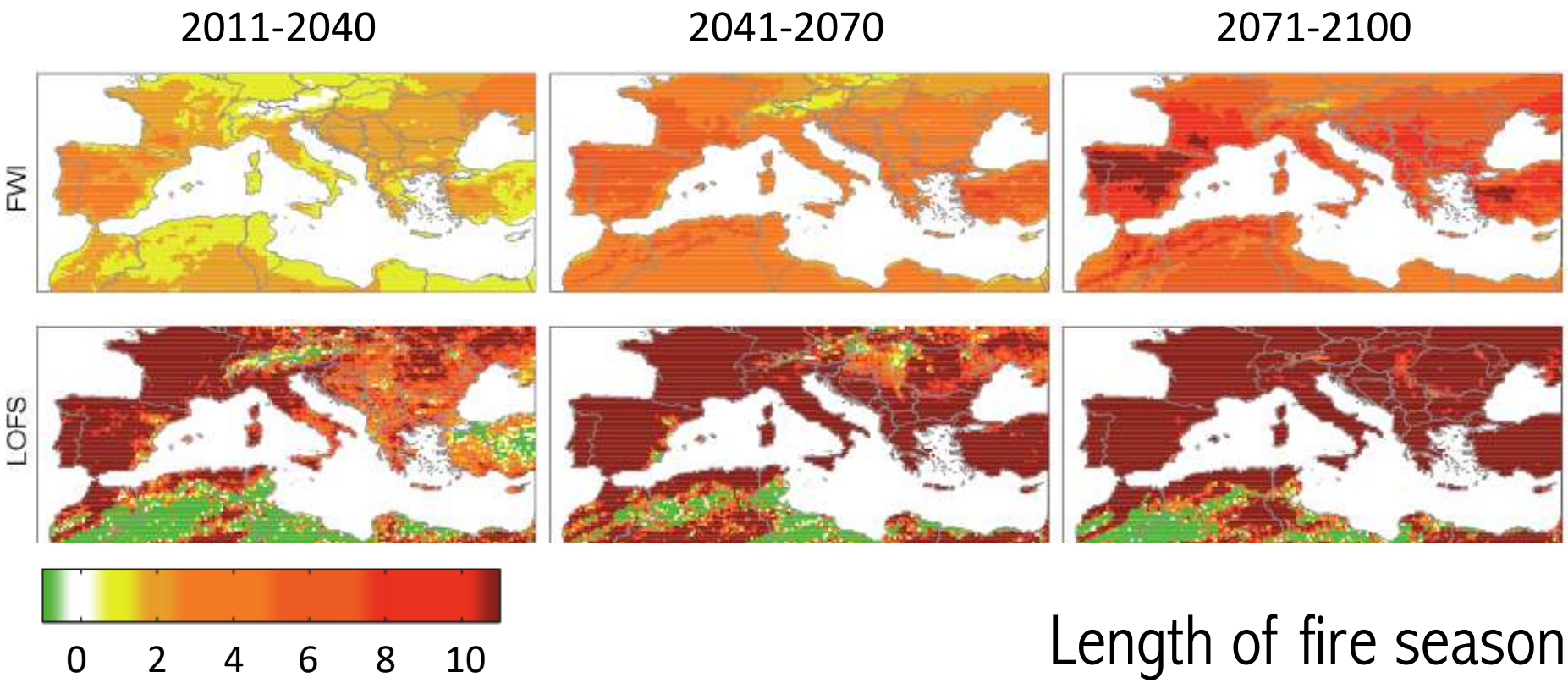
…but…

also management contributed (via changes in forest structure and composition)



