

Global perspectives on soil carbon sequestration

Measurements, mechanisms, and feedbacks

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How much C can we emit?

Sharing global CO₂ emission reductions among one billion high emitters

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Contributed by Stephen Pacala, May 19, 2009 (sent for review March 16, 2009)

We present a framework for allocating a global carbon reduction target among nations, in which the concept of “common but differentiated responsibilities” refers to the emissions of individuals instead of nations. We use the income distribution of a country to estimate how its fossil fuel CO₂ emissions are distributed among its citizens, from which we build up a global CO₂ distribution. We then propose a simple rule to derive a universal cap on global individual emissions and find corresponding limits on national aggregate emissions from this cap. All of the world’s high CO₂-emitting individuals are treated the same, regardless of where they live. Any future global emission goal (target and time frame) can be converted into national reduction targets, which are determined by “Business as Usual” projections of national carbon emissions and in-country income distributions. For example, reducing projected global emissions in 2030 by 13 GtCO₂ would require the engagement of 1.13 billion high emitters, roughly equally distributed in 4 regions: the U.S., the OECD minus the U.S., China, and the non-OECD minus China. We also modify our methodology to place a floor on emissions of the world’s lowest CO₂ emitters and demonstrate that climate mitigation and alleviation of extreme poverty are largely decoupled.

climate change | climate equity | climate policy | individual emissions | inequality

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) created a 2-tier world. It called upon the developed (“Annex I”) countries to “take the lead” in reducing carbon emissions, and, under the principle of “common but differentiated responsibilities,” established no time frame for developing countries to follow. However, a consensus is now emerging in favor of low stabilization targets. These targets cannot be achieved without the participation of developing countries, which today emit about half of global CO₂ emissions and whose future emissions increase faster than the emissions of industrialized countries under “business as usual” scenarios (1). On what terms should developing countries participate? There

derived by summing the excess emissions of all “high emitter” individuals in a country—“high emitters” are those whose emissions exceed a universal individual emission cap. The scheme does not specify how any nation meets its responsibilities.

Our approach is restricted to future fossil-fuel CO₂ emissions and focuses on the next 2 decades. We do not include biospheric CO₂, other greenhouse gases, and aerosols, because they are not strongly correlated with personal expenditures and national carbon intensities. By imputing national emissions to individuals, we neglect embedded carbon in exports and imports, a component that is relevant for countries with large shares of trade in their economy. We also do not tackle historical responsibility. These are all important topics, and a complete scheme suitable for use in negotiations would need to take them into account.

Baer et al. (2) uses a similar approach, but relies on high incomes rather than high emissions and on a fixed income cap at \$7500 (PPP adjusted). In contrast, our scheme is based on individual emissions rather than income to reward improvements in national carbon intensity. Several others explore allocation regimes based on convergence of national average per capita emissions in the long-term, typically beyond 2050 (3–5), whereas our proposal specifies a transient path that can lead ultimately to long-term convergence.

Individual Emission Distributions. We begin by obtaining a picture of how 26 GtCO₂ of global emissions in 2003 were distributed across the world’s 6.2 billion people. We first construct national income distributions from World Bank data (6). We then convert these income distributions into individual CO₂ emission distributions, assuming unitary elasticity* and anchoring means using country level emissions data. We use present and projected emissions data from the Energy Information Agency (EIA) (7), a freely available database with geographically disaggregated emissions projections to 2030.

Fig. 1 shows how our method works for 2 representative

SUSTAINABILITY
SCIENCE

Acceptable world-wide average:

0.35 tC capita⁻¹ yr⁻¹

(Chakravarty et al. 2009)

A modest proposal for US climate policy

Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO₂ Eq.)

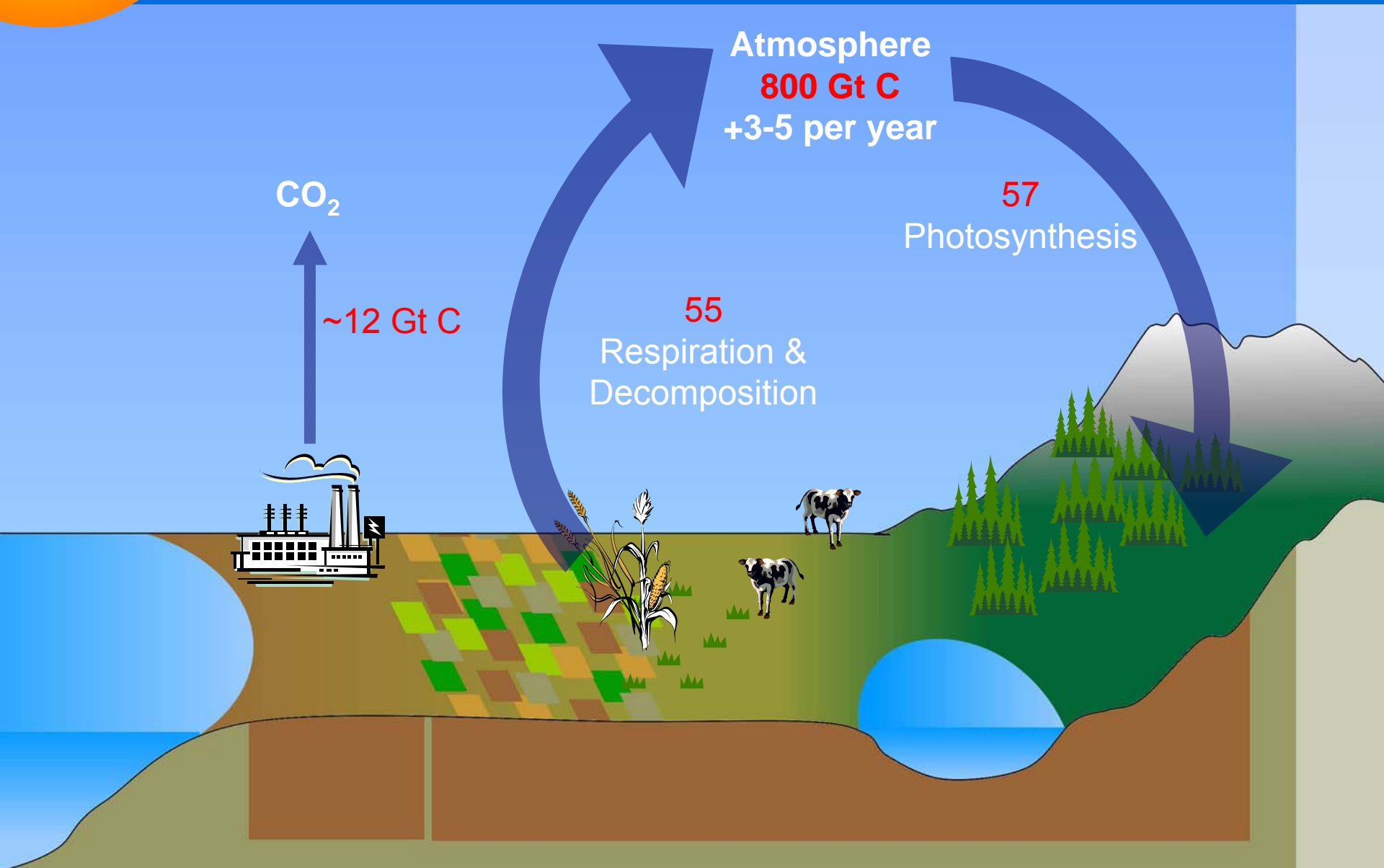
Chapter/IPCC Sector	1990	1995	2000	2005	2006	2007
Energy	5,202.1	5,528.7	6,072.1	6,183.7	6,095.0	6,178.5
Industrial Processes	303.5	319.4	330.0	312.8	318.7	328.4
Solvent and Other Product Use	4.4	4.6	4.9	4.4	4.4	4.4
Agriculture	384.2	402.0	399.5	410.8	410.3	413.1
Land Use, Land-Use Change, and Forestry (Emissions)	14.2	15.4	32.7	22.7	37.2	35.3
Waste	177.1	174.7	154.6	160.2	163.0	165.6
Total Emissions	6,085.5	6,444.8	6,993.8	7,094.7	7,028.7	7,125.2

