Climate Change and KS Agriculture: Impacts, Adaptation and Mitigation

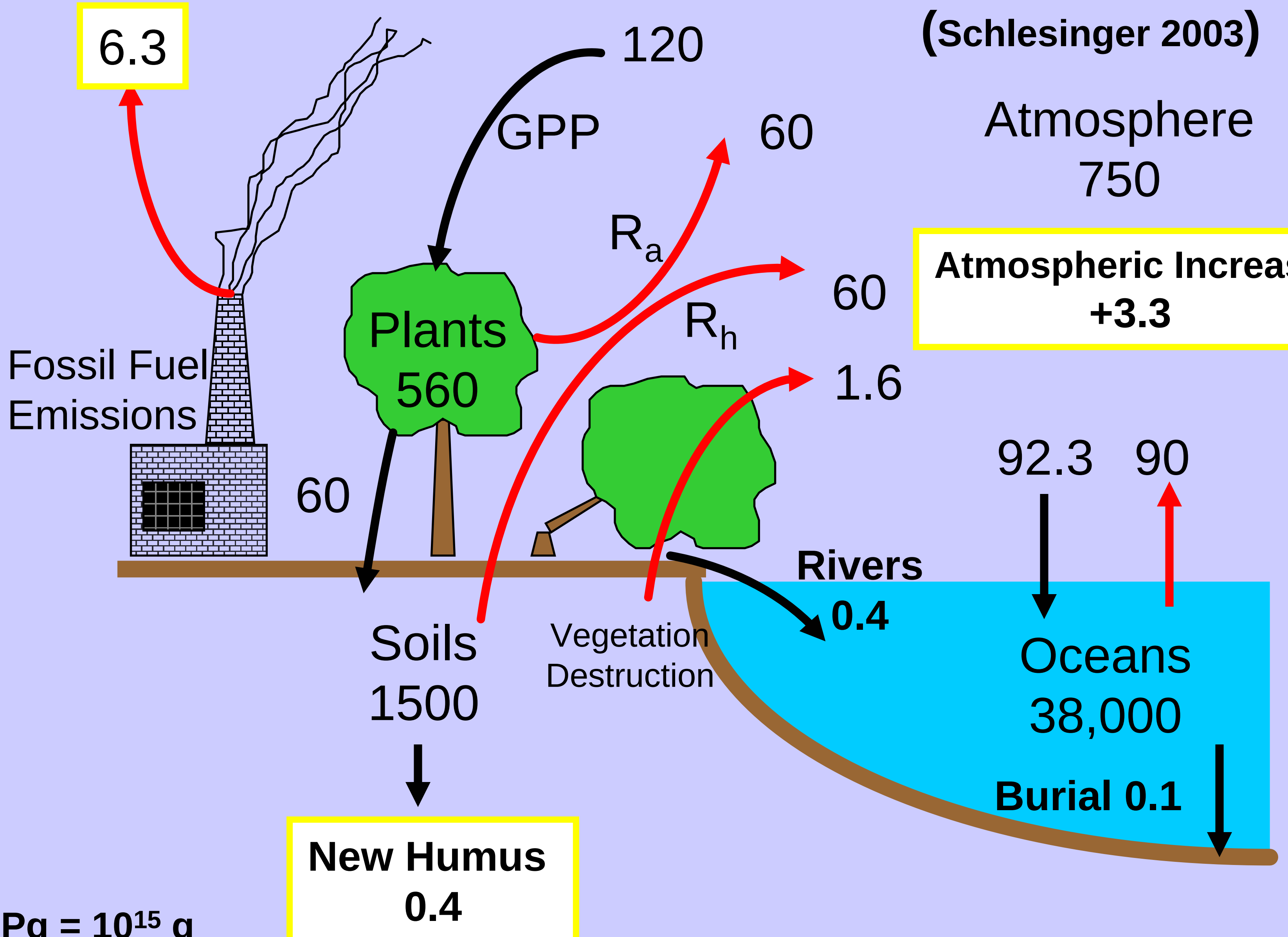
Charles W. Rice
Soil Microbiologist
Department of Agronomy

Lead Author, IPCC AR4 WGIII

K-State Research and

Global Carbon Cycle (Pg C)

(Schlesinger 2003)