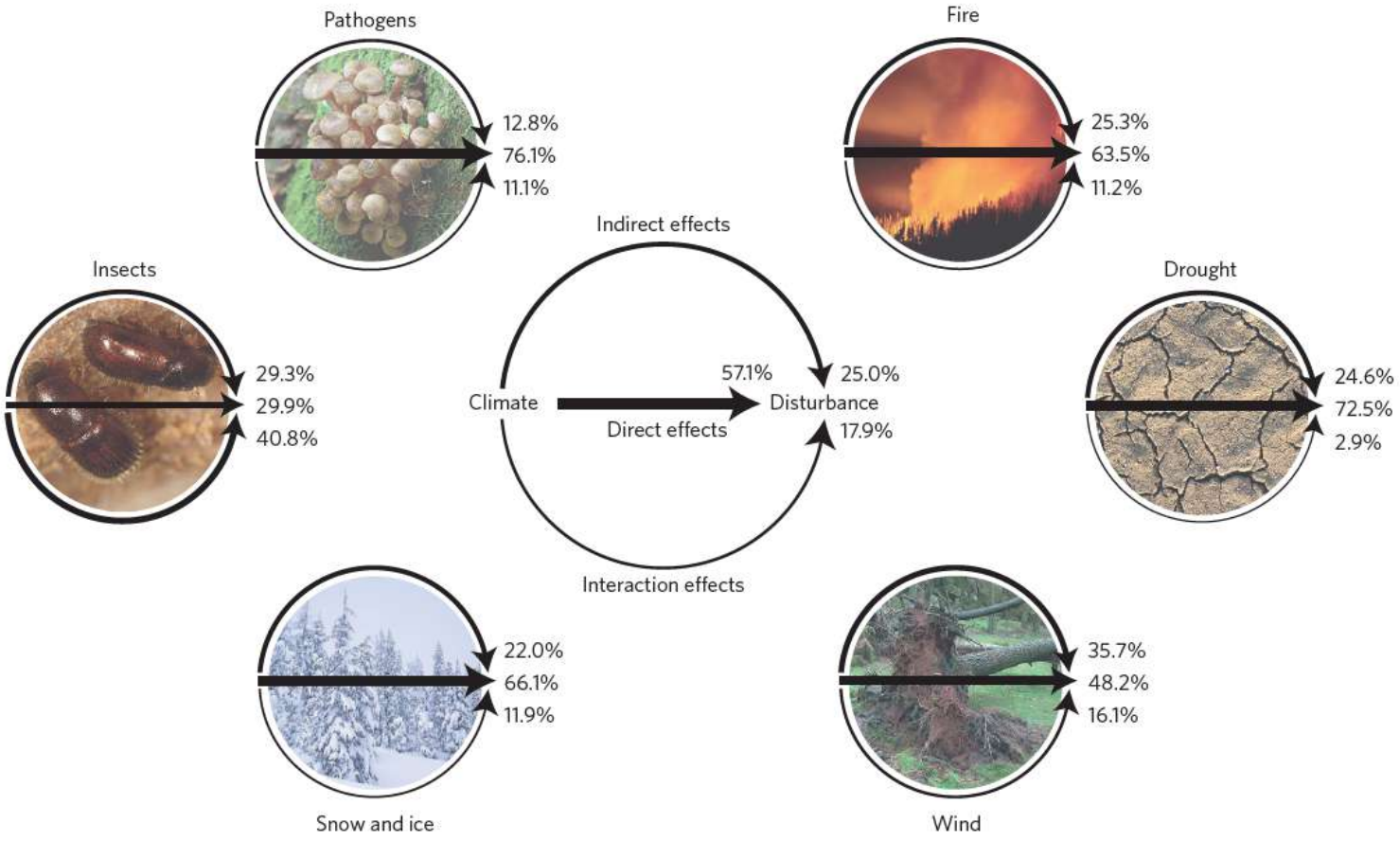
Seidl et al. (2011, Glob. Change Biol.)