1.65 Pg C yr⁻¹

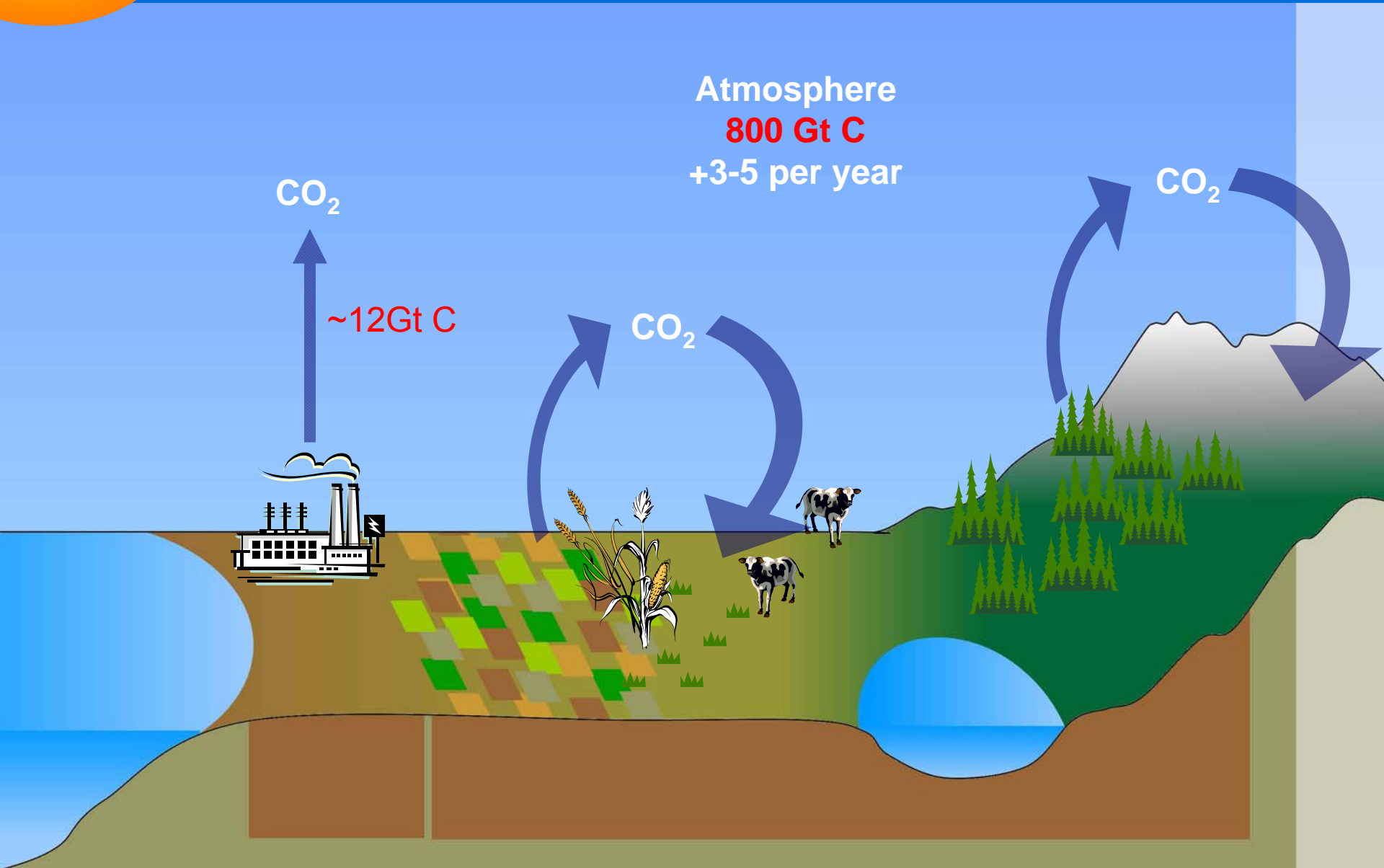
4.2 tC capita⁻¹ yr⁻¹

(US EPA emission inventory 2009)

Global Carbon Cycle



Global Carbon Cycle



A modest proposal for US climate policy

Table 1. Sinks of carbon for 1980–90 in the coterminous United States (Pg C year^{-1}).

Category	Low	High	Land area 1980–90 (10^6 ha)	Houghton <i>et al.</i> (8)	Birdsey and Heath (12)
Forest trees	0.11	0.15	247–247	0.06*	0.11
Other forest	0.03	0.15	247–247	–0.01	0.18
organic matter					
Cropland soils	0.00	0.04	185–183	0.14	–
Nonforest,	0.12†	0.13†	334–336‡	0.12	–
noncropland					
(woody					
encroachment)					
Wood products	0.03	0.07	–	0.03	0.03
Reservoirs,	0.01	0.04	–	–	–
alluvium,					
colluvium					
Exports minus	0.04	0.09	–	–	–
imports of					
food, wood					
Fixed in United	0.03	0.04	–	–	–
States but					
exported by					
rivers					
Apparent§ U.S.	0.25	0.58	766	0.15–0.23	0.31
sink without					
woody					
encroachment					
Apparent§ U.S.	0.37	0.71	766	0.15–0.35	–
sink including					
woody					
encroachment					
Sink¶	0.30	0.58	766	0.15–0.35	0.31

*Assumes that the $0.05 \text{ Pg C year}^{-1}$ estimated in (8) to be accumulating in western pine woodlands as a result of fire suppression is assigned to forest instead of row 4. †These numbers are not bounds, but rather the only two existing estimates.

‡Total area for all lands other than forest and croplands. Possible woody encroachment because of fire suppression on up to about two-thirds of this land (10, 16). §By "apparent" sink, we mean the net flux from the atmosphere to the land that would be estimated in an inversion. It includes all terms in the table. ||Lower bound reflects uncertainty in the estimates for the effects of fire suppression.

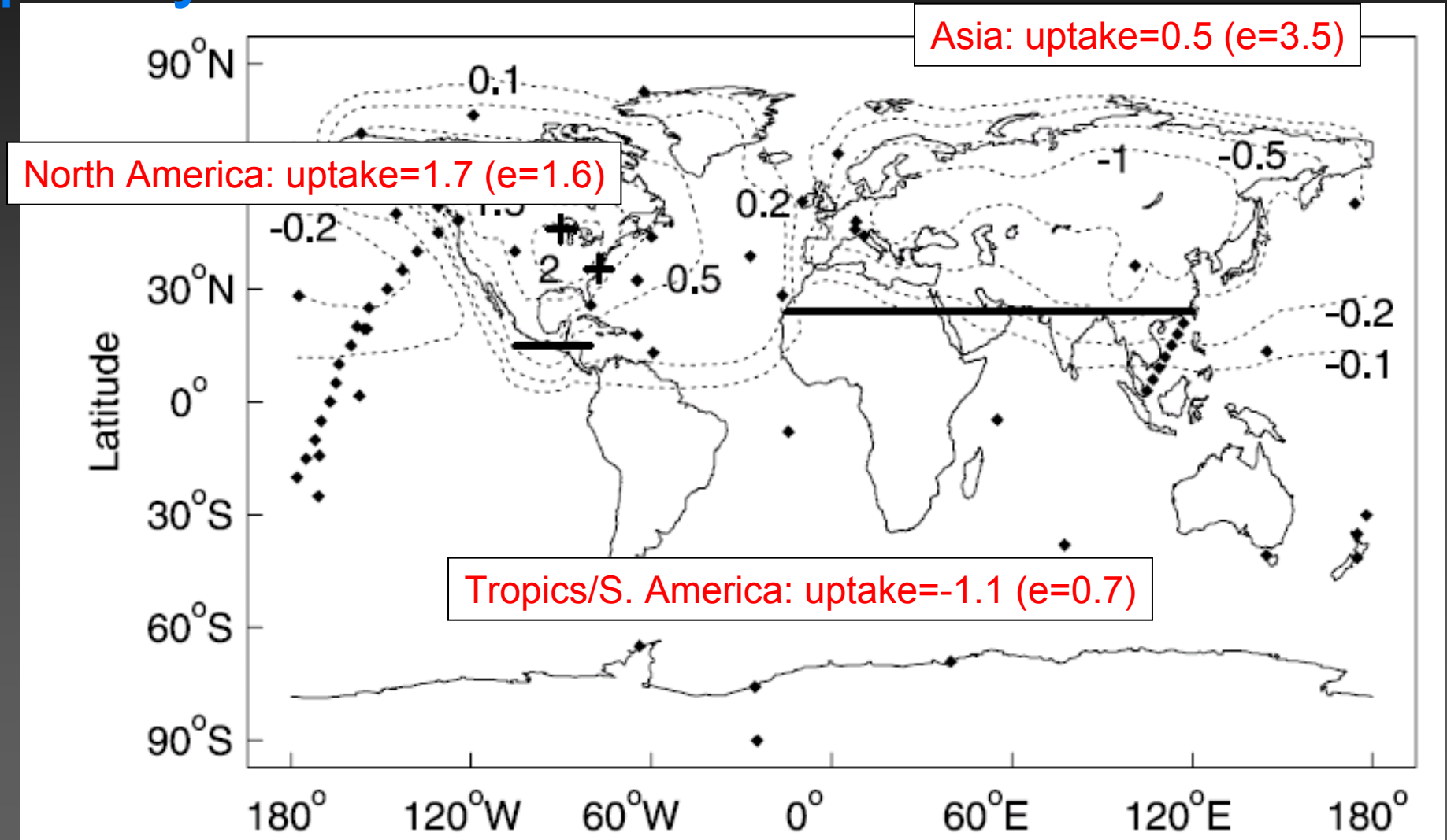
¶Excludes sinks caused by the export/import imbalance for food and wood products and river exports because these create corresponding sources outside the United States.

