Global perspectives on soil carbon sequestration

Measurements, mechanisms, and feedbacks

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How much C can we emit?

PNAS

Sharing global CO_2 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 CO_2 emissions are distributed among its citizens, from which we build up a global CO_2 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 CO_2-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 $GtCO_2$ 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 CO_2 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 CO_2 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 CO_2 emissions and focuses on the next 2 decades. We do not include biospheric CO_2, 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 $GtCO_2$ 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 CO_2 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

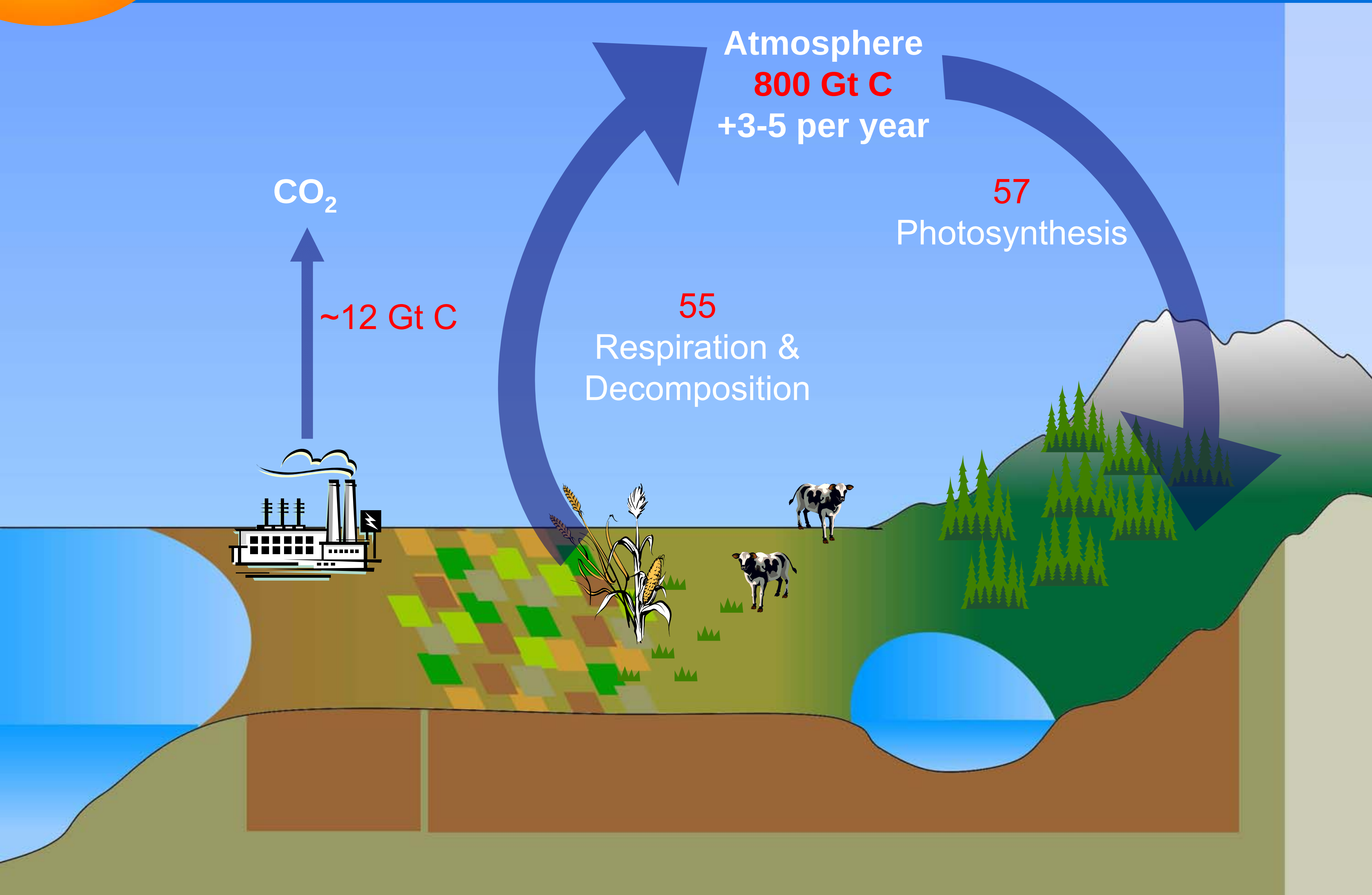
Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

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**

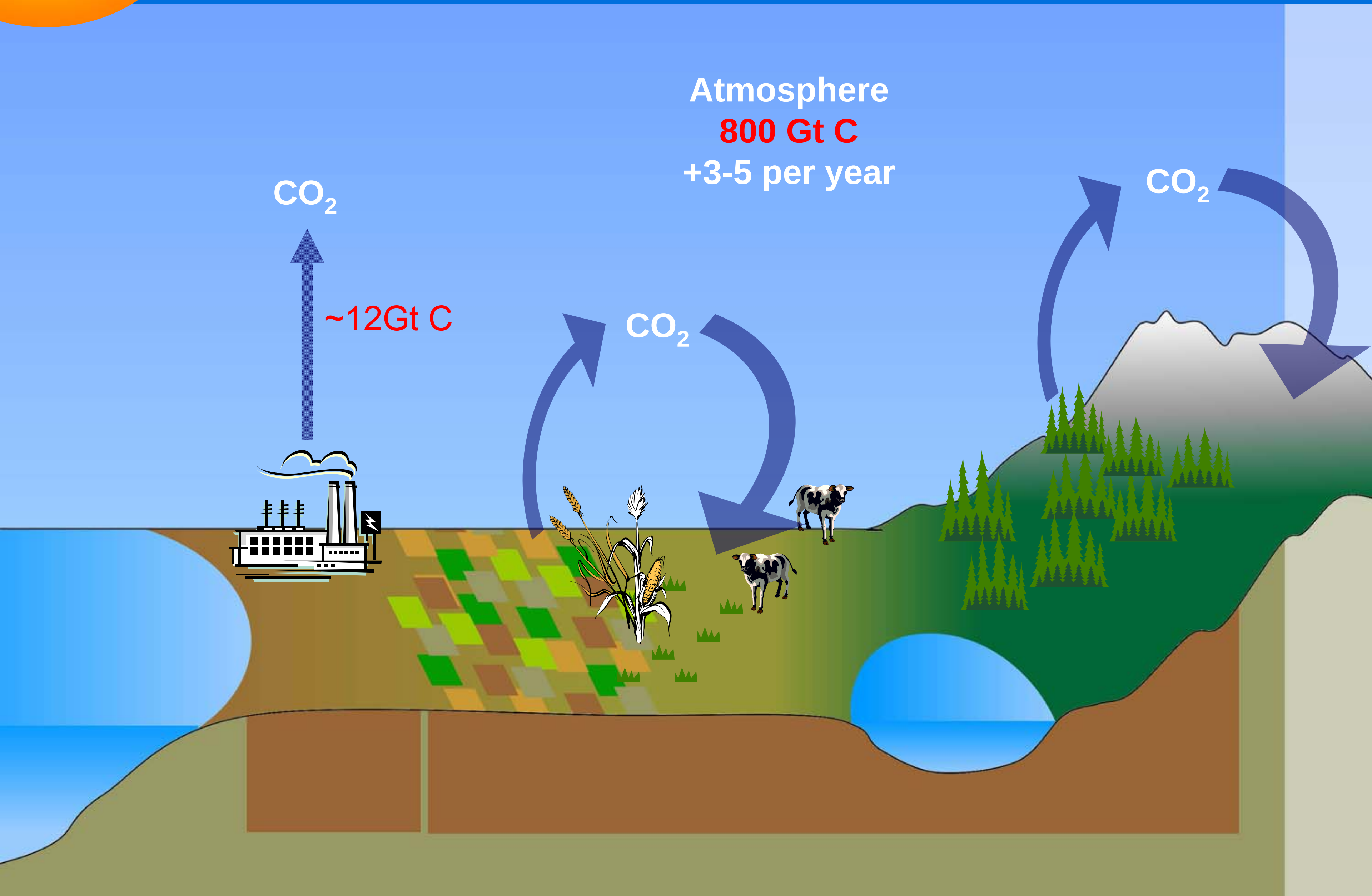
1.65 Pg C yr^{-1} → 4.2 tC $capita^{-1}$ yr^{-1}