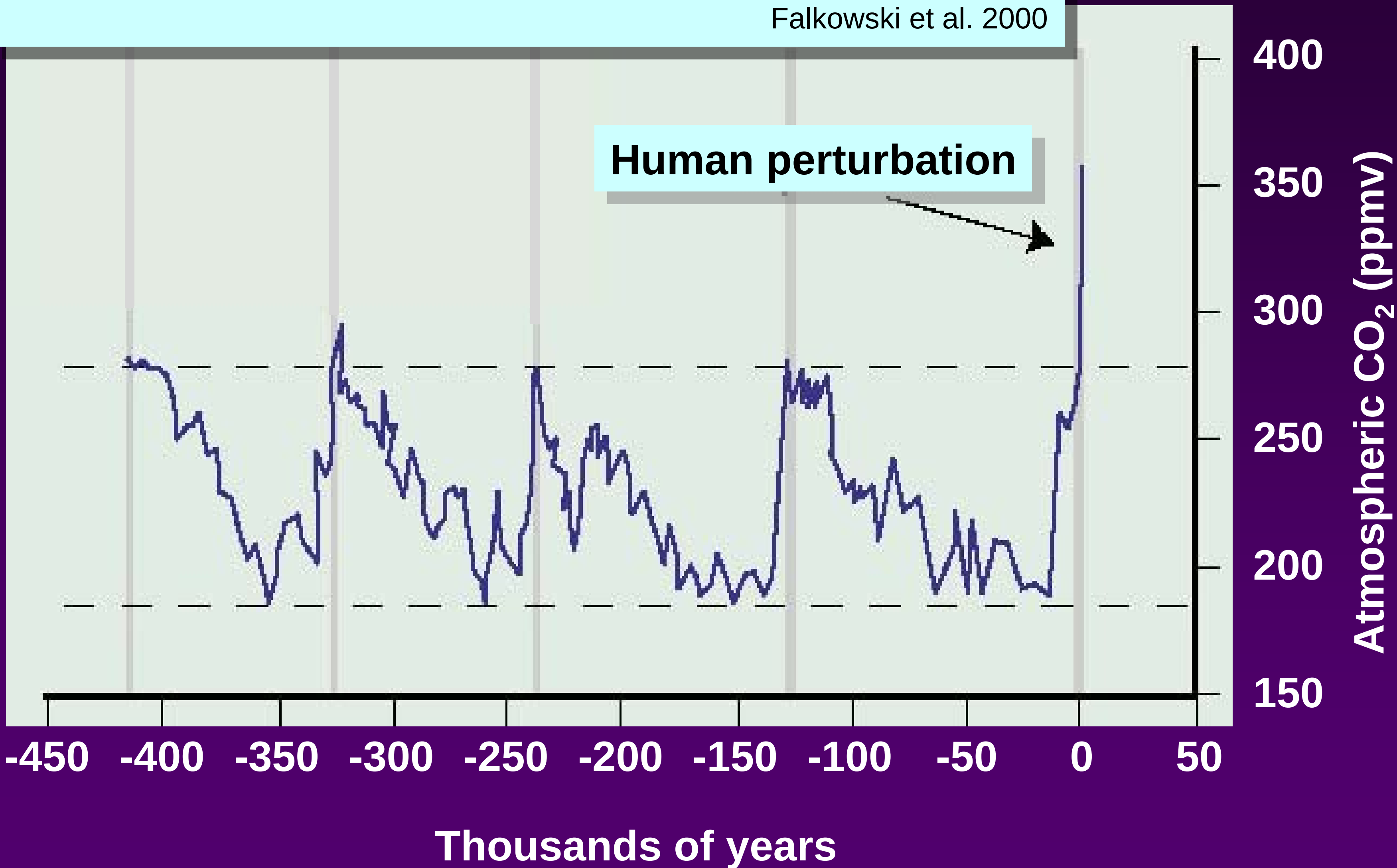


1 Pg = 10^{15} g

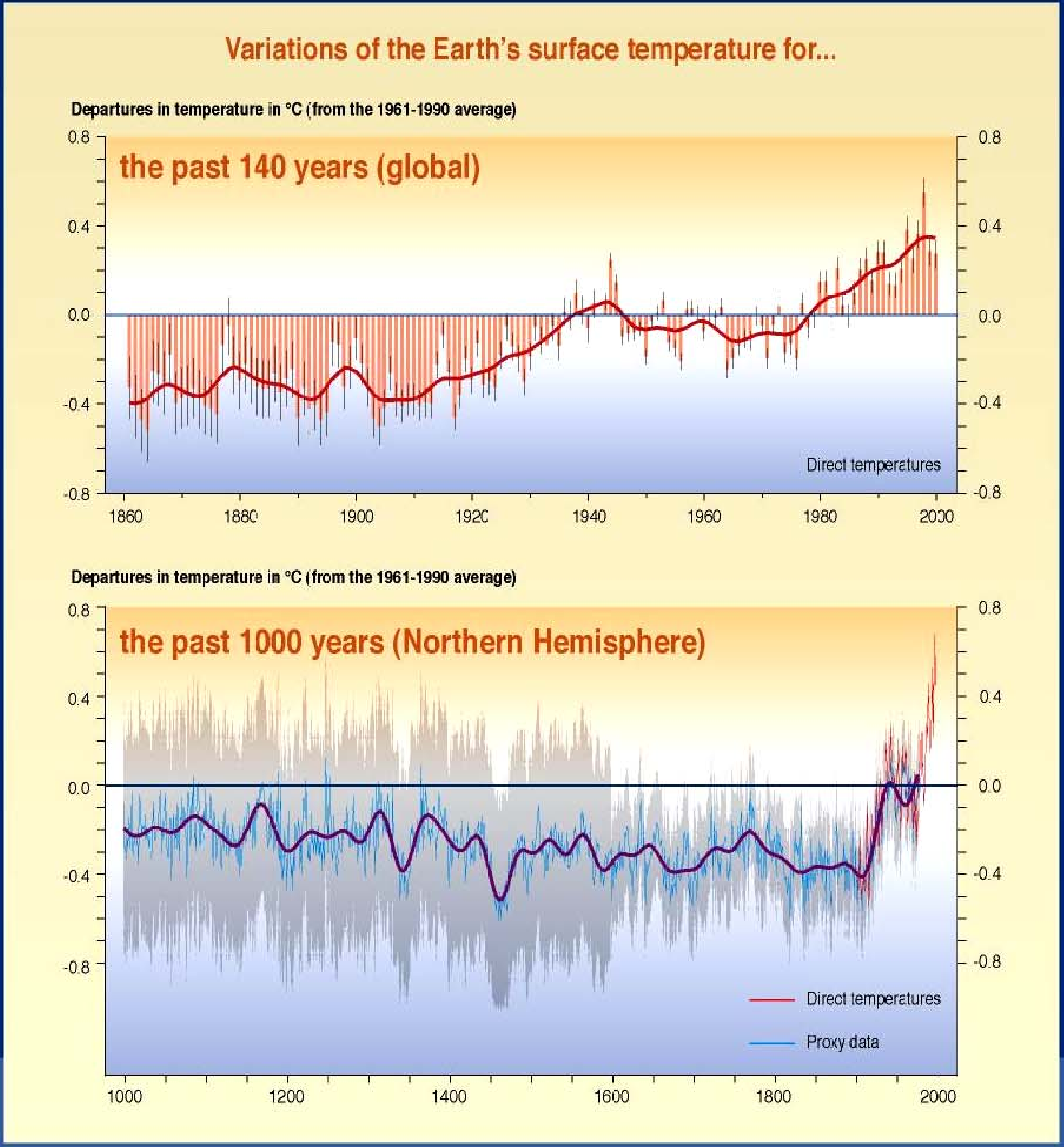
= 1 billion tons

We have left the domain that defined the Earth system for the 420,000 years before the Industrial Revolution