1.65 Pg C yr^{-1}
–0.31 Pg C yr^{-1}

1.32 Pg C yr^{-1}

3.3 $\text{tC capita}^{-1} \text{ yr}^{-1}$

A modest proposal for US climate policy



(Fan et al. 1998 Science)

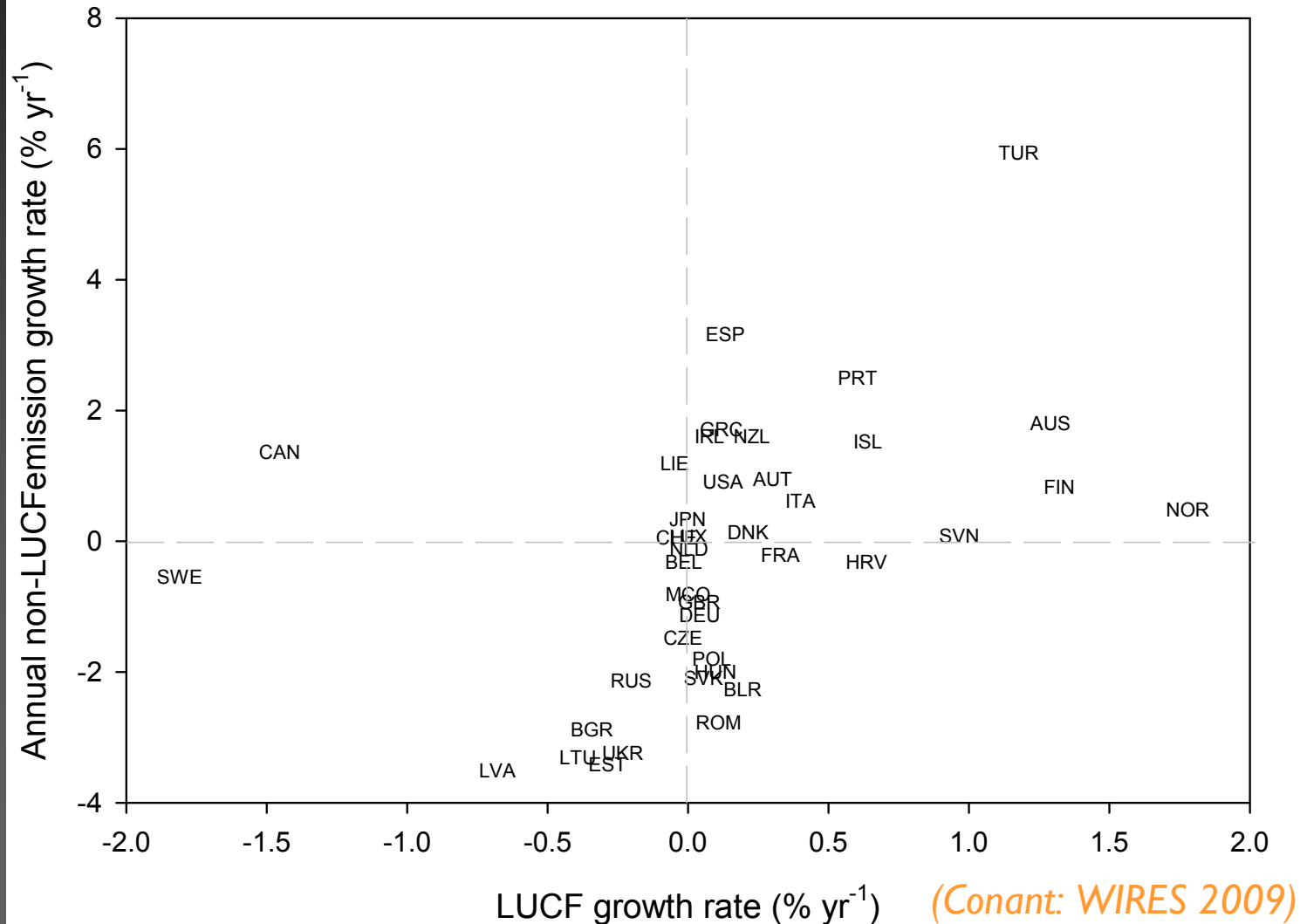
A modest proposal for US climate policy

1. Continue to sequester more C in land than released by fossil fuel burning
2. Contribute to other nations' C management strategies by exchanging C emission offsets with them

A modest proposal for US climate policy- what's wrong with it?

- I. Reduces incentives to deal with emissions – delays implementation of emission reduction and de-carbonization policies

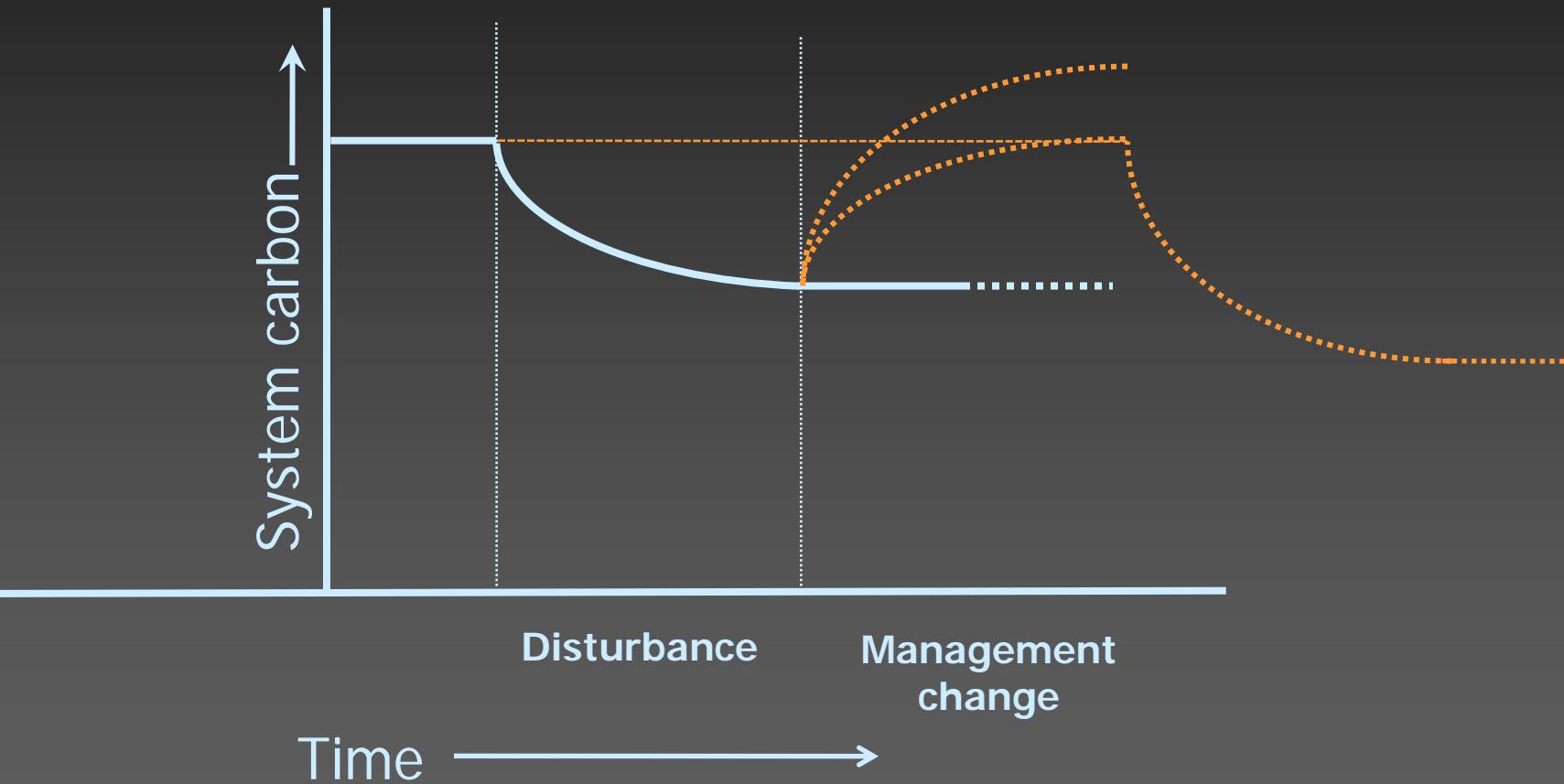
Does it delay implementation of other emission reductions?