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

*Assumes that the 0.05 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}

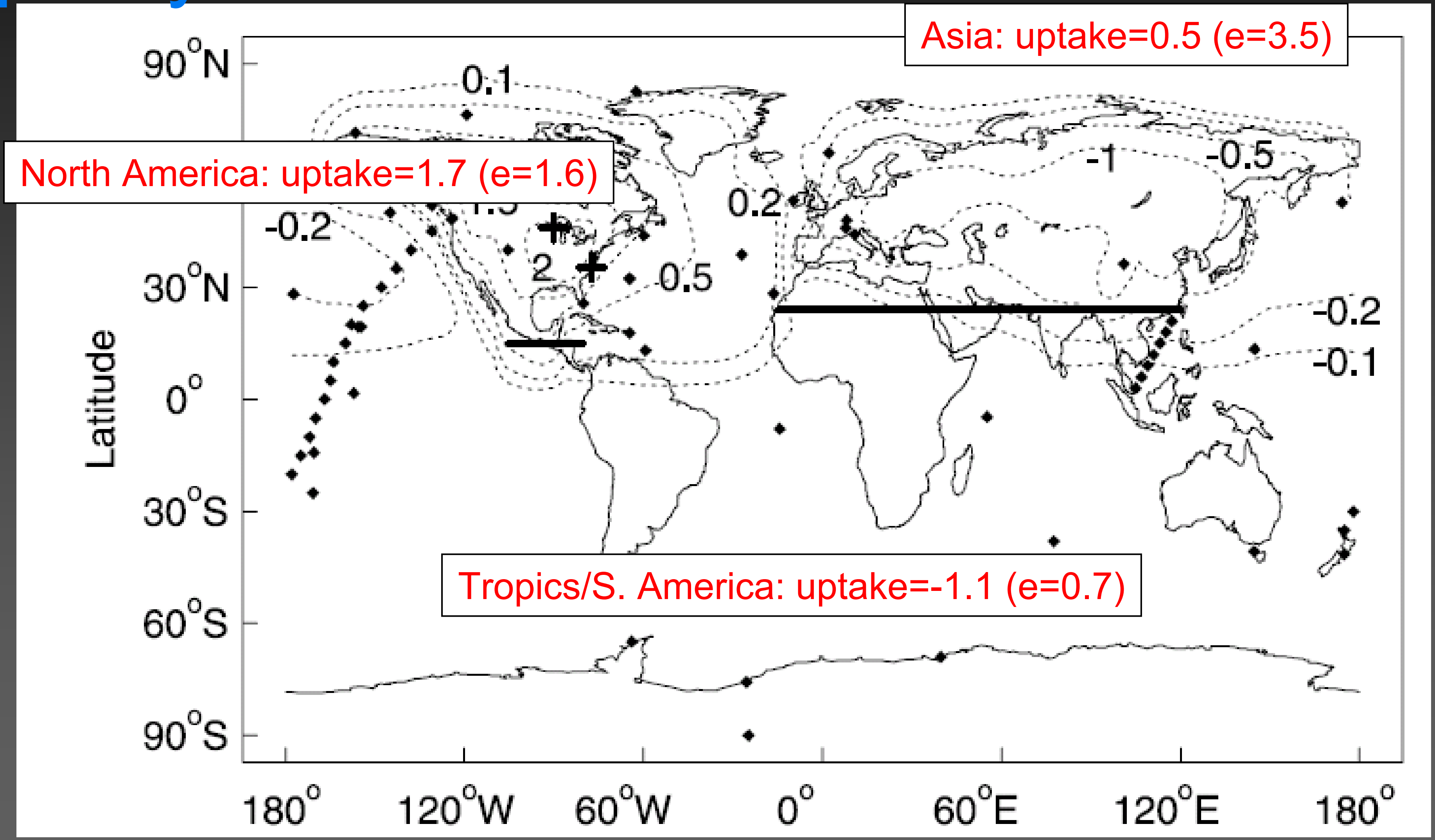
-0.31 Pg C yr^{-1}1

1.32 Pg C yr^{-1}

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

(Pacala et al. 2003 Science)

A modest proposal for US climate policy



(Fan et al. 1998 Science)

A modest proposal for US climate policy

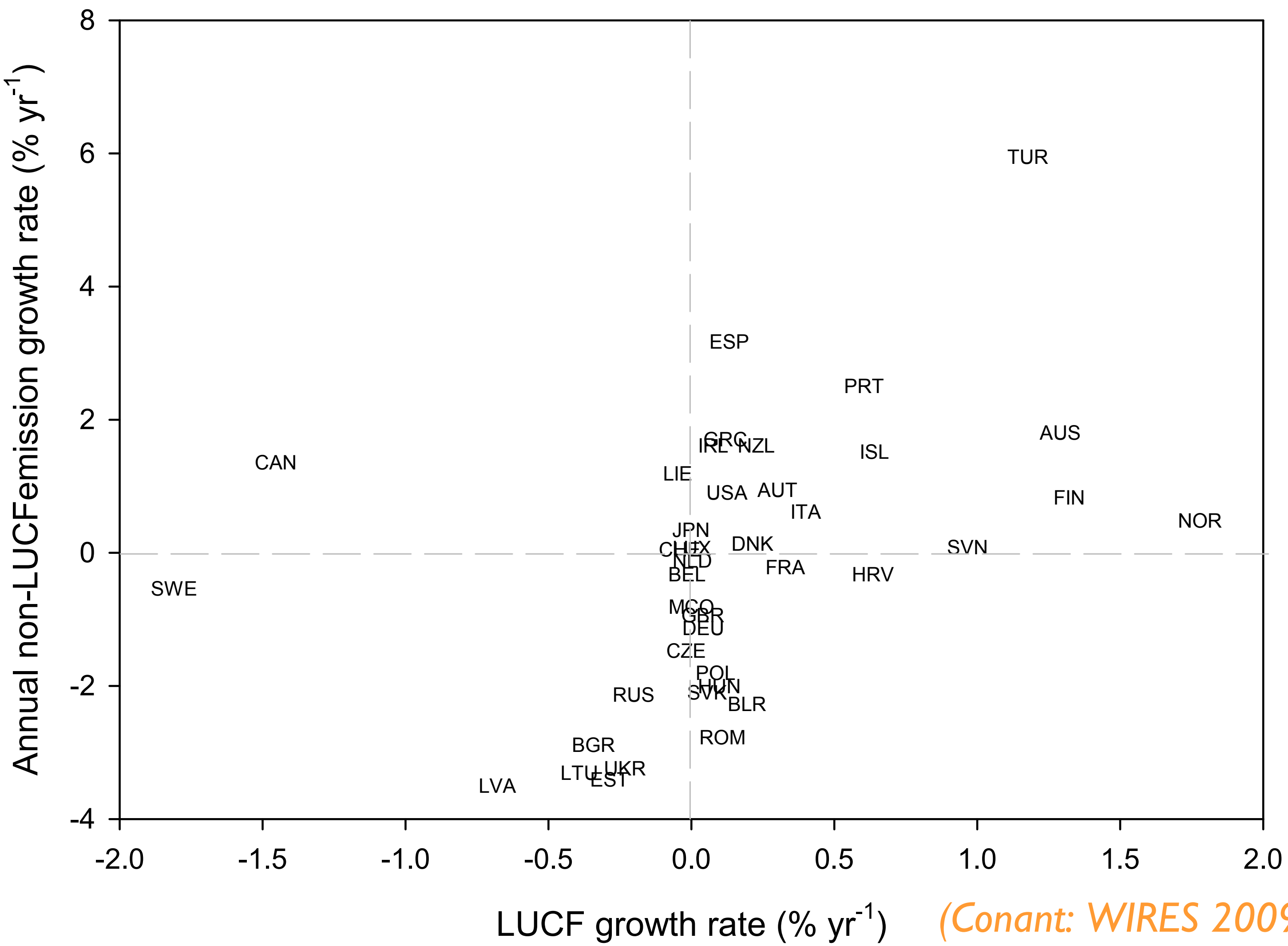
1. Continue to sequester more C in land than released by fossil fuel burning