Fire Weather Index

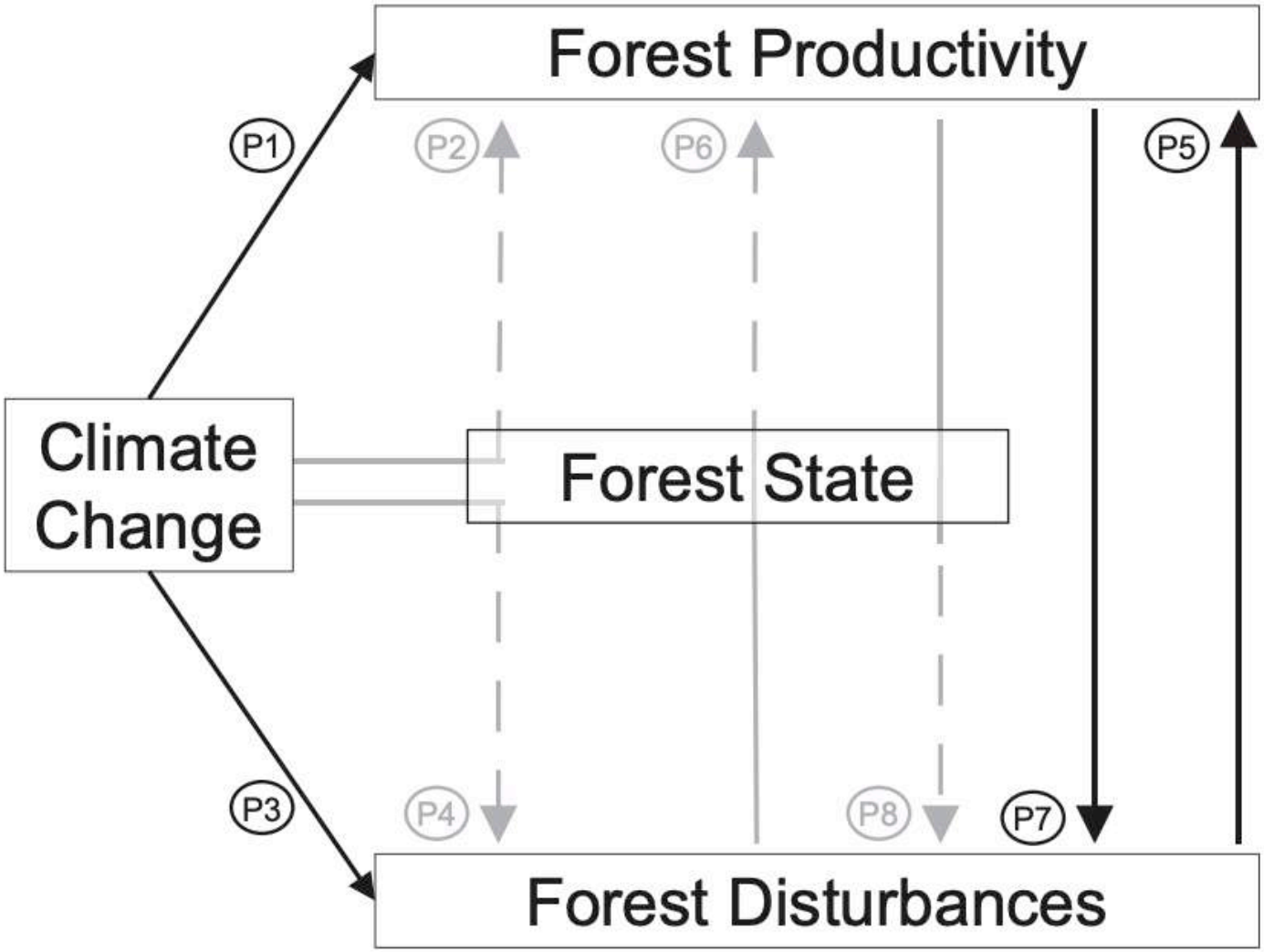


Length of fire season