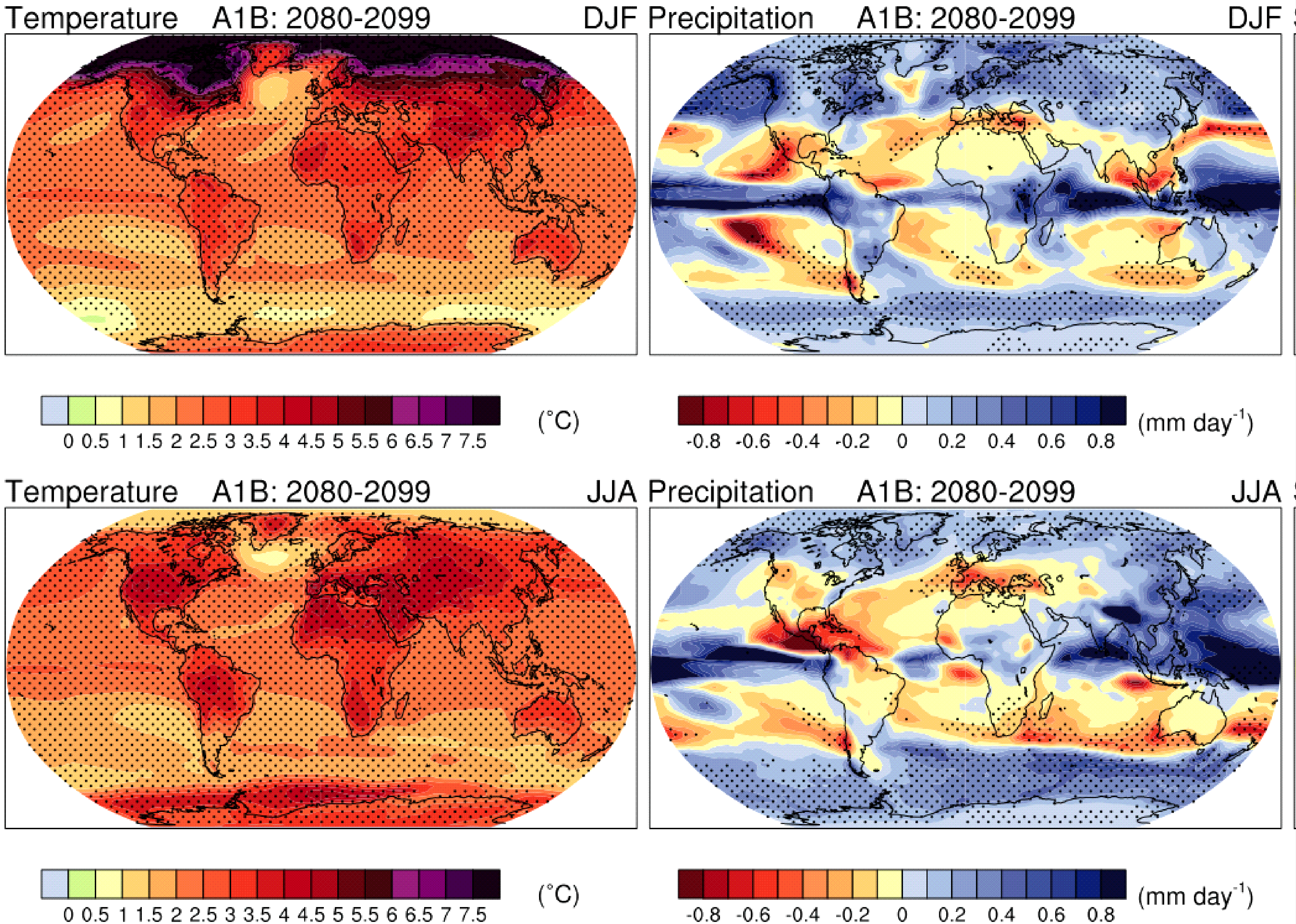
Falkowski et al. 2000



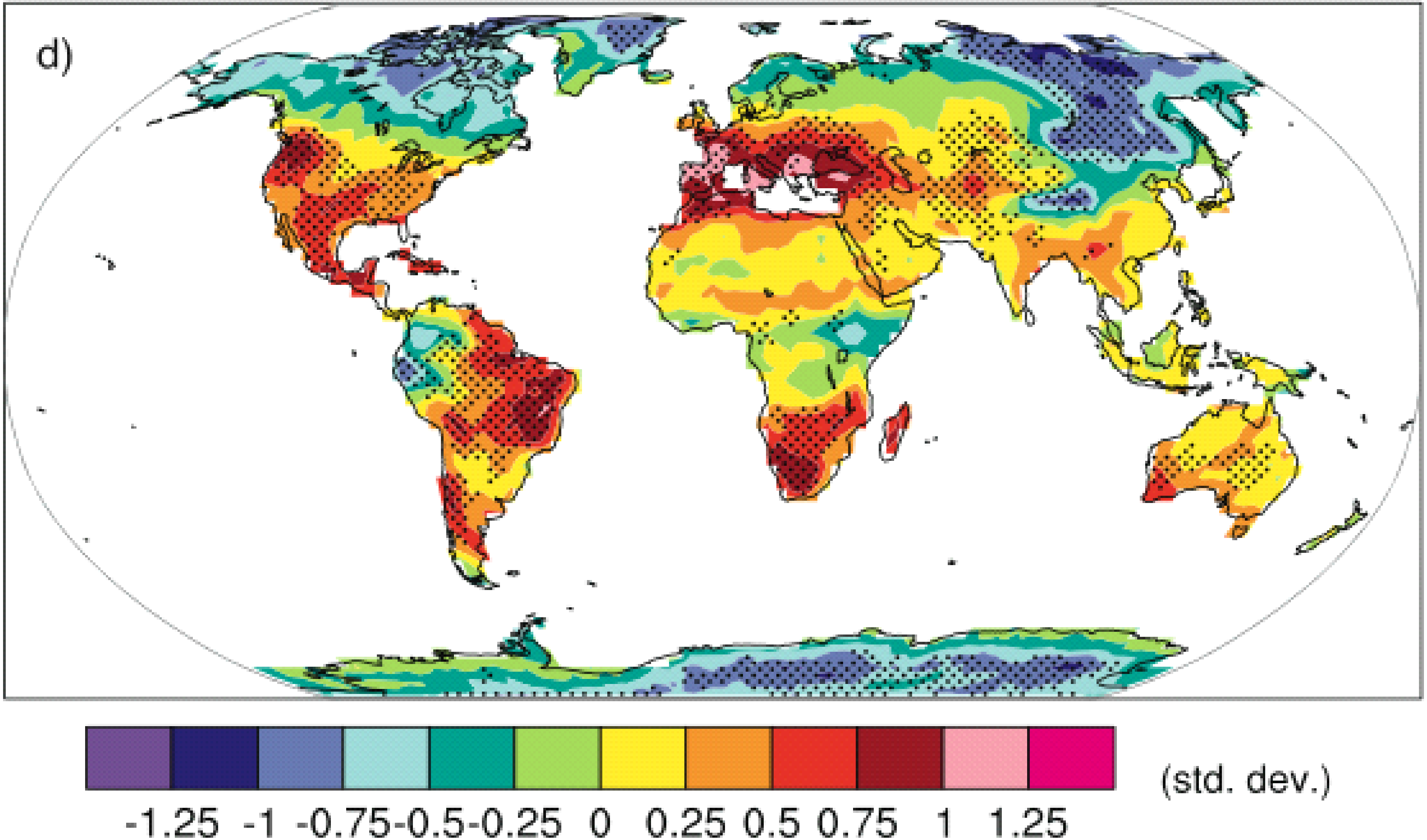
Source: Petit et al. 1999

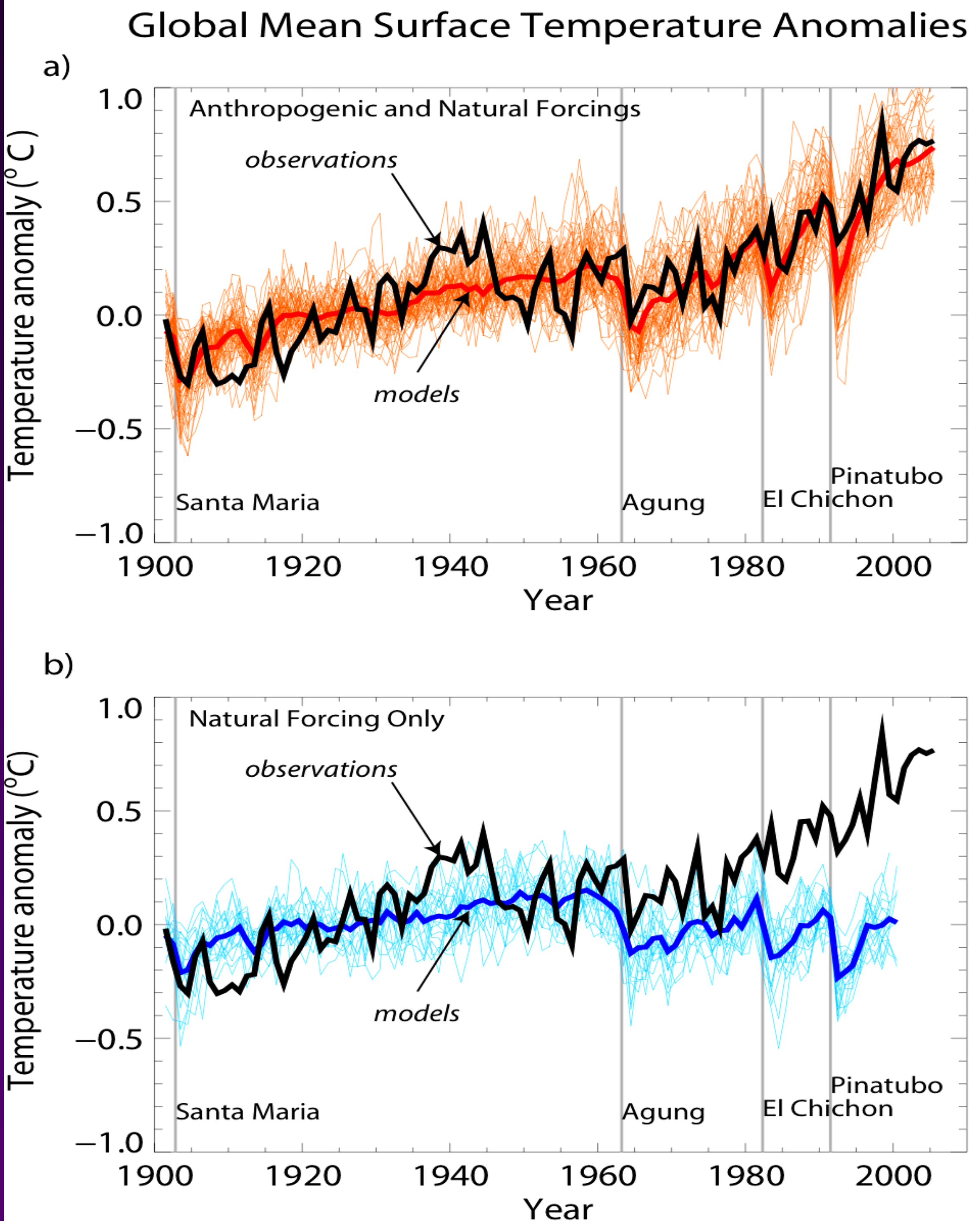


SYR - FIGURE 2-3


Temperature A1B: 2080-2099 DJF
Precipitation A1B: 2080-2099 DJF
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
(mm day-1)
Temperature A1B: 2080-2099 JJA
Precipitation A1B: 2080-2099 JJA
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
(°C)
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
(mm day-1)