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?

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

Does it delay implementation of other emission reductions?



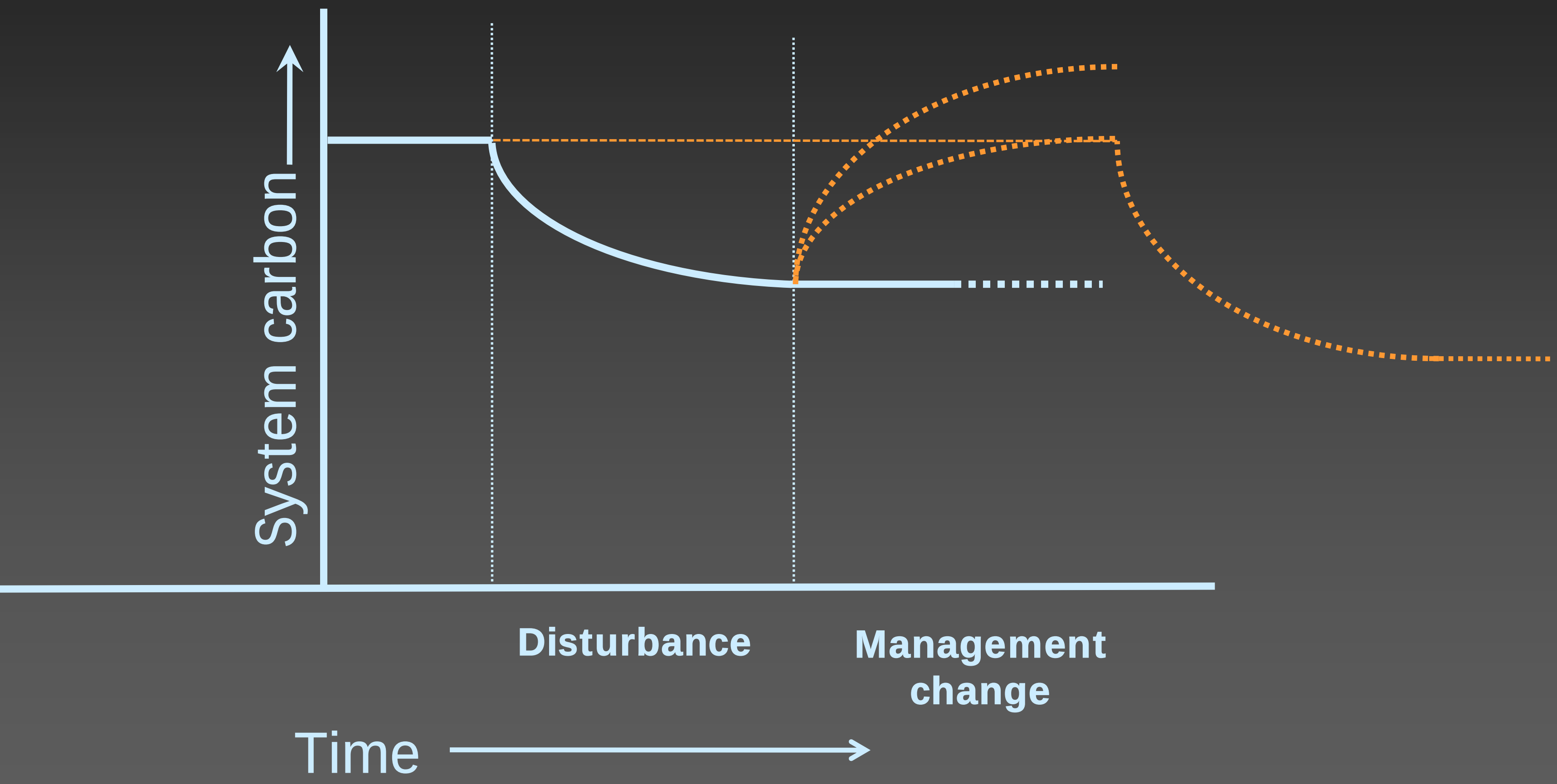
(Conant: WIRES 2009)