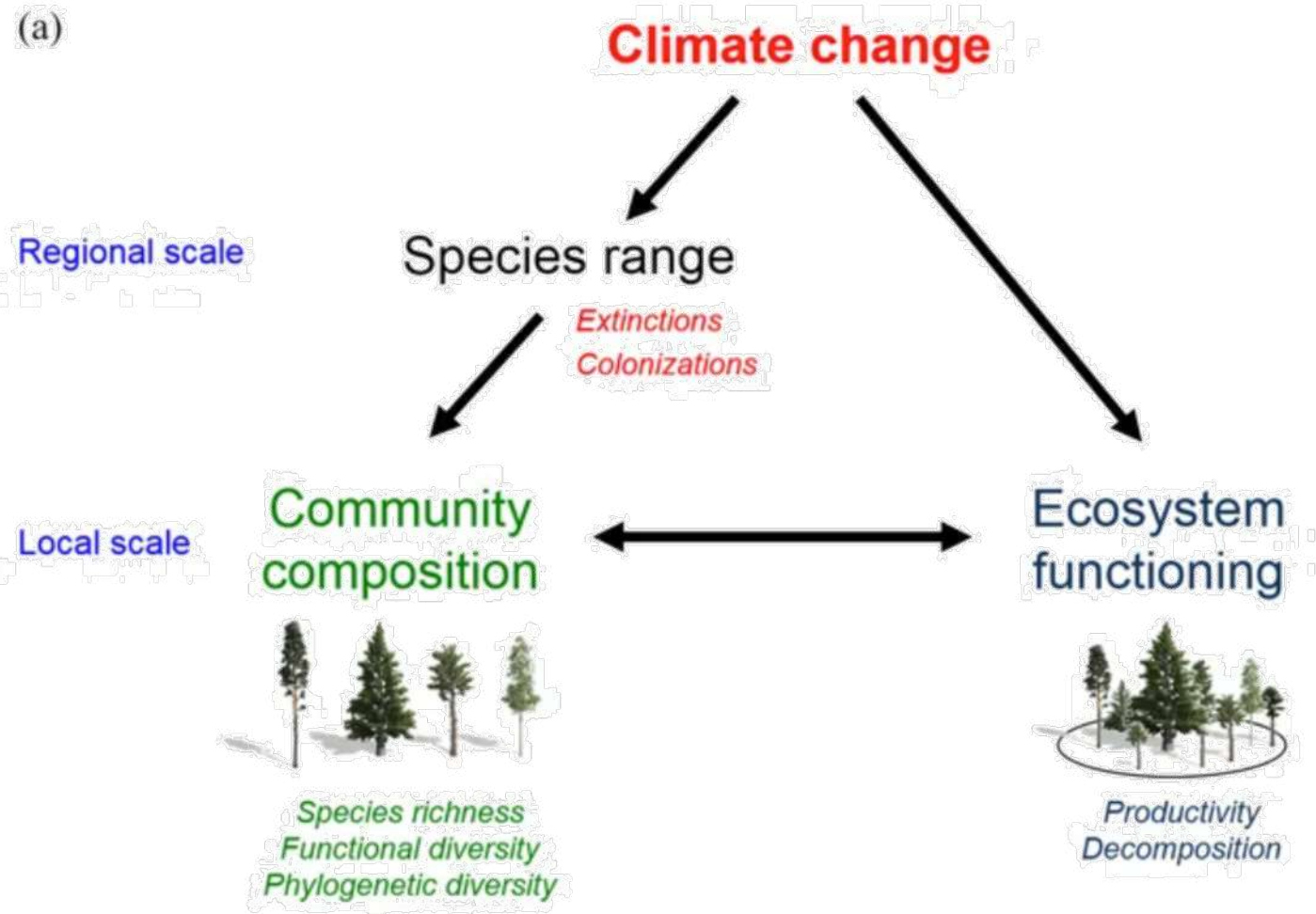
https://link.springer.com/article/10.1007/s10584-013-1005-z