Dry days



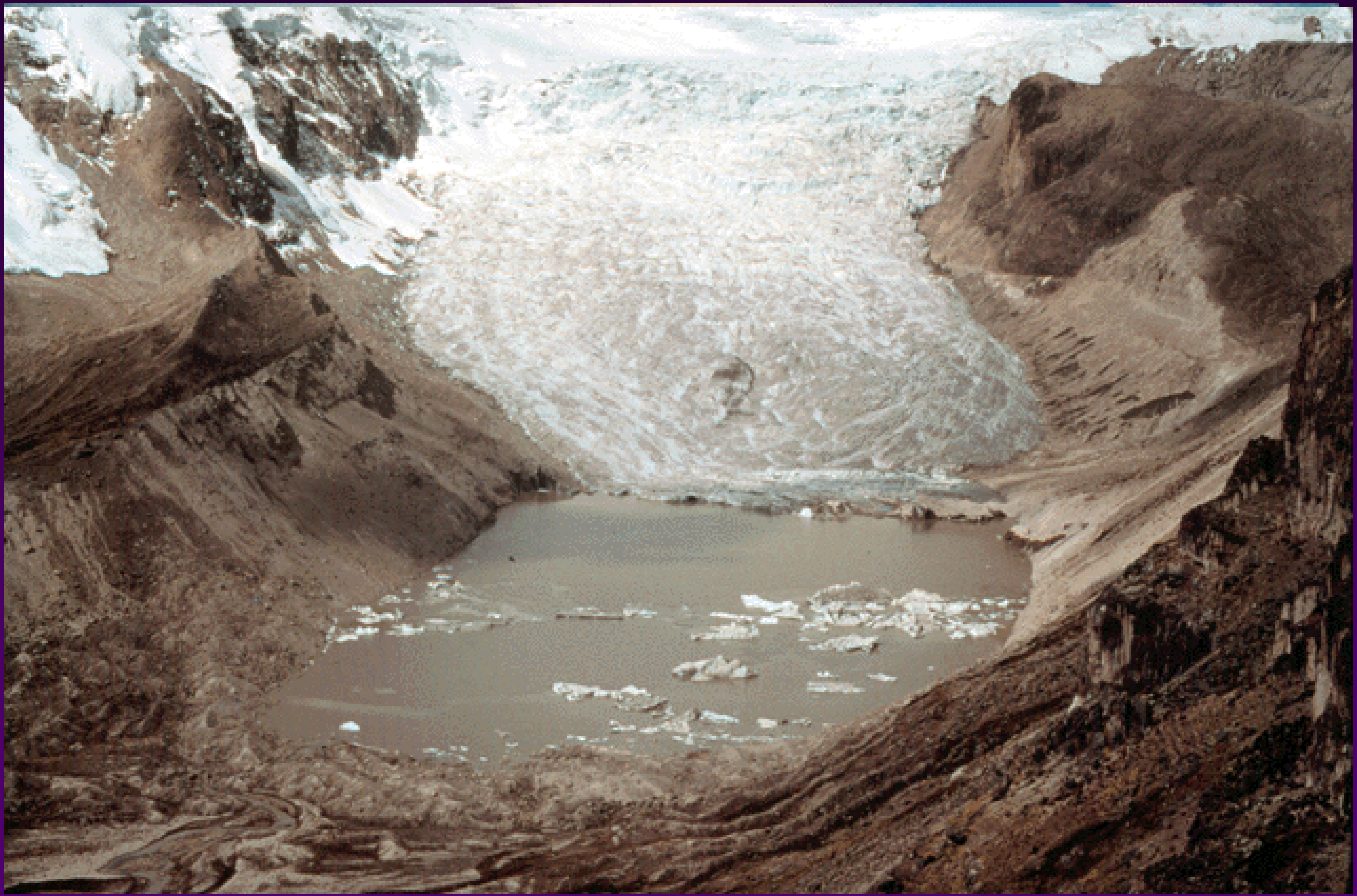


Global Mean Surface Temperature Anomalies
a)
Anthropogenic and Natural Forcings
observations
models
Temperature anomaly (°C)
1.0
0.5
0.0
−0.5
−1.0
Santa Maria
Agung
El Chichon
Pinatubo
1900
1920
1940
1960
1980
2000
Year
b)
Natural Forcing Only
observations
models
Temperature anomaly (°C)
1.0
0.5
0.0
−0.5
−1.0
Santa Maria
Agung
El Chichon
Pinatubo
1900
1920
1940
1960
1980
2000
Year

TS-23

Qori Kalis, Peruvian Andes

1978… …And Today

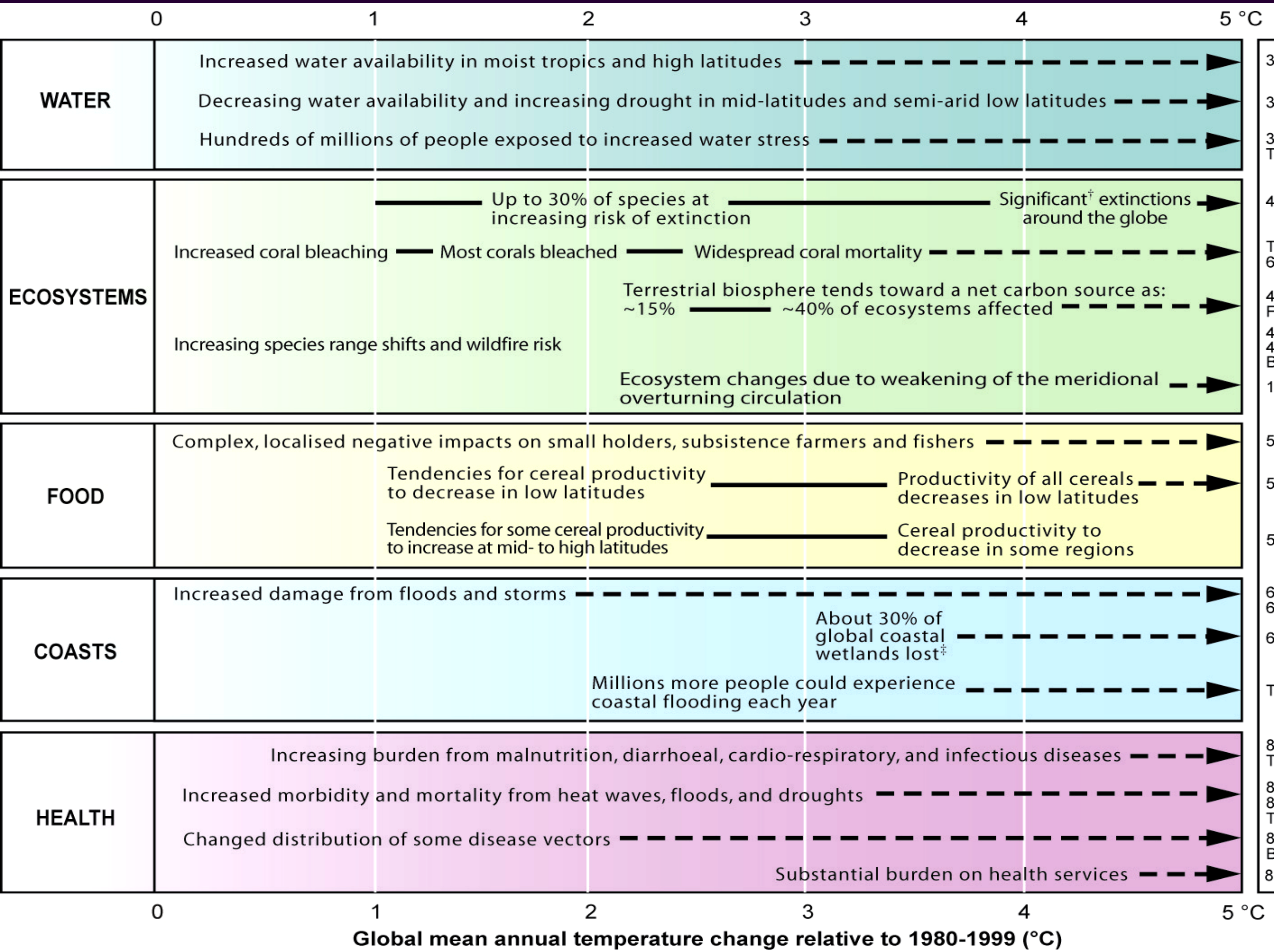


- In 1978, the Qori Kalis Glacier looked like this, flowing out from the Quelccaya Ice Cap in the Peruvian Andes Mountains.