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

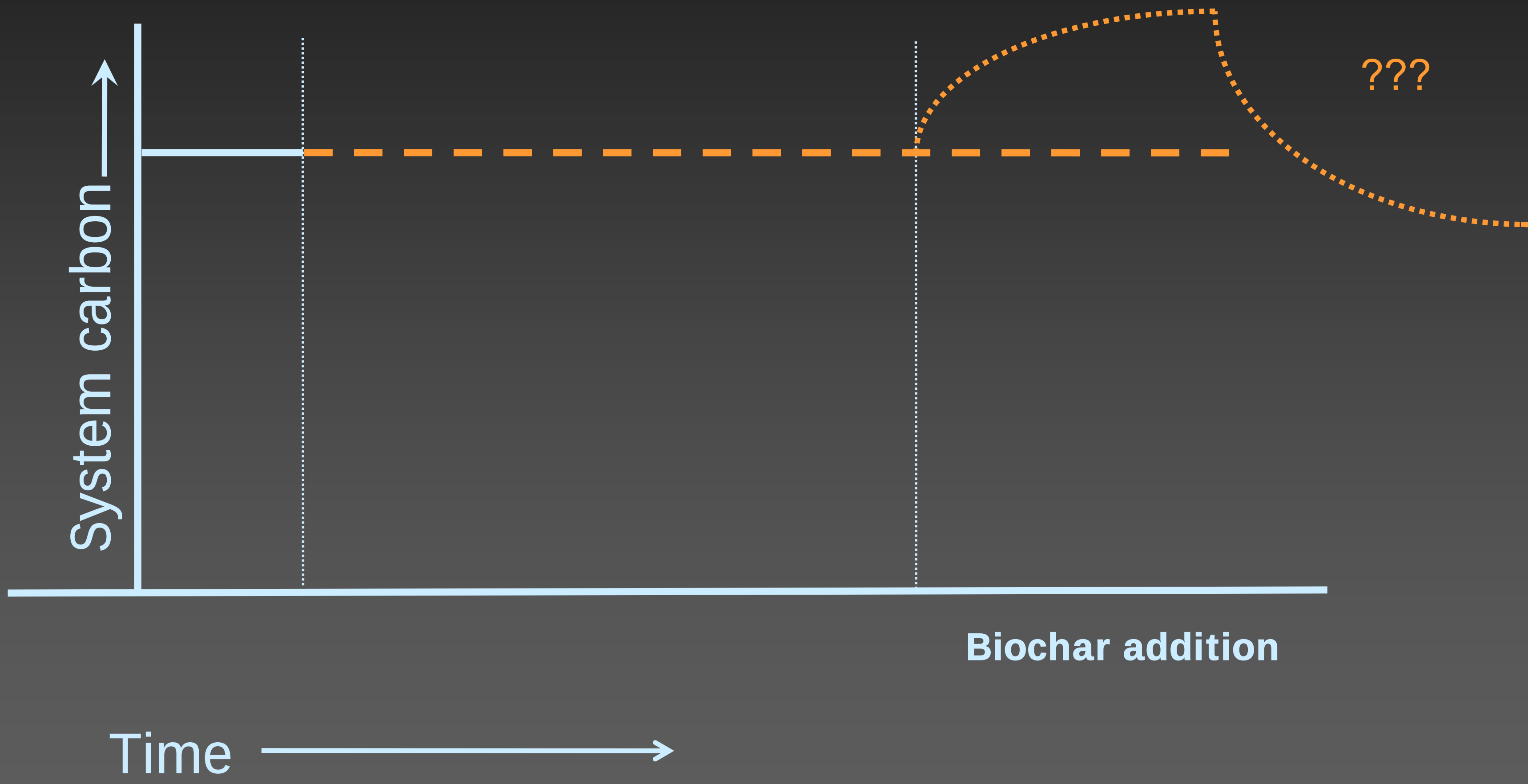
1. Reduces incentives to deal with emissions – delays implementation of emission reduction and de-carbonization policies

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

Terrestrial C trajectories



Terrestrial C trajectories

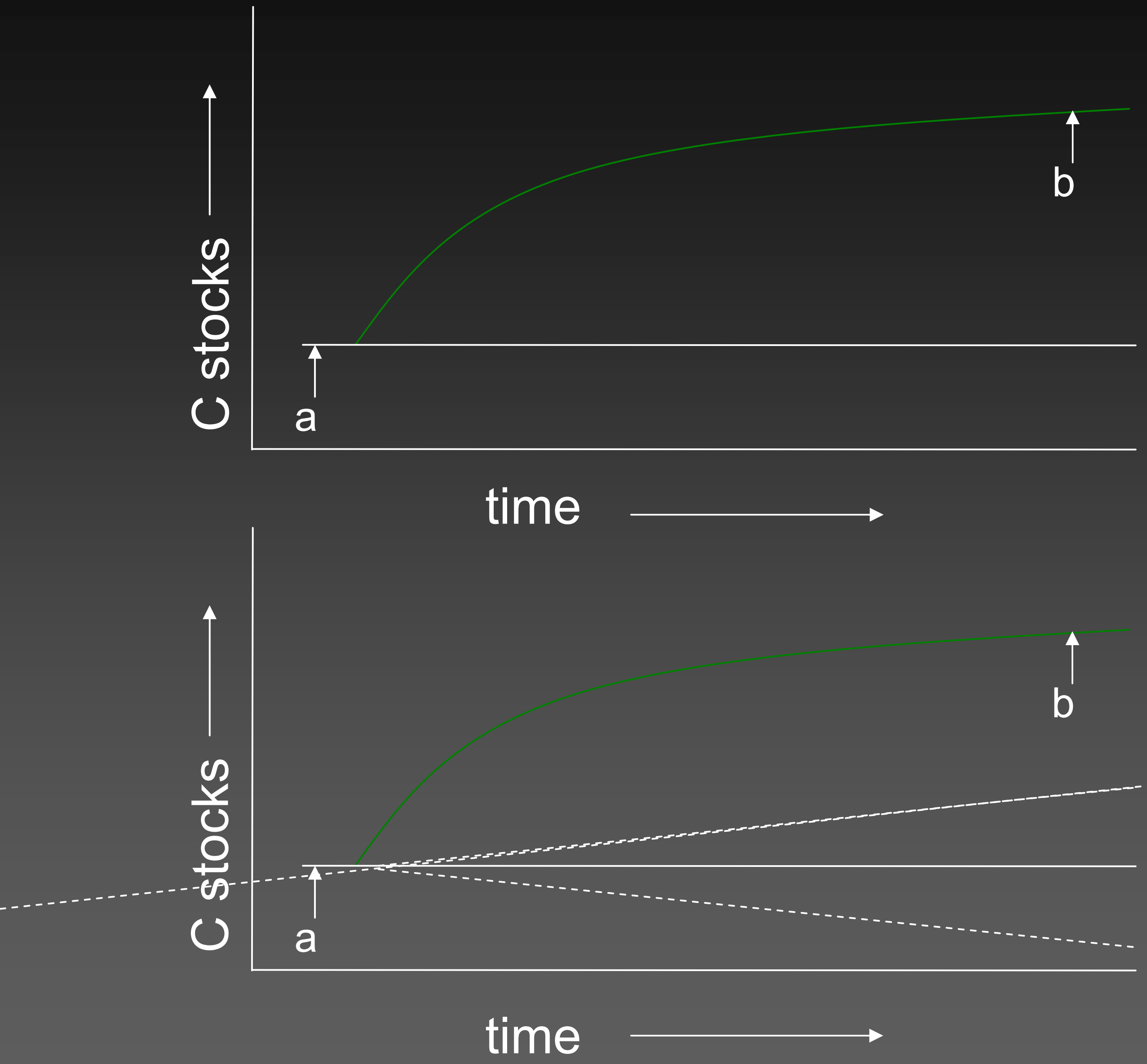


A modest proposal for US climate policy- what's wrong with it?