https://www.nature.com/articles/nclimate3303



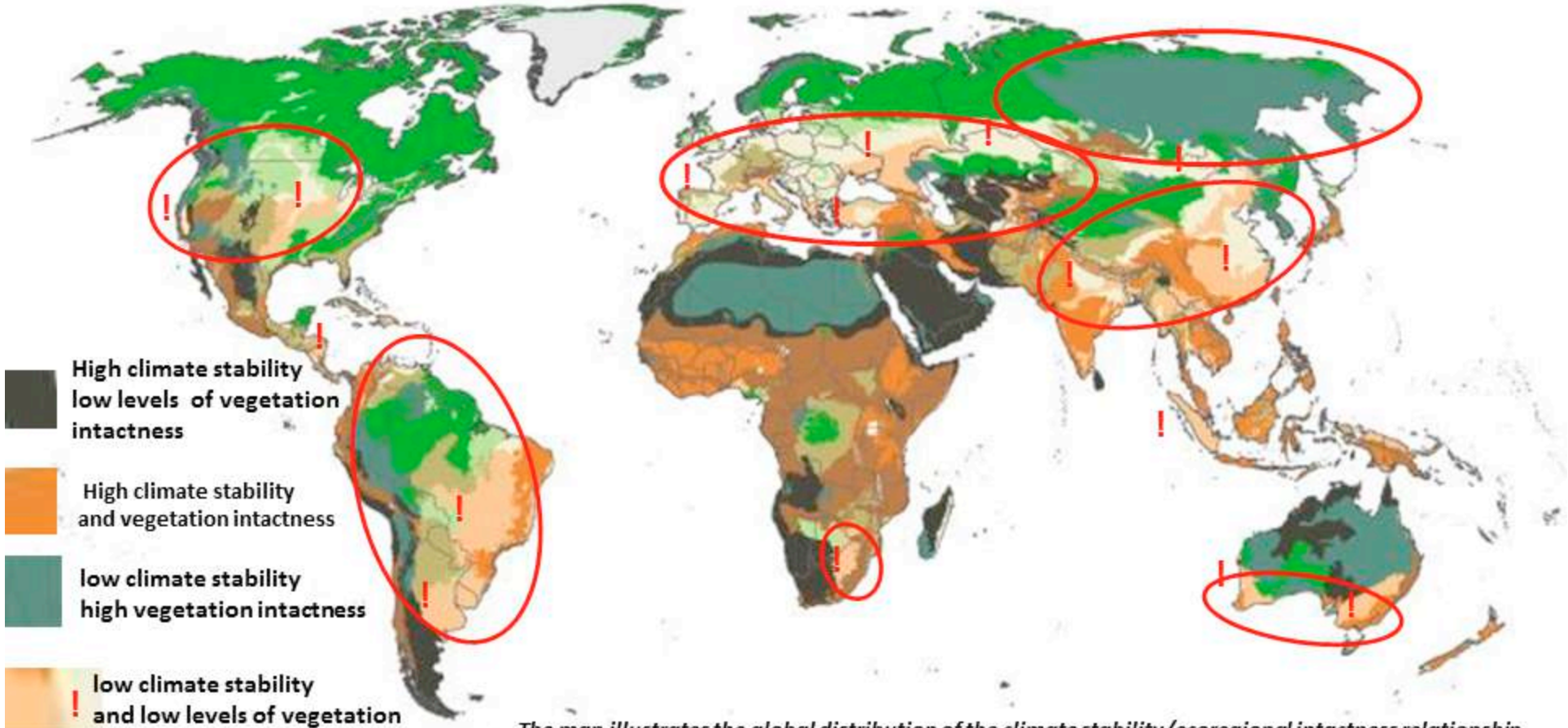
https://iopscience.iop.org/article/10.1088/1748-9326/aa5ef1/meta



https://www.nature.com/articles/s41598-018-23763-y

Ecosystem climate change vulnerability and conservation

Mapping vulnerability and conservation adaptation strategies under climate change James E. M. Watson, Nature Climate Change September 2013