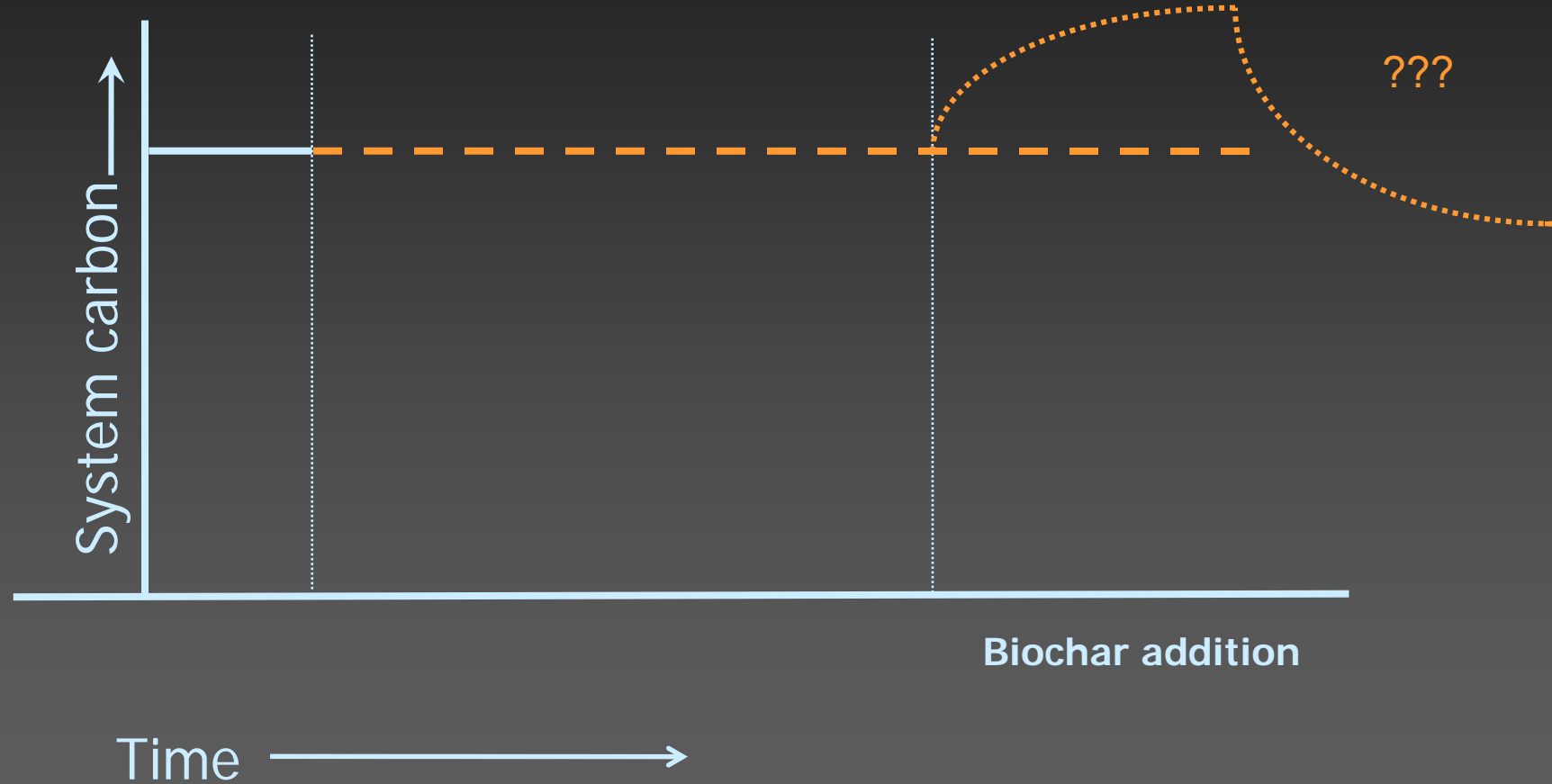
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2. Carbon sequestered is subject to reversals – losses due to fire, tillage, etc.