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 CO_2 rise



Assuming constant baseline, SOC offset = b-a

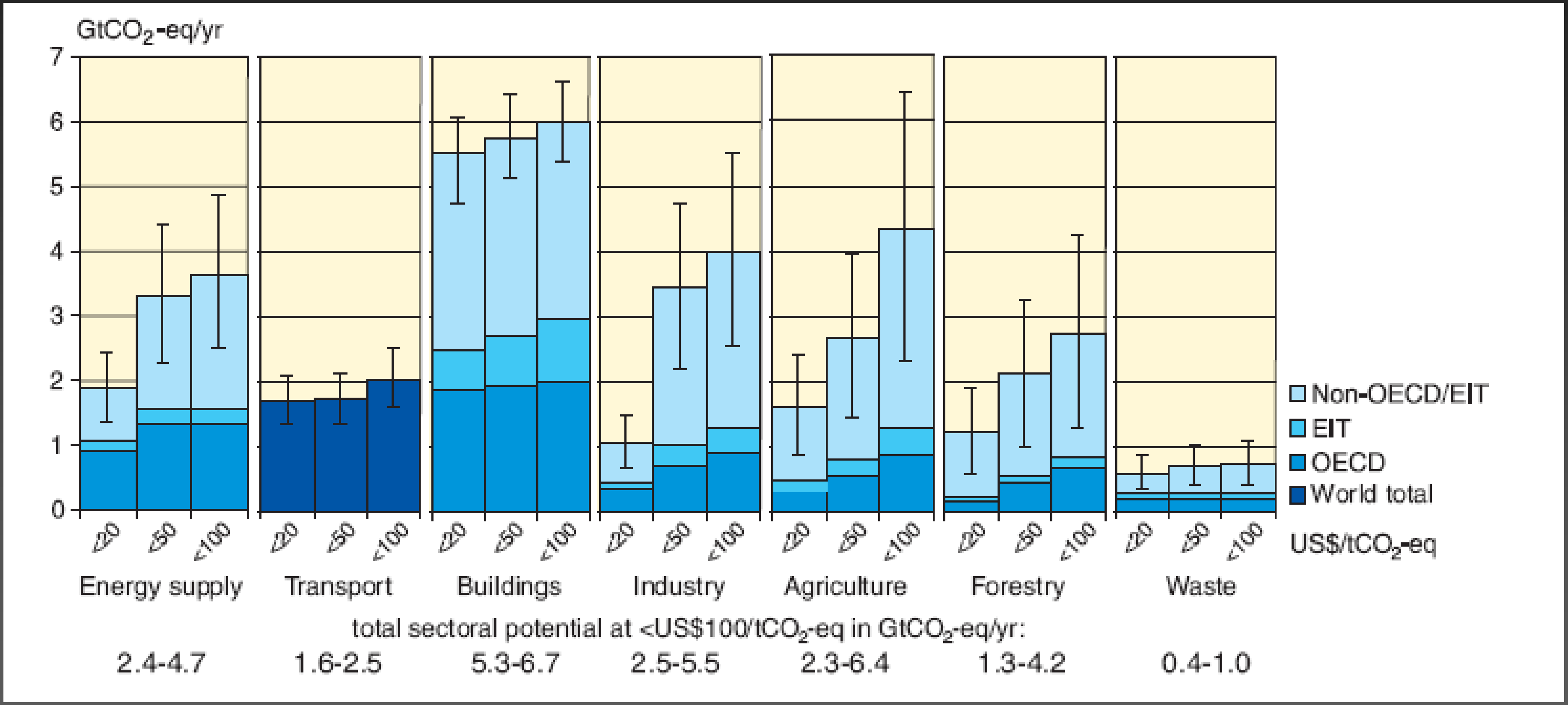
Other factors can drive SOC gains or SOC losses; offset ≠ b-a

(Conant et al. 2009)

Benefits of policies that favor C sequestration

1. Technical potential for carbon sequestration is large

Technical potential for C sequestration is large

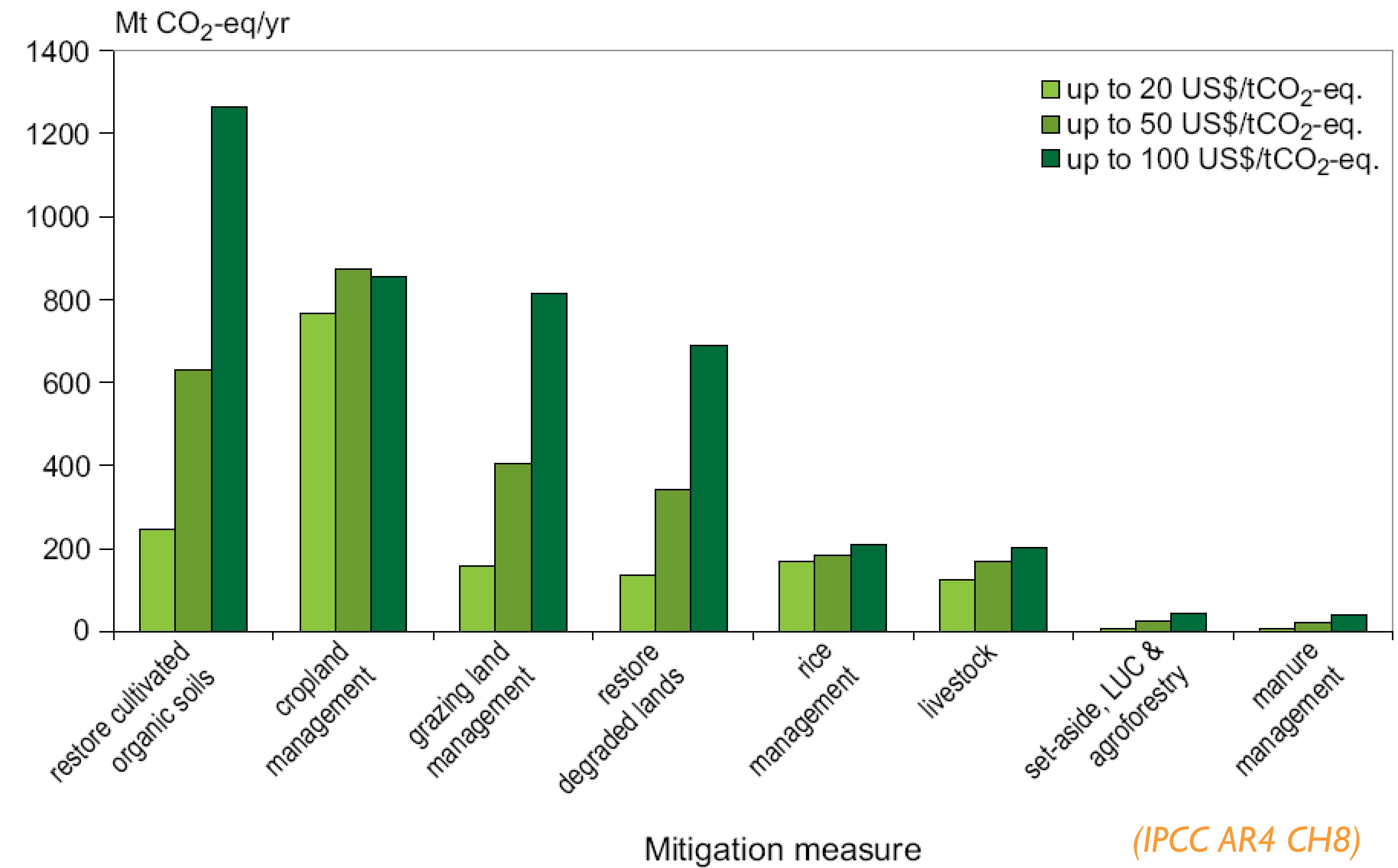


(IPCC AR4 SfPM)

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.

Technical potential for C sequestration is large



(IPCC AR4 CH8)

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:

...ation 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
	+	+/-	+/-	+	+/-	+/-	-	+	+/-
	-/+	+		+	+		+		
...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	-					-	+	-	

...H8)