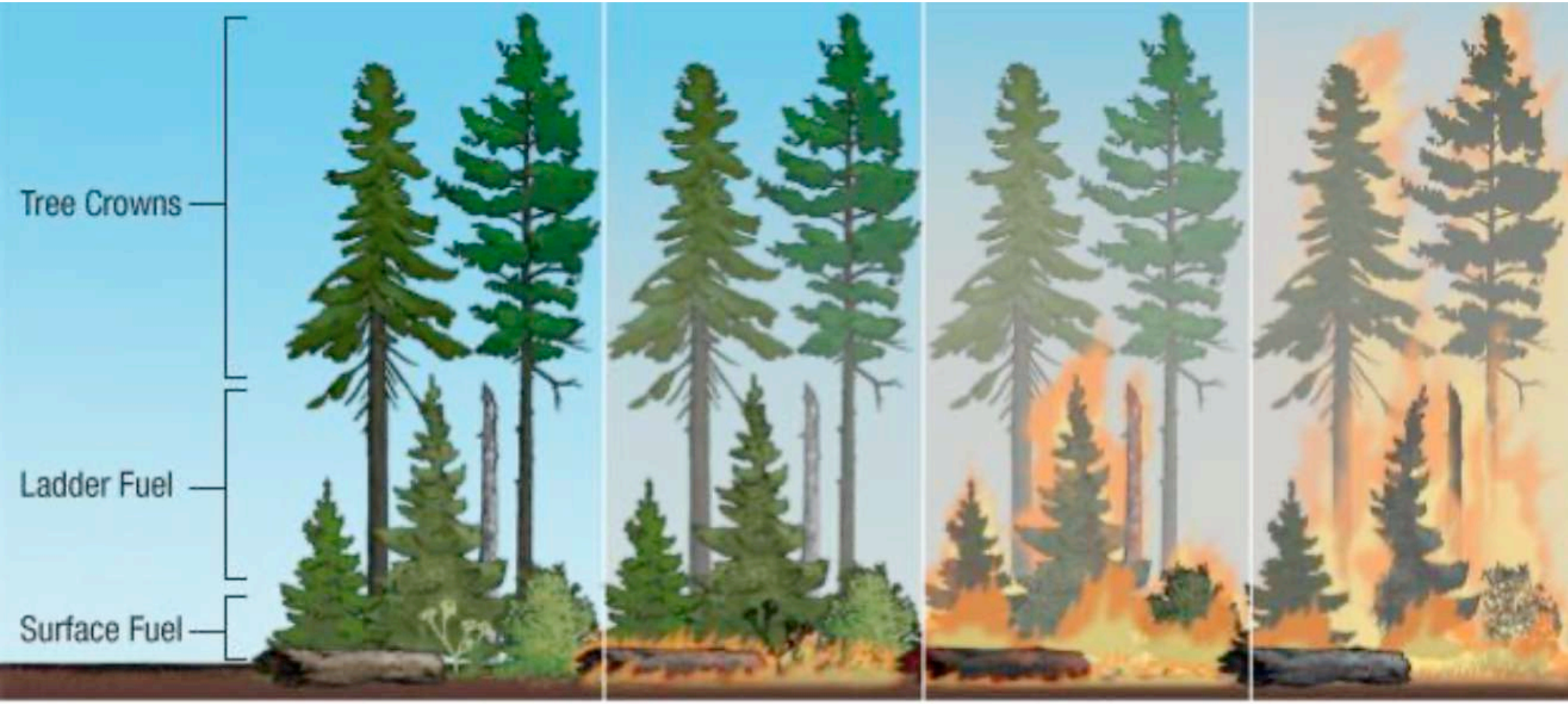


The map illustrates the global distribution of the climate stability/ecoregional intactness relationship. Ecoregions with both high climate stability and vegetation intactness are dark grey. Ecoregions with high climate stability but low levels of vegetation intactness are dark orange. Ecoregions with low climate stability but high vegetation intactness are dark green. Ecoregions that have both low climate stability and low levels of vegetation intactness are pale cream.