Terrestrial C trajectories

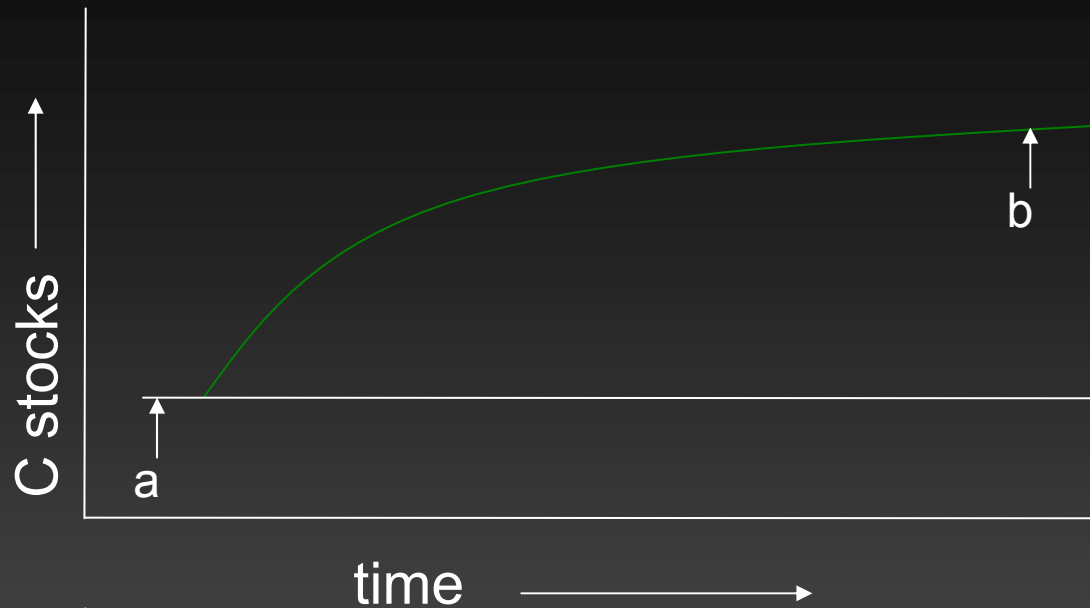


Terrestrial C trajectories

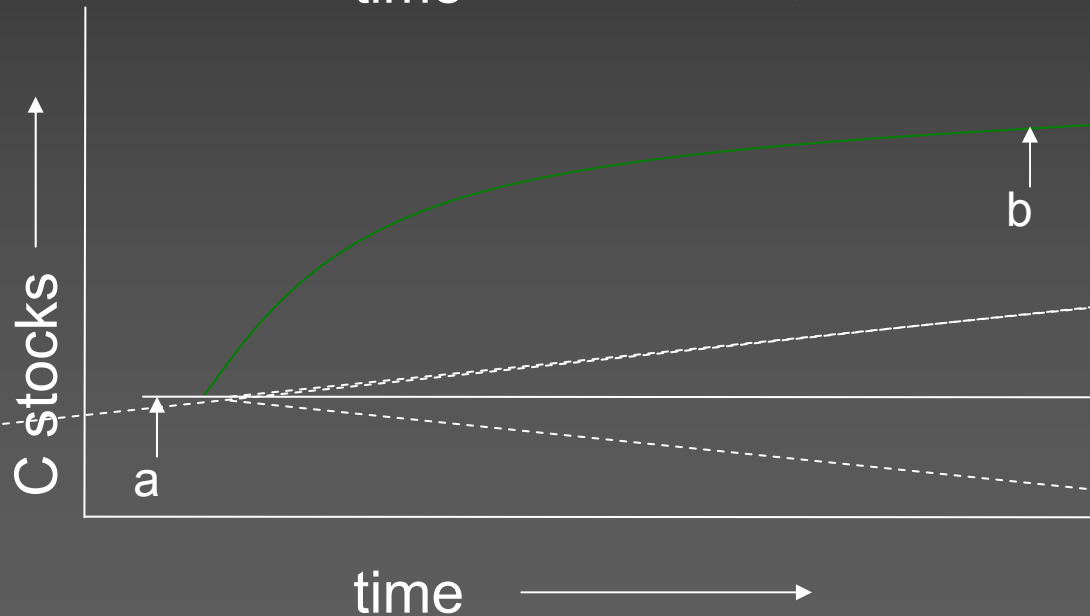


A modest proposal for US climate policy- what's wrong with it?

1. Reduces incentives to deal with emissions – delays implementation of emission reduction and de-carbonization policies
2. Carbon sequestered is subject to reversals – losses due to fire, tillage, etc.
3. These practices are not *additional* – they don't alter the current trajectory of CO₂ rise



Assuming constant
baseline, SOC
offset = $b-a$

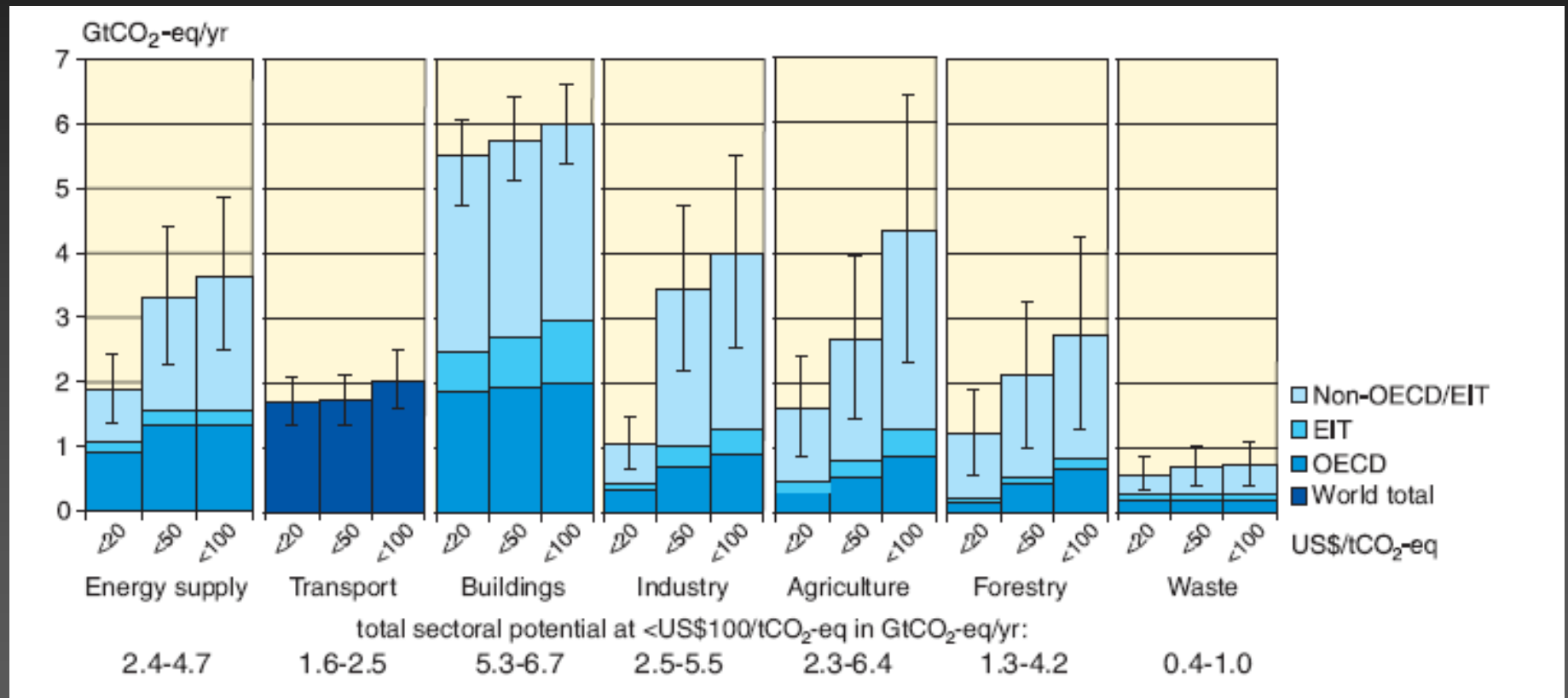


Other factors can
drive SOC gains or
SOC losses; offset
 $\neq b-a$

Benefits of policies that favor C sequestration

- I. Technical potential for carbon sequestration is large

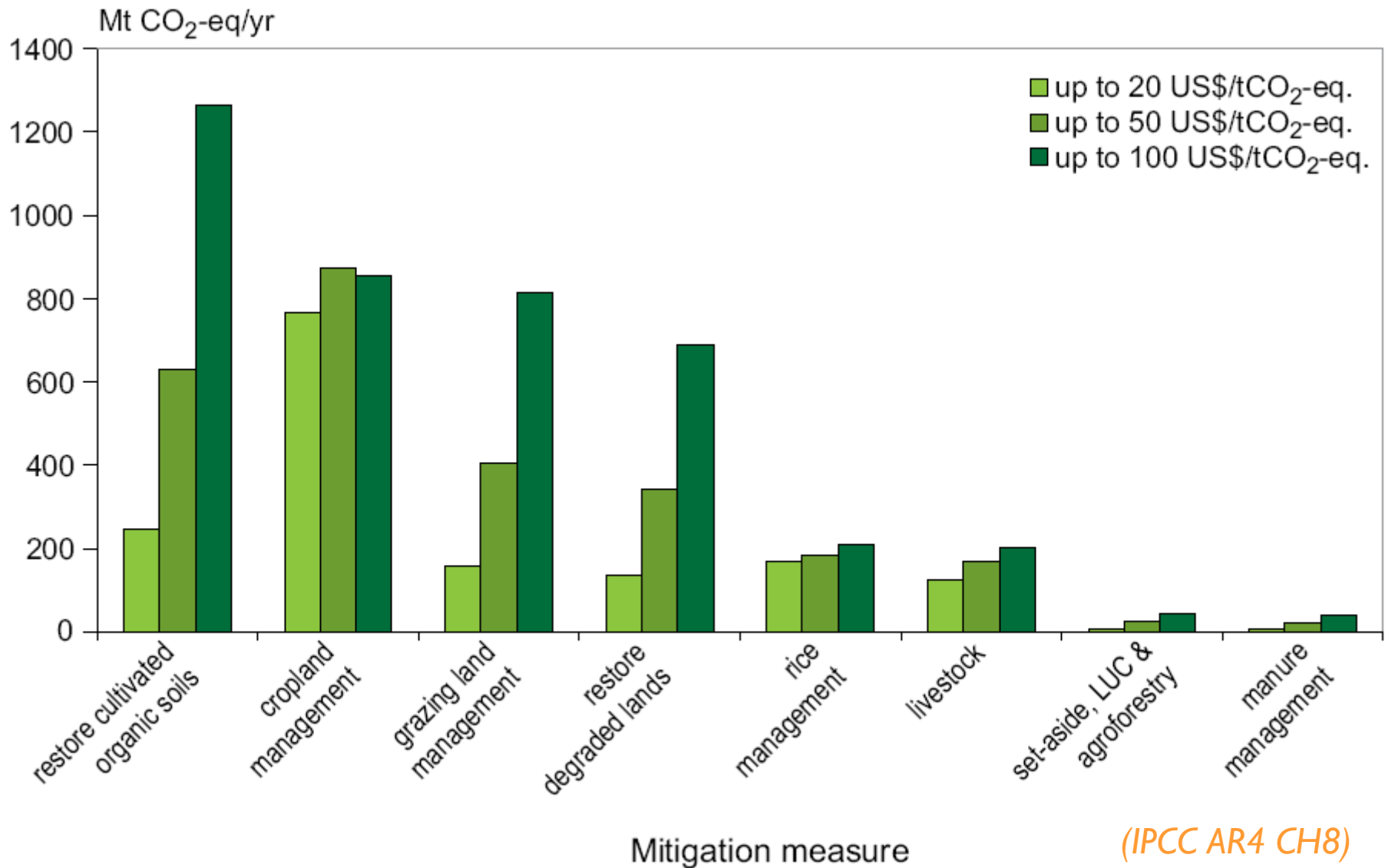
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Benefits of policies that favor C sequestration

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Technical potential for C sequestration is large



Benefits of policies that favor C sequestration

1. Technical potential for carbon sequestration is large.
2. Sequestration is inexpensive and easy to implement with current technology.
3. Sequestration can lead to environmental, social, and economic co-benefits.