Benefits of policies that favor C sequestration

1. Technical potential for carbon sequestration is large.
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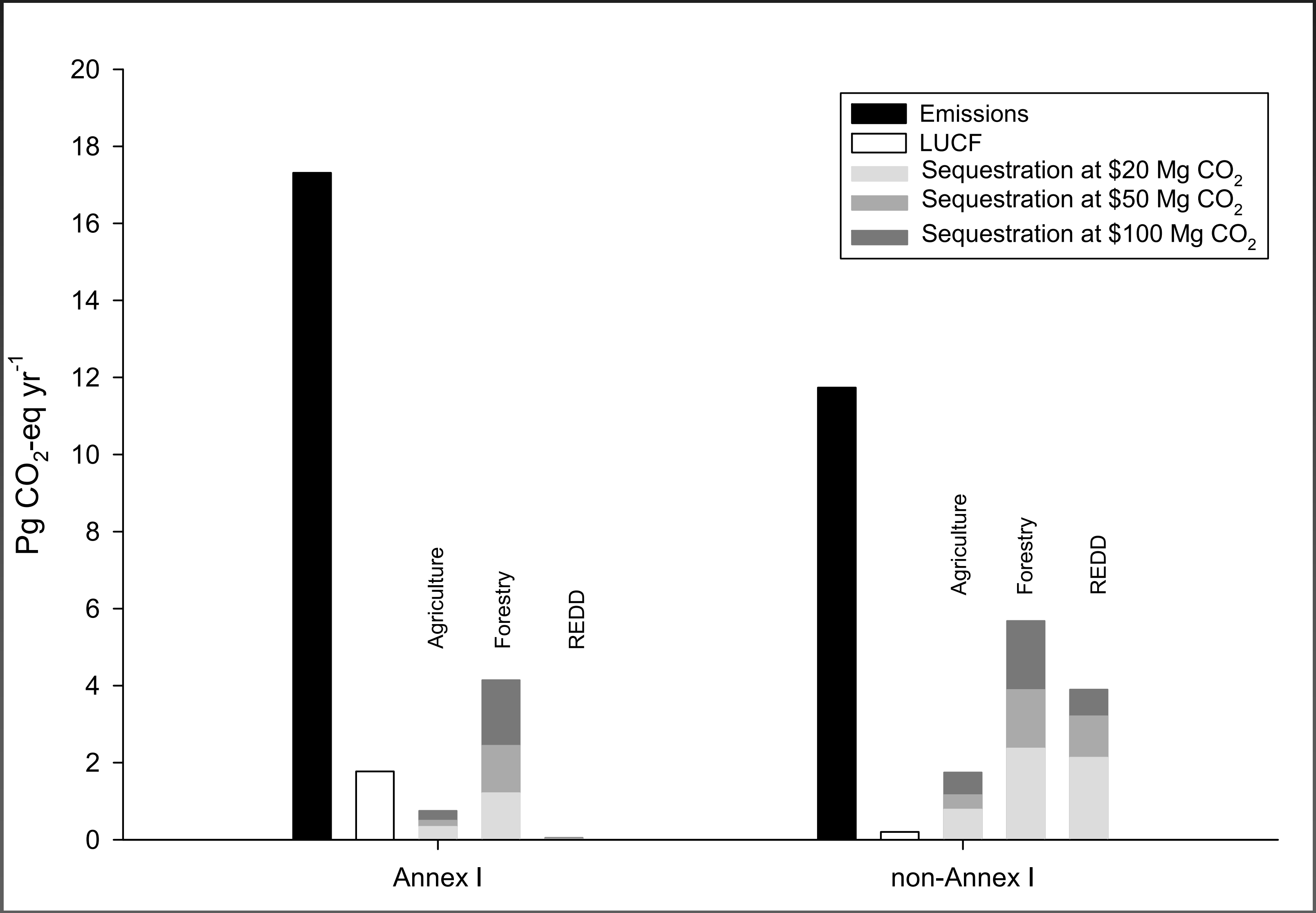
3. Sequestration can lead to environmental, social, and economic co-benefits.
4. Unlike emission reductions C sequestration can be used to draw-down atmospheric CO_2 concentrations.

Developing nations could be engaged



(Conant: WIRES 2009)

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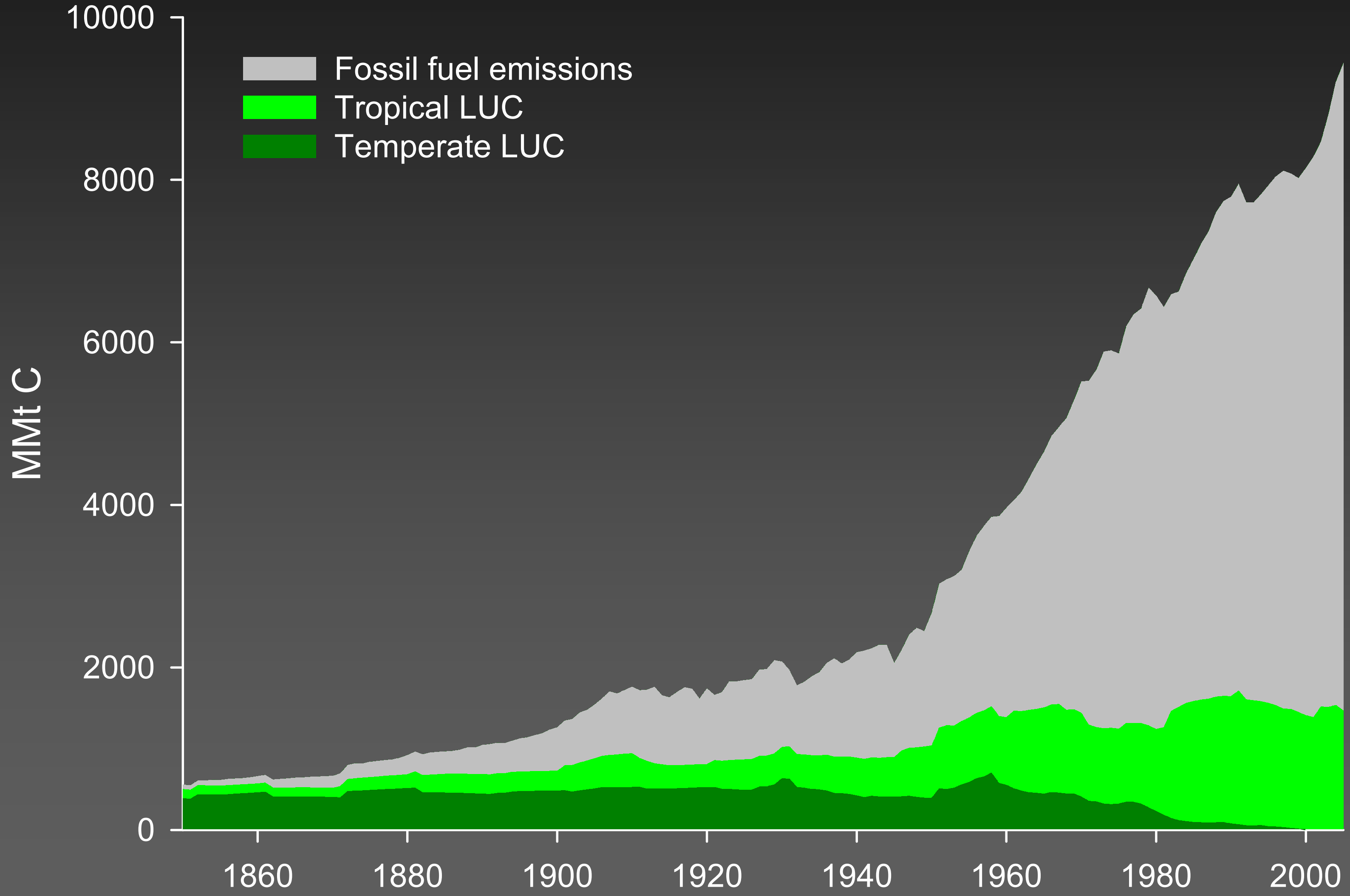
5. Developing nations could be engaged in climate agreements via sequestration