Glaciers are shrinking nearly worldwide

Source: L. Thompson

Impact, Vulnerability, and Adaptation

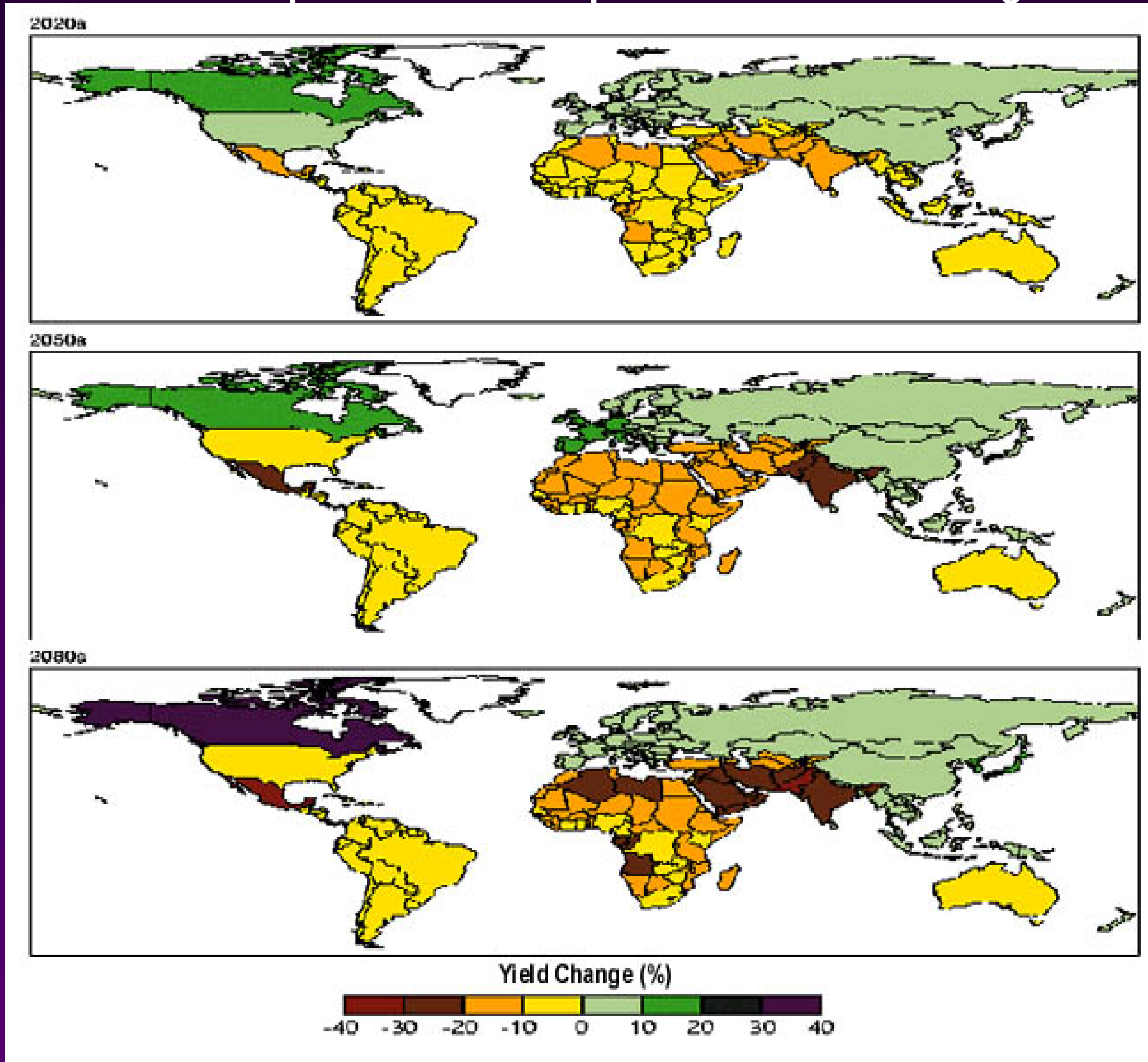

0 1 2 3 4 5 °C
WATER
Increased water availability in moist tropics and high latitudes
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
Hundreds of millions of people exposed to increased water stress
ECOSYSTEMS
Up to 30% of species at increasing risk of extinction
Significant† extinctions around the globe
Increased coral bleaching
Most corals bleached
Widespread coral mortality
Terrestrial biosphere tends toward a net carbon source as:
~15%
~40% of ecosystems affected
Increasing species range shifts and wildfire risk
Ecosystem changes due to weakening of the meridional overturning circulation
FOOD
Complex, localised negative impacts on small holders, subsistence farmers and fishers
Tendencies for cereal productivity to decrease in low latitudes
Productivity of all cereals decreases in low latitudes
Tendencies for some cereal productivity to increase at mid- to high latitudes
Cereal productivity to decrease in some regions
COASTS
Increased damage from floods and storms
About 30% of global coastal wetlands lost‡
Millions more people could experience coastal flooding each year
HEALTH
Increasing burden from malnutrition, diarrhoeal, cardio-respiratory, and infectious diseases
Increased morbidity and mortality from heat waves, floods, and droughts
Changed distribution of some disease vectors
Substantial burden on health services
0 1 2 3 4 5 °C
Global mean annual temperature change relative to 1980-1999 (°C)

Initially increased agricultural productivity in some mid-latitude regions & reduction in the tropics and sub-tropics even with warming of a few degrees

2020s

2050s

2080s



Consequences of Climate Change on Agriculture

- Increased productivity potential
  - Water Availability
    - Drought
    - Erosion
  - Nitrogen availability
    - Impacts forage quality
    - Grain quality
    - Increased need for N fertilization
  - Increased pests
    - Warmer nights
    - Warmer winters
    - Increased pesticide use?
  - Hasten maturity and shorten growing season

- Increased risk and uncertainty

Consequences of Increased Temperature: Effect on Water Resources

- Crop water requirements will increase
- Warmer winters
  - Reduced winter storage thus low stream flows in late summer and early fall
- Increased competition for water resources
  - Agriculture, urban, industrial, domestic

Future risks-Kansas

- Decreasing water availability (& quality)
- More frequent and more severe heat waves
- Heat stress for some plants and animals
- More inputs and associated costs
- Greater variability and uncertainty