Sequestration/GHG reduction co-benefits:

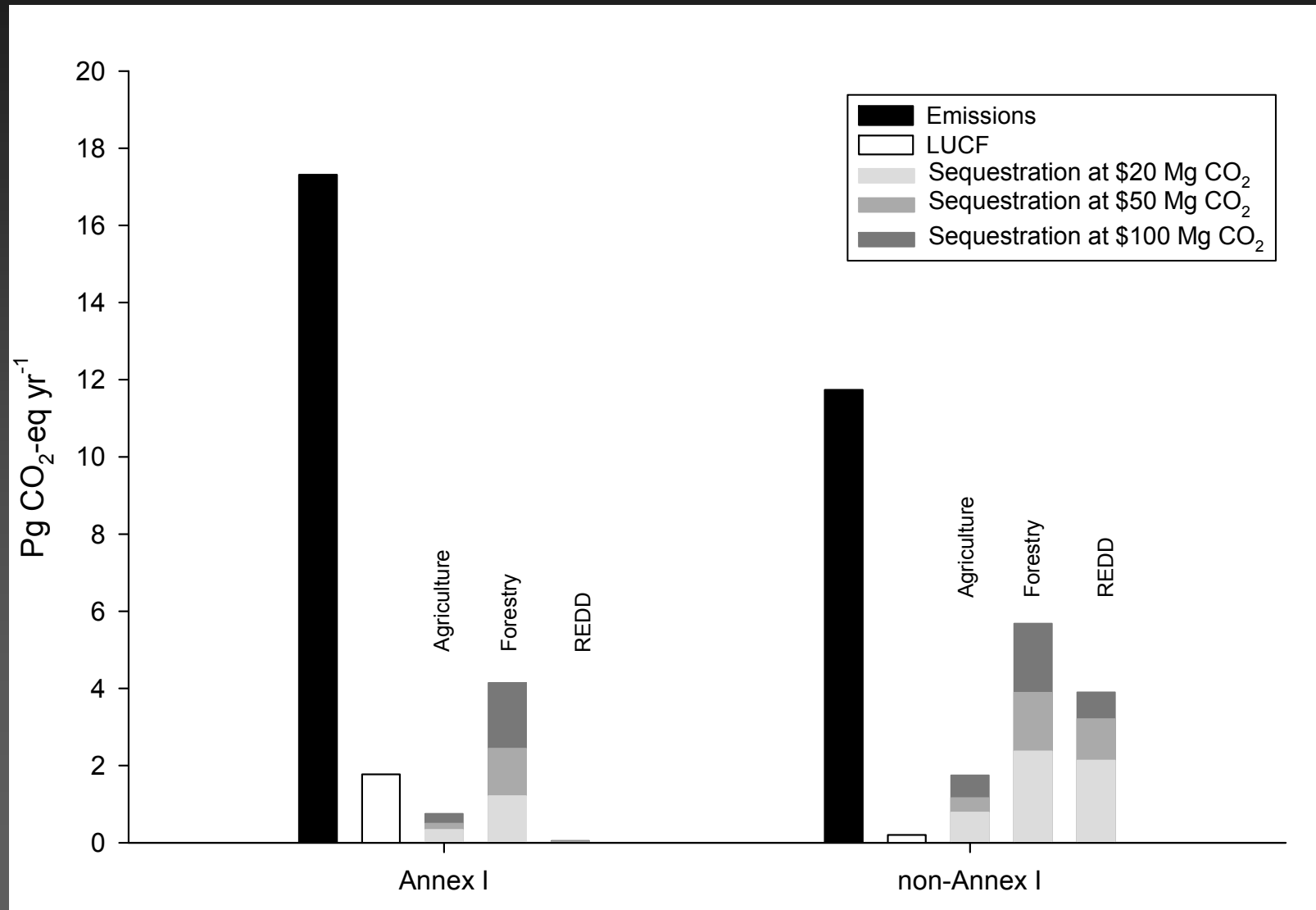
sequestration options in agriculture

	Food security (productivity)	Water quality	Water conservation	Soil quality	Air quality	Bio-diversity, wildlife habitat	Energy conservation	Conservation of other biomes	Aesthetic/ amenity value	of other biomes	Aesthetic/ amenity value
	+	+/-	+/-	+	+/-	+/-	-	+	+/-		+/-
ent	-/+	+		+	+		+				
ation, drainage)	+	+/-	+	+		+	+				
	+	+/-	+/-	+/-			-	+			
	+	+	+/-		+/-			+			+
	+/-	+/-	-			+	+				+
ge	-	+	+	+	+	+	+	-	+		
	+/-			+		+			+		+/-
g., fertilization)	+	+/-									+/-
	+	+/-	+	+		+	-	+	+/-		+
	+	+			+	+/-			+/-		+
uding legumes)	+			+			+				
wetlands	-			+		+	+	-	+		
amendments, nutrient amendments	+	+		+		+		+	+		
es	+			+/-				+			
ry additives	+										
d management changes and animal breeding	+										
ndling	+	+/-		+	+/-						
					+		+				
ient source	+	+		+	+		+				
d, biogas, residues	-					-	+	-			

Benefits of policies that favor C sequestration

1. Technical potential for carbon sequestration is large.
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4. Unlike emission reductions C sequestration can be used to draw-down atmospheric CO₂ concentrations.