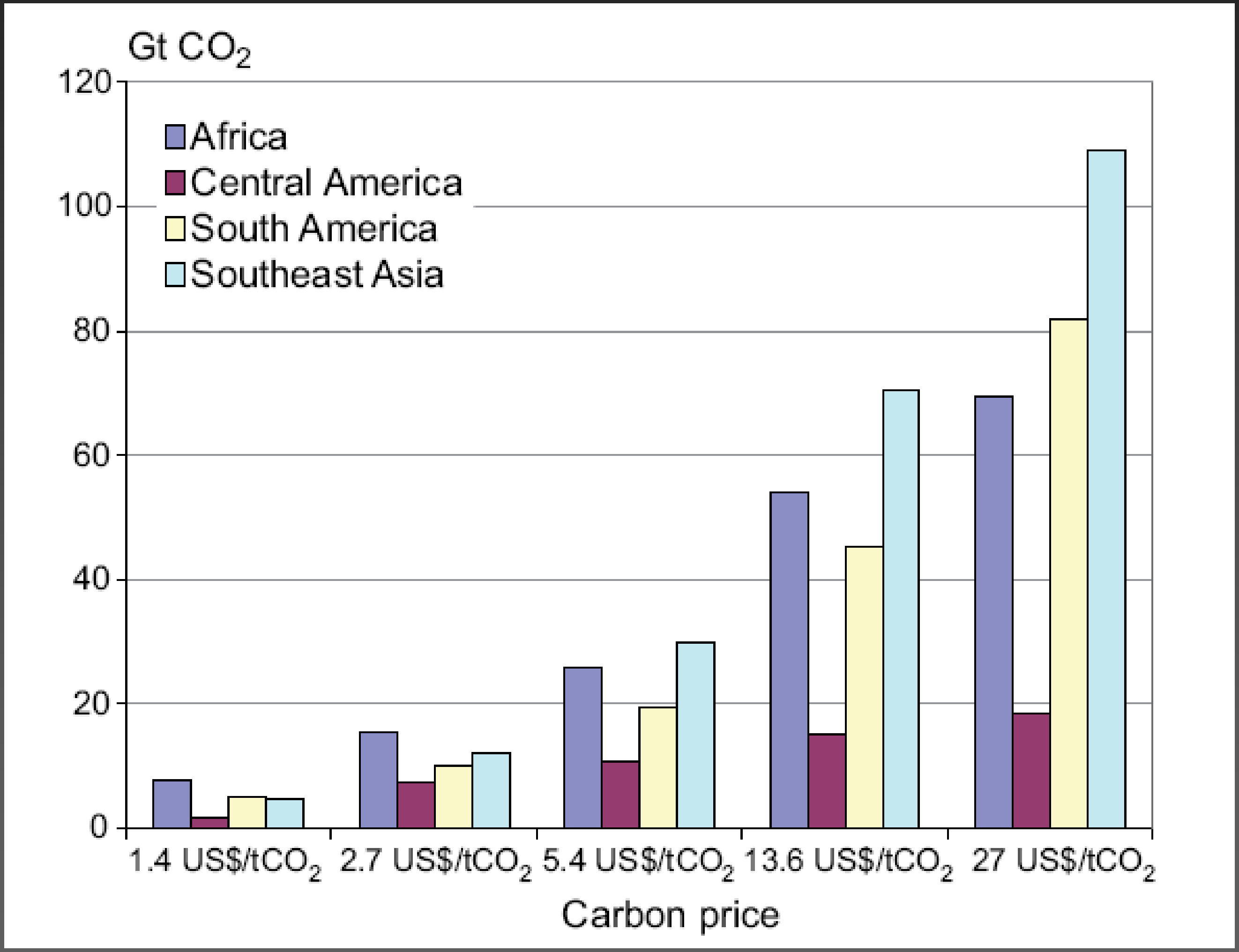
CO_2 concentrations are increasing:

Human activities are driving increases in atmospheric CO_2



Land management contributes to emissions too

-REDD emission reduction potential



(IPCC AR4 CH9)

Benefits of policies that favor C sequestration

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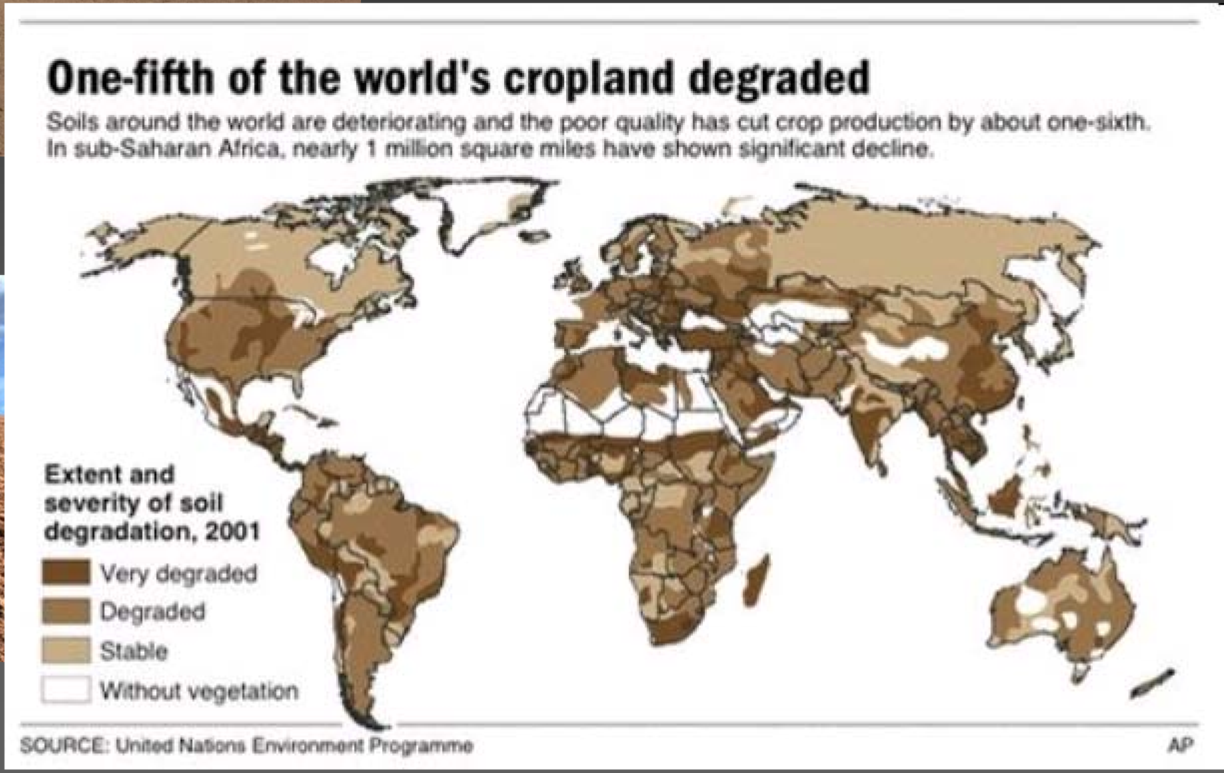
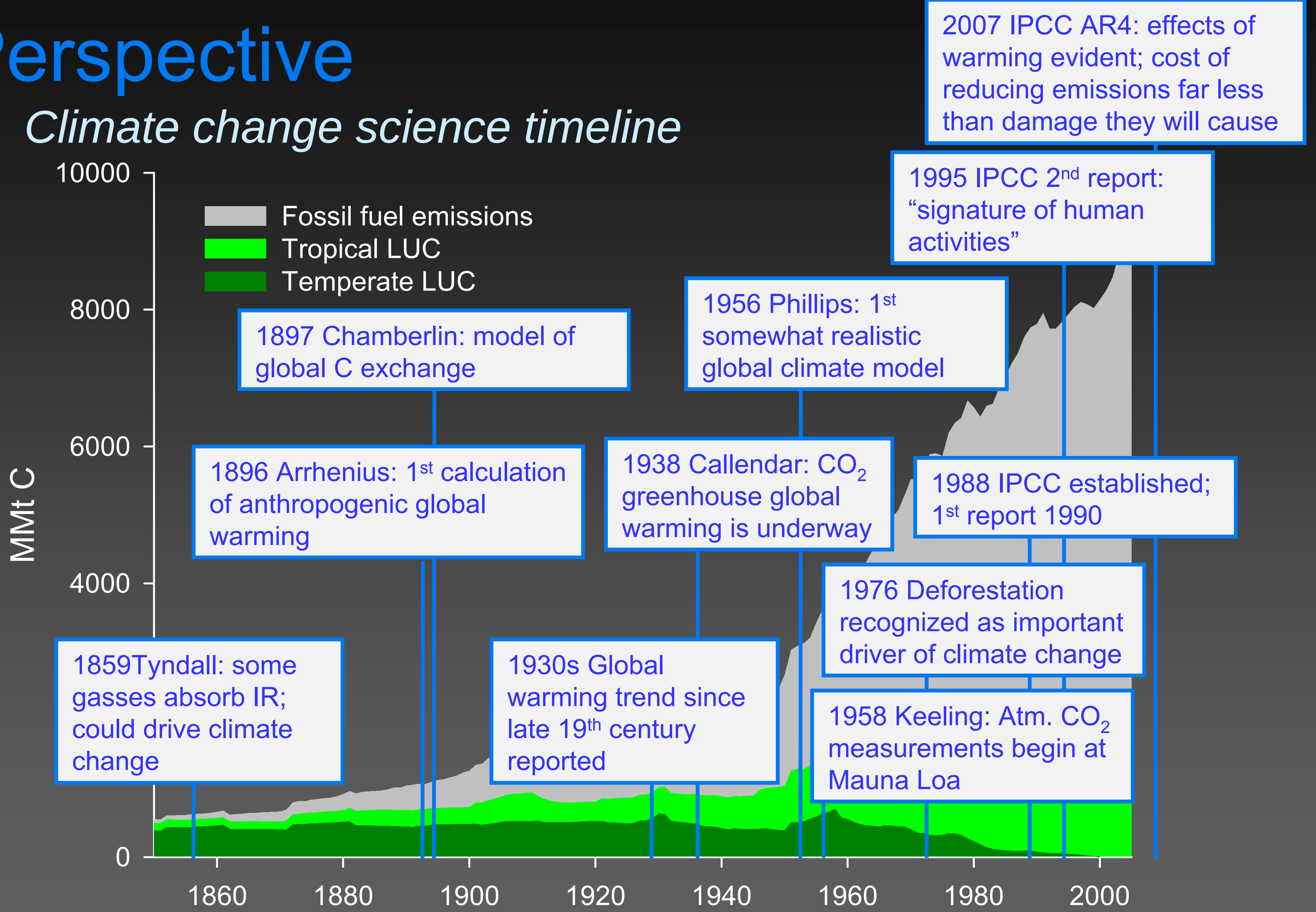
4. Unlike emission reductions C sequestration can be used to draw-down atmospheric CO_2 concentrations.
5. Developing nations could be engaged in climate agreements via sequestration
6. Sequestration could foster adaptation