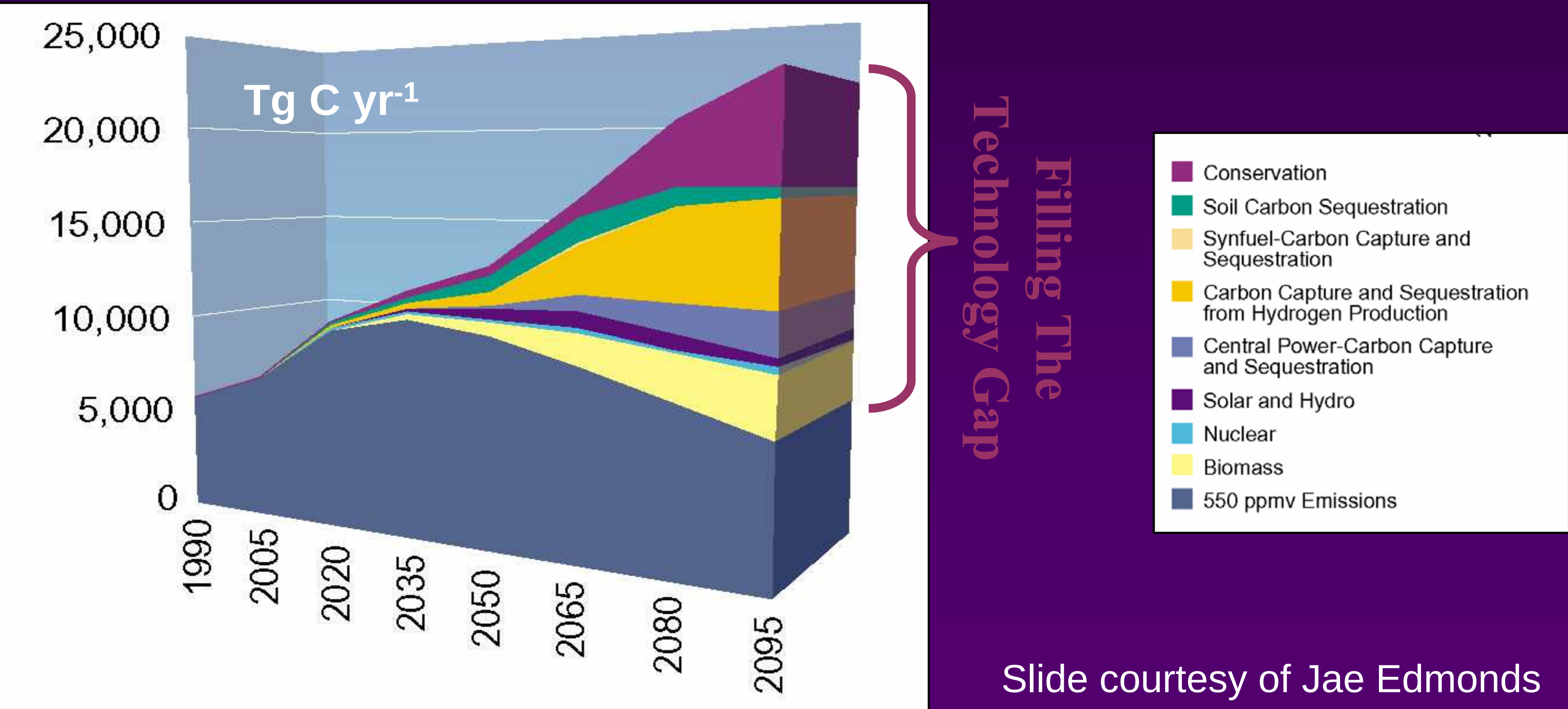
Mitigation

Strategies to Reduce Atmospheric CO_2

- Strategies
  - Reduce fossil fuel consumption
    - Improve efficiency
    - Renewable energy sources
  - Identify sinks and sequestration rate
    - Terrestrial
      - Soils
      - Plants
    - Aquatic
    - Geologic

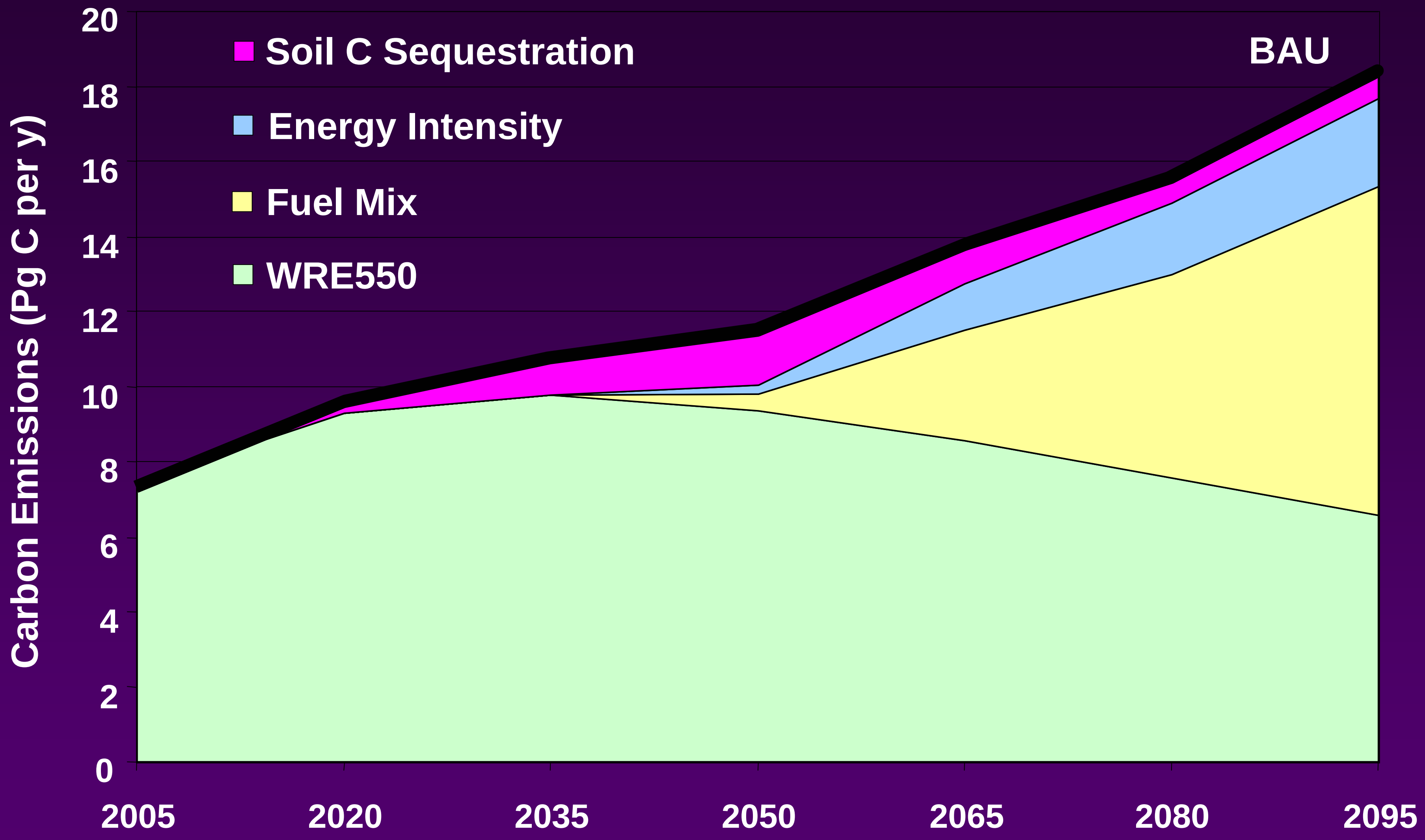
Stabilizing CO_2 concentrations means…

- Changing the global energy system
- Developing a least-cost technology portfolio