Developing nations could be engaged

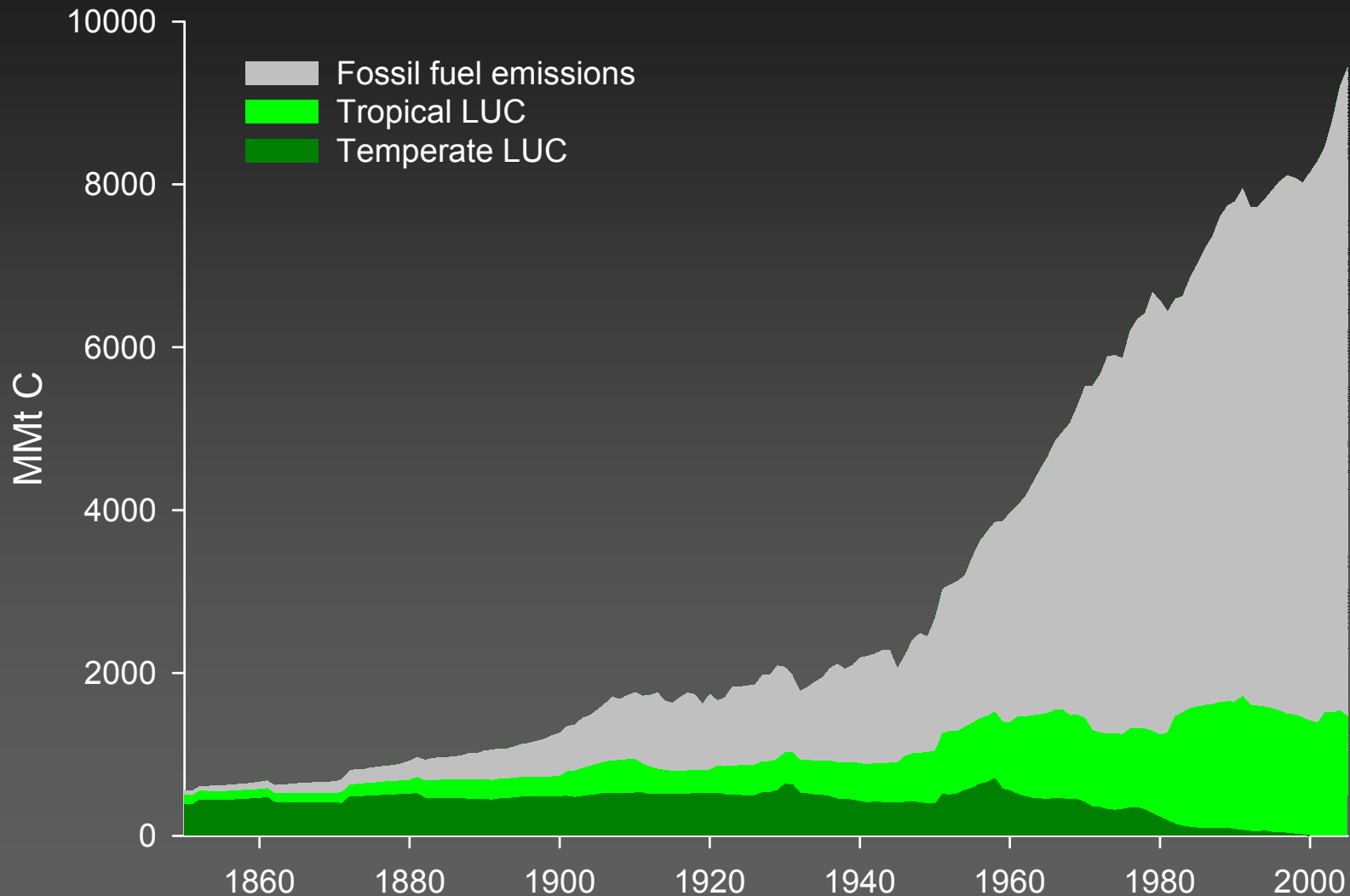


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5. Developing nations could be engaged in climate agreements via sequestration

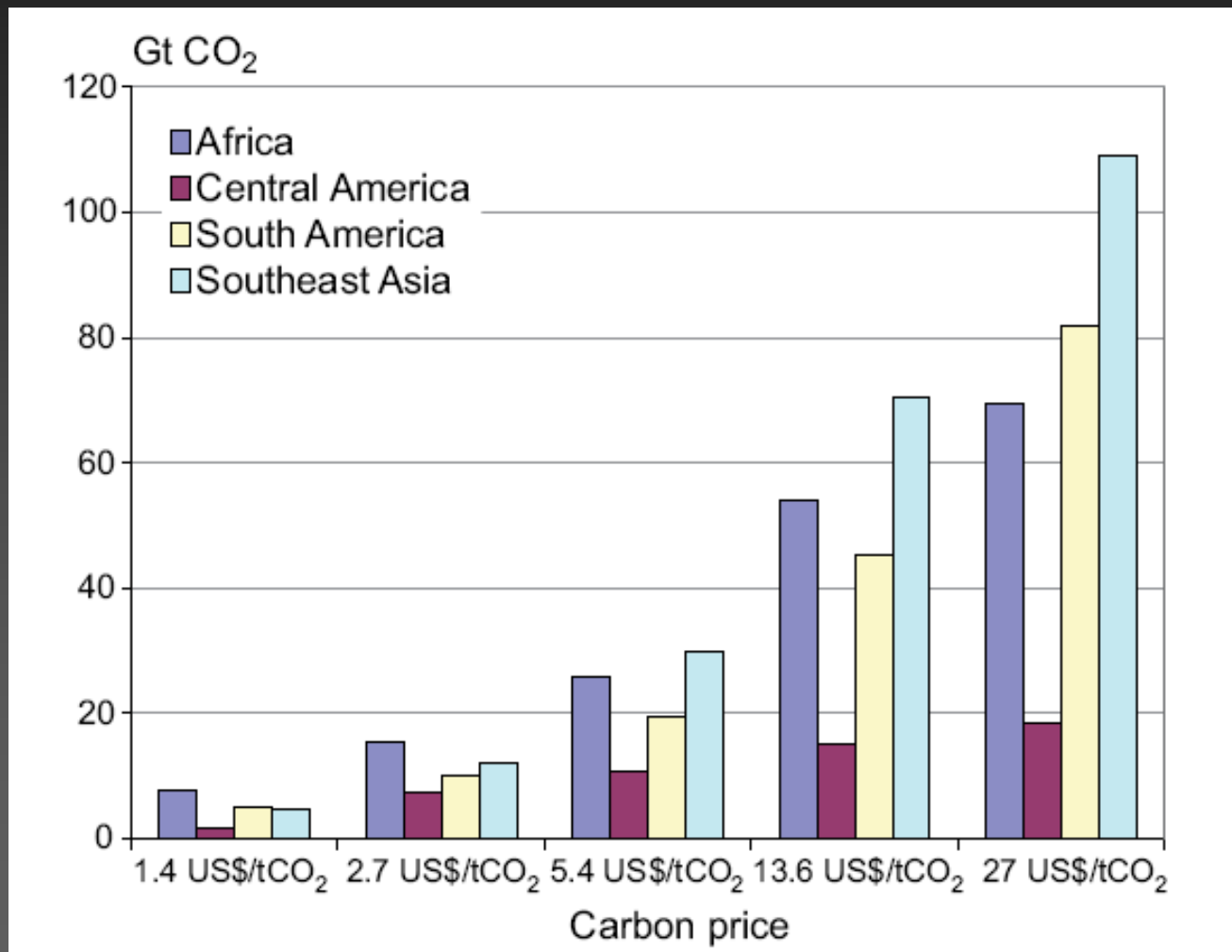
CO₂ concentrations are increasing:

Human activities are driving increases in atmospheric CO₂



Land management contributes to emissions too

-REDD emission reduction potential



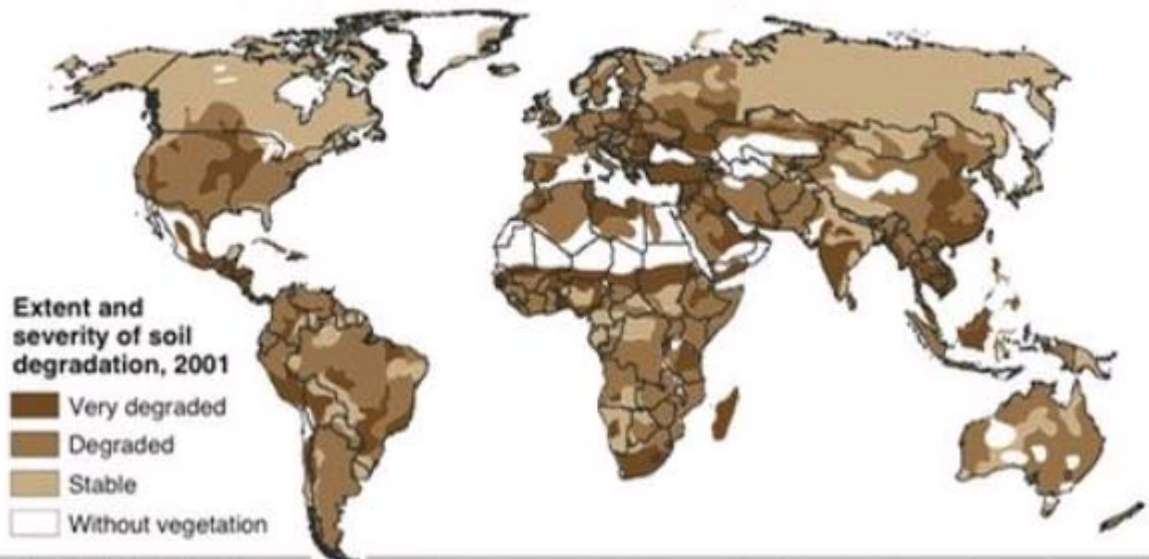
Benefits of policies that favor C sequestration

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5. Developing nations could be engaged in climate agreements via sequestration
6. Sequestration could foster adaptation



One-fifth of the world's cropland degraded

Soils around the world are deteriorating and the poor quality has cut crop production by about one-sixth. In sub-Saharan Africa, nearly 1 million square miles have shown significant decline.