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.
Extent and severity of soil degradation, 2001
Very degraded
Degraded
Stable
Without vegetation
SOURCE: United Nations Environment Programme
AP

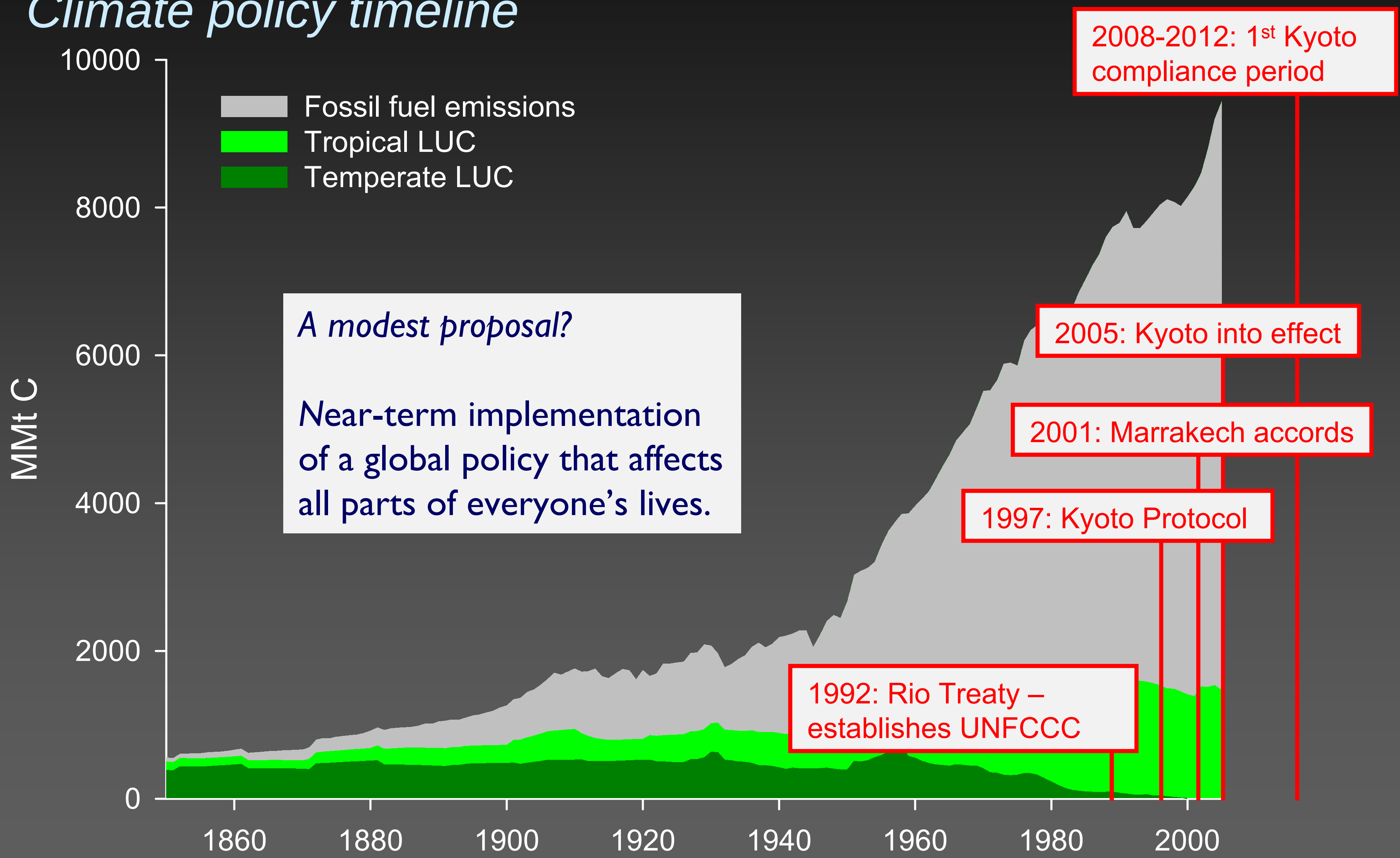
Perspective

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