Increasing **resistance** + **resilience**

Thinning to alleviate drought

Preventive silviculture



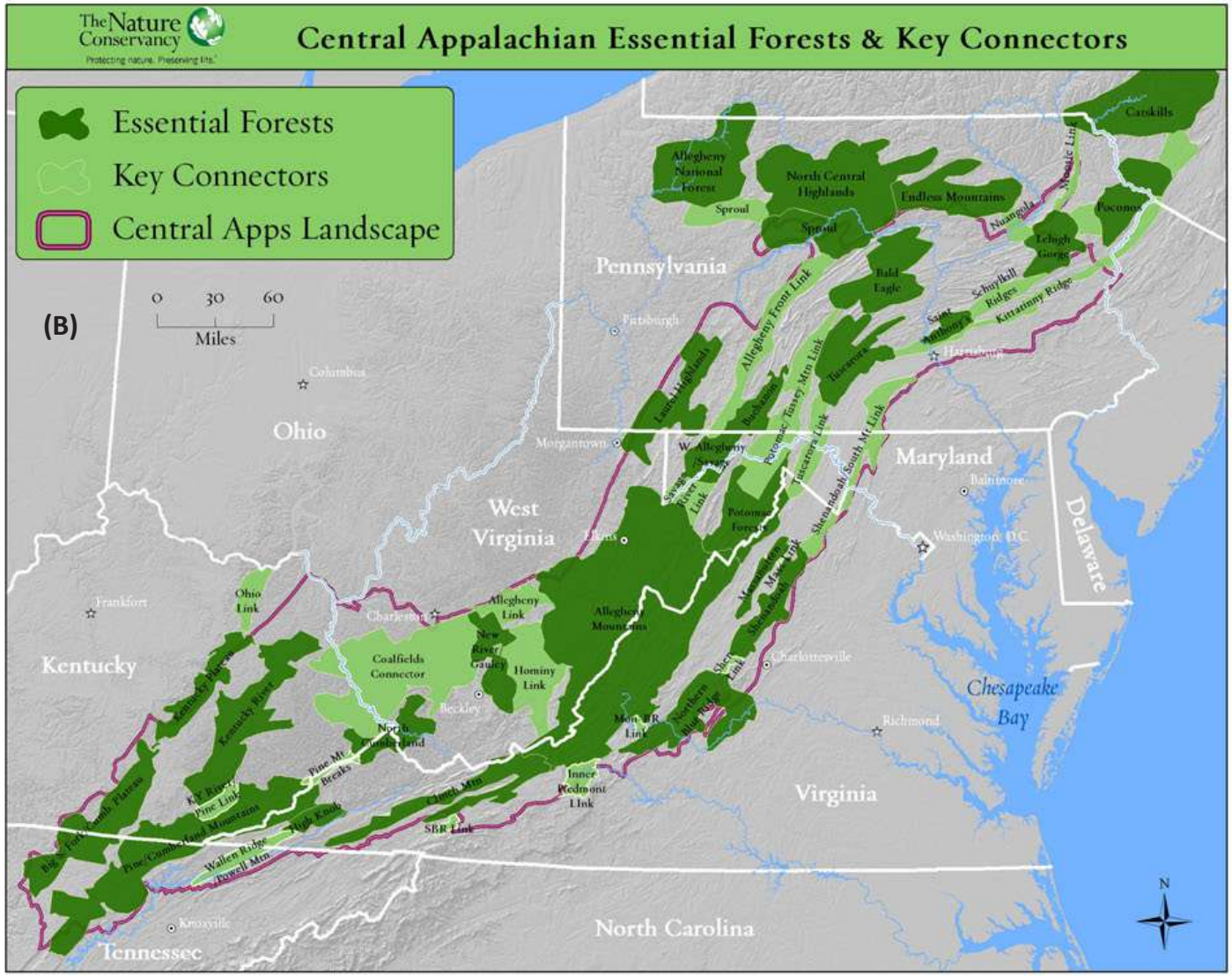
In a forest where fires rarely happen, fuel builds up: There's **surface fuel** (grass, logs, woody debris, brush); **ladder fuel** (shrubs, small trees, snags); and **tree crowns**.

1. Surface fires spread quickly through brush and woody debris.
2. Ladder fuels allow the fire to move up toward the forest canopy.
3. Tree crown fires are so intense, they're difficult to control.