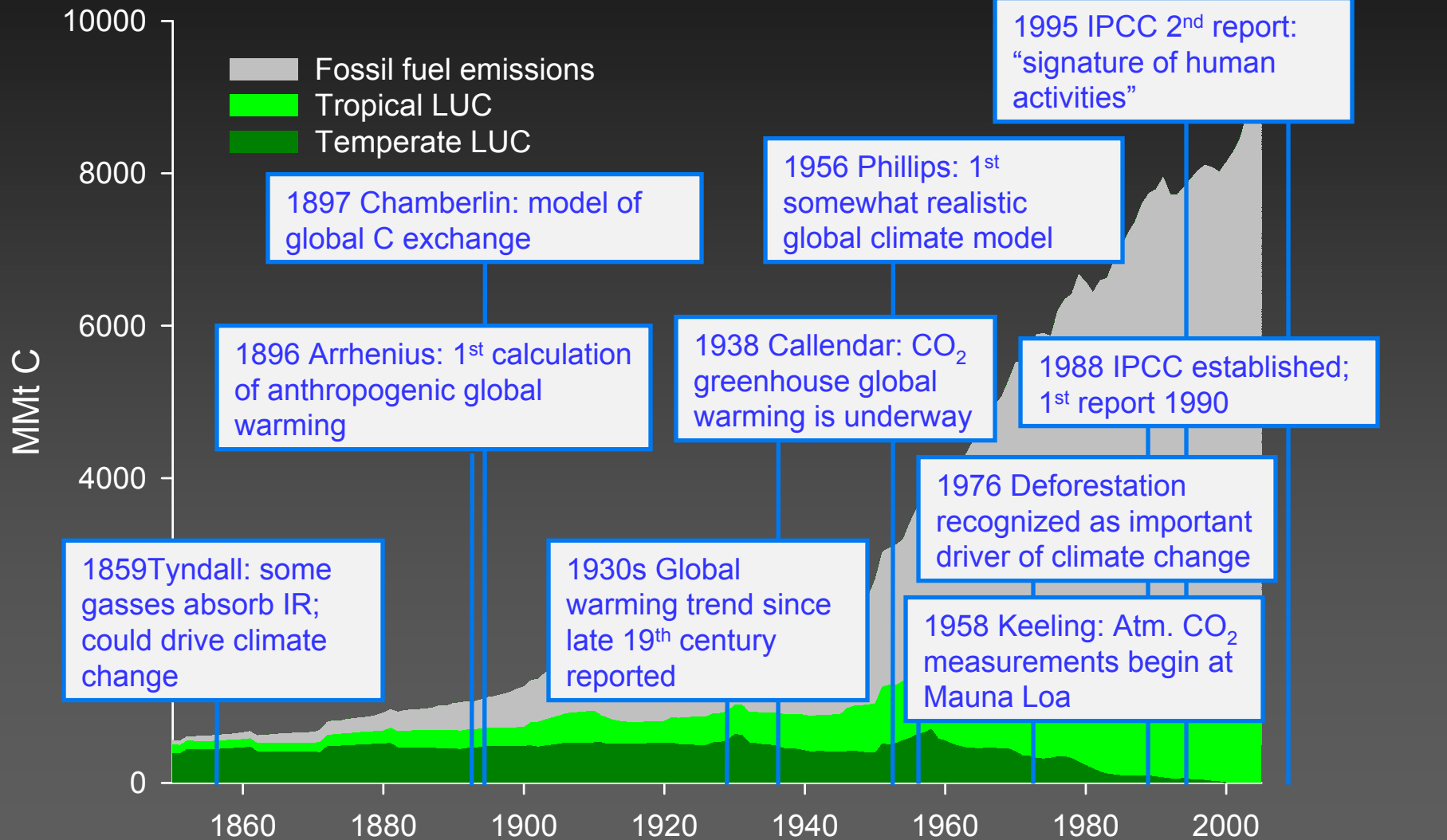


SOURCE: United Nations Environment Programme



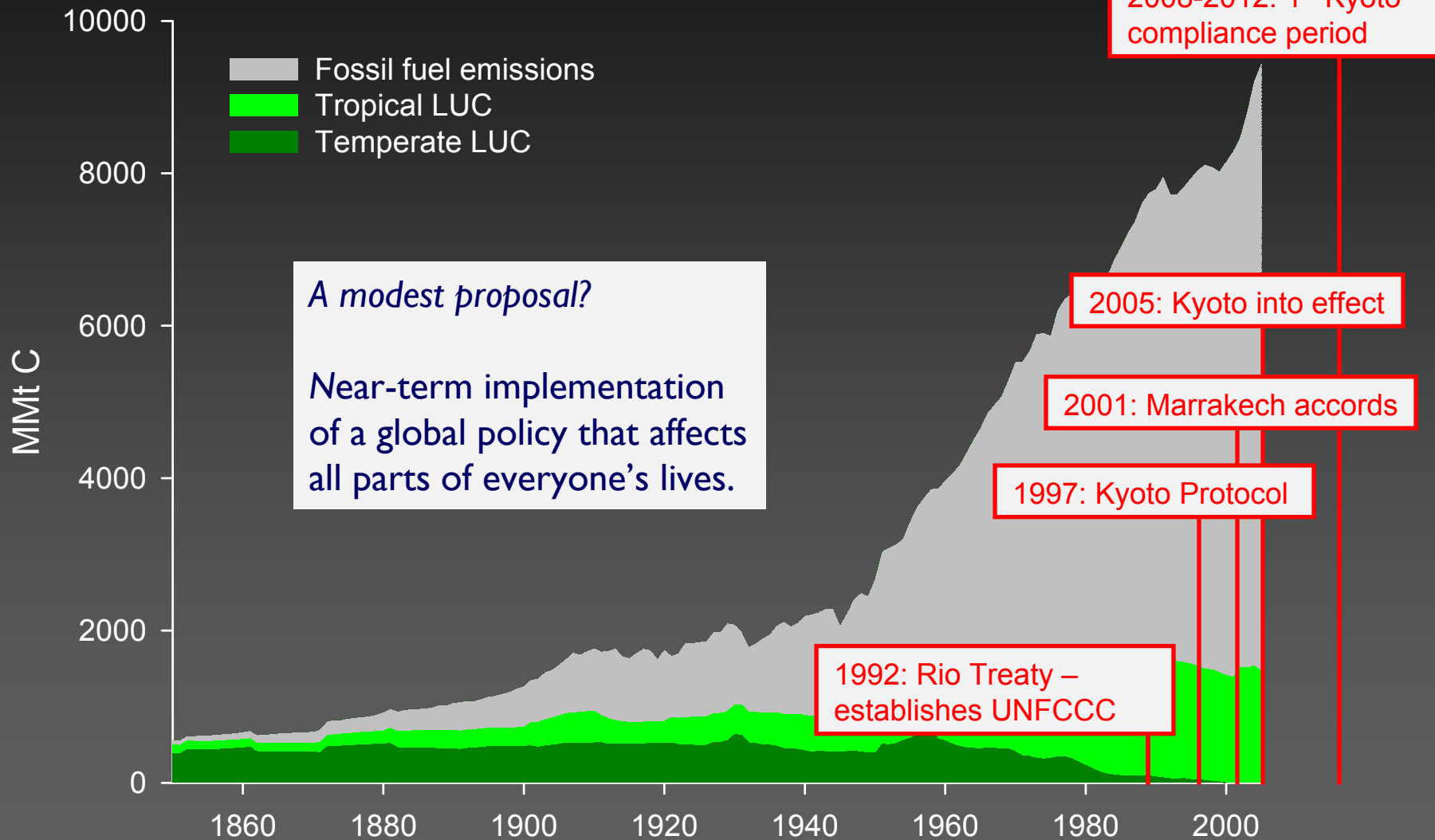
Perspective

Climate change science timeline



Perspective

Climate policy timeline



2007 Bali action plan:

1. Focus negotiations on adaptation, mitigation, technology transfer, financing
2. Reduce emissions from deforestation and forest degradation (REDD)
3. Mitigation actions from developing countries
4. Mitigation commitments from developed countries
 - a. Agree on targets by 2009
 - b. Develop means to achieve targets: markets; national policies; address accounting issues; role of LU/LUCF