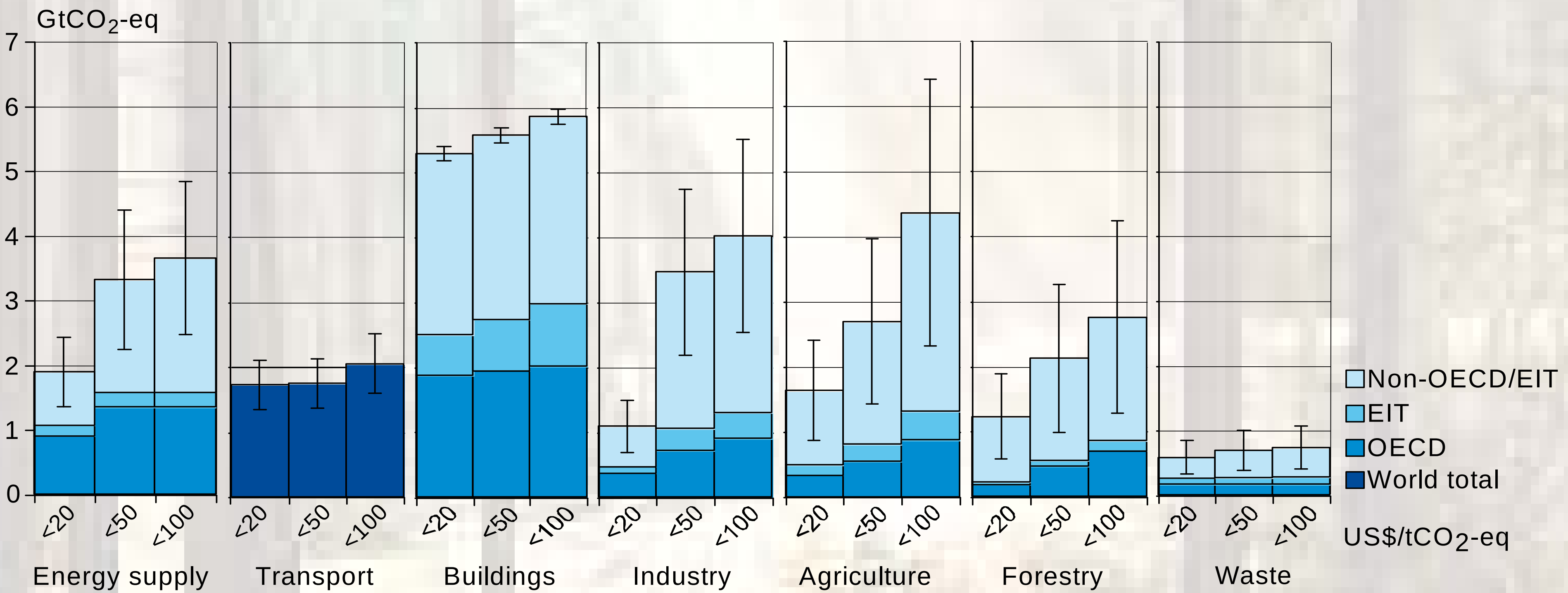
Slide courtesy of Jae Edmonds

Carbon Emissions Reductions: WRE 550 with Soil Carbon Sequestration Credits



From: Rosenberg, N.J., R.C. Izaurralde, and E.L. Malone (eds.). 1999. Carbon Sequestration in Soils: Science, Monitoring and Beyond. Battelle Press, Columbus, OH. 201 pp.

Global economic mitigation potential for different sectors at different carbon prices

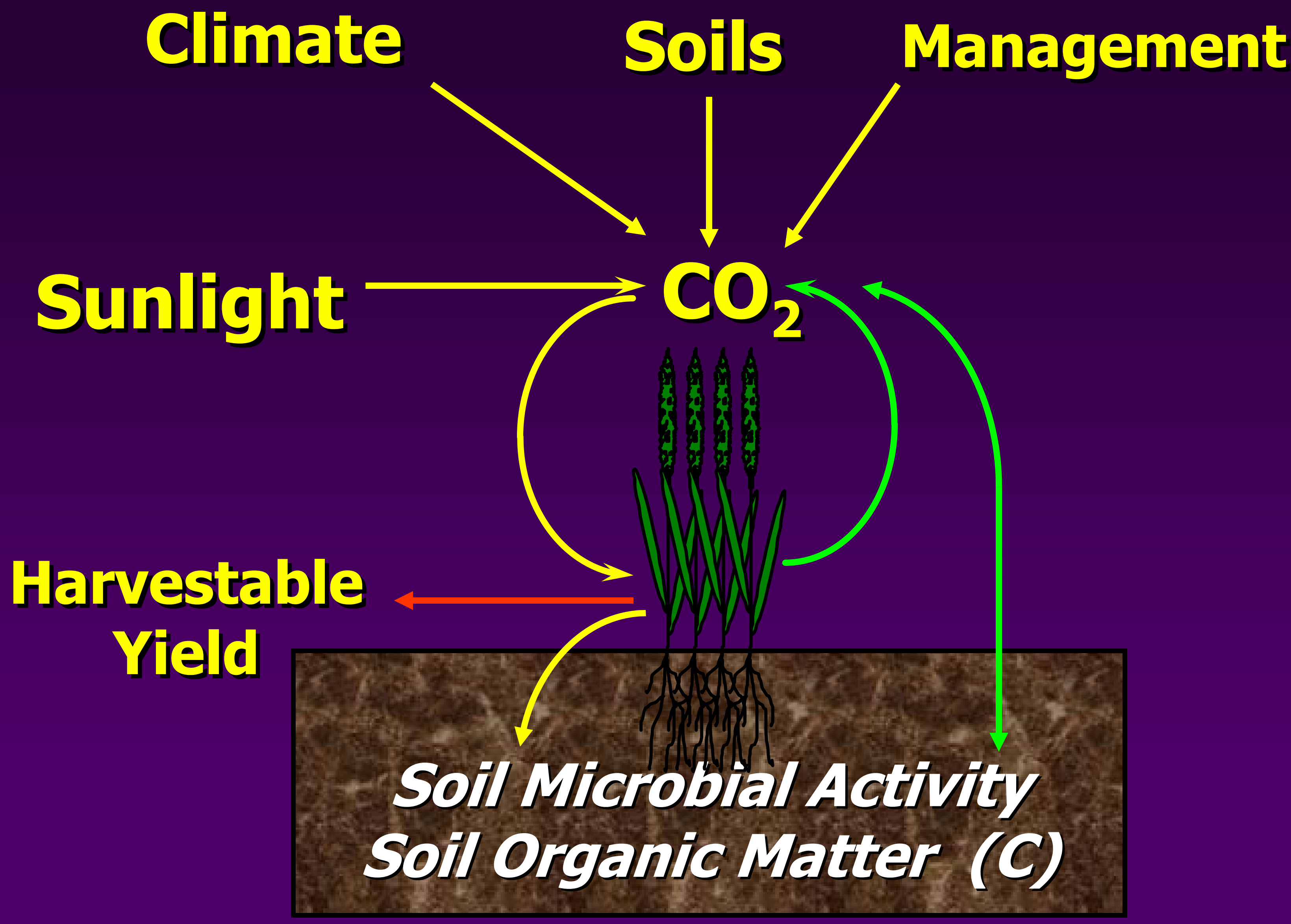