Management of forest fuels

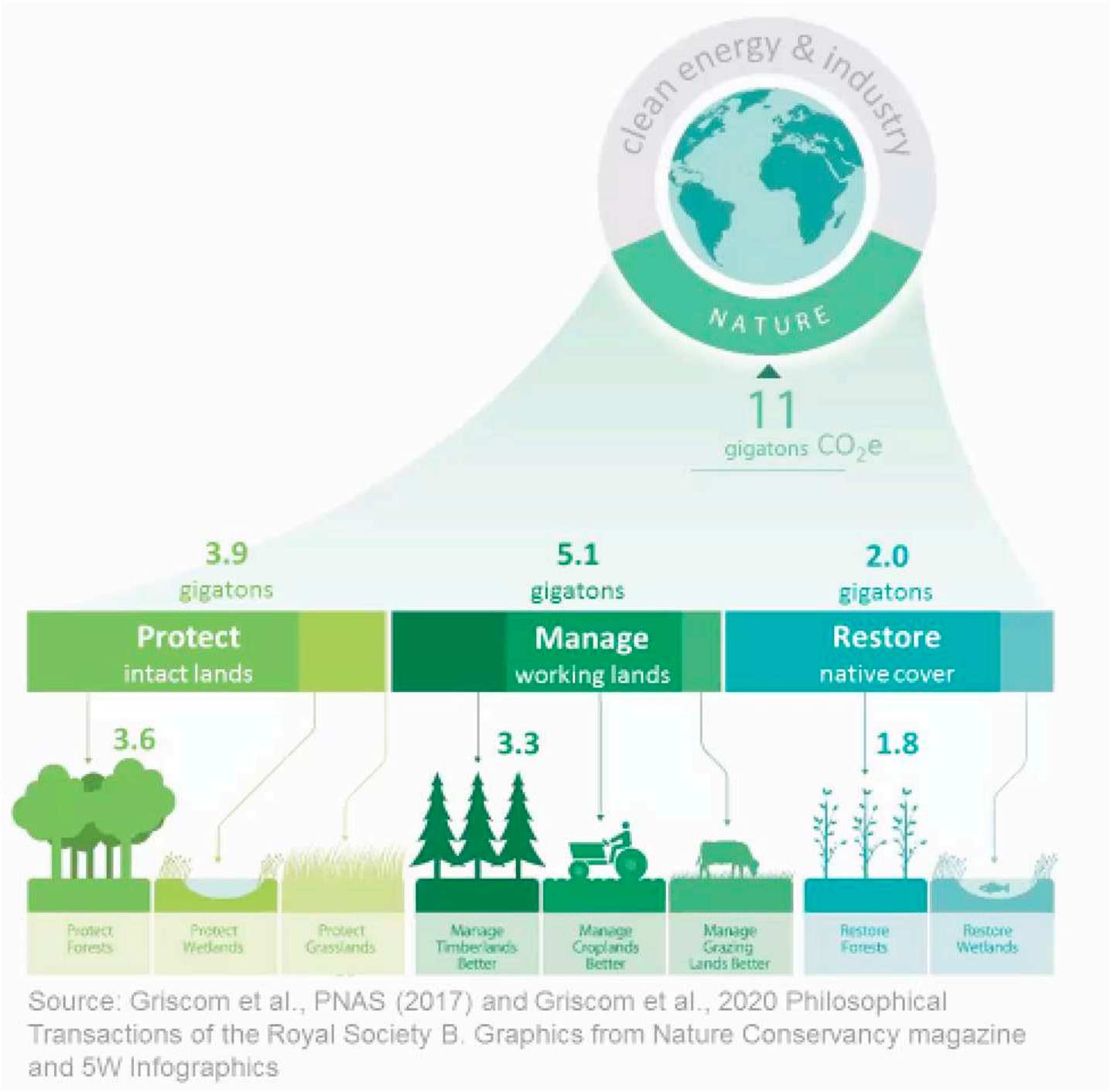
Genetic and functional diversity

Spatial connectivity of forests



Forest fragmentation

Post disturbance restoration



Source: Griscom et al., PNAS (2017) and Griscom et al., 2020 Philosophical Transactions of the Royal Society B. Graphics from Nature Conservancy magazine and 5W Infographics

UNIVERSITÀ DEGLI STUDI DI MILANO

LA STATALE

DiSAA

DIPARTIMENTO di SCIENZE AGRARIE e AMBIENTALI

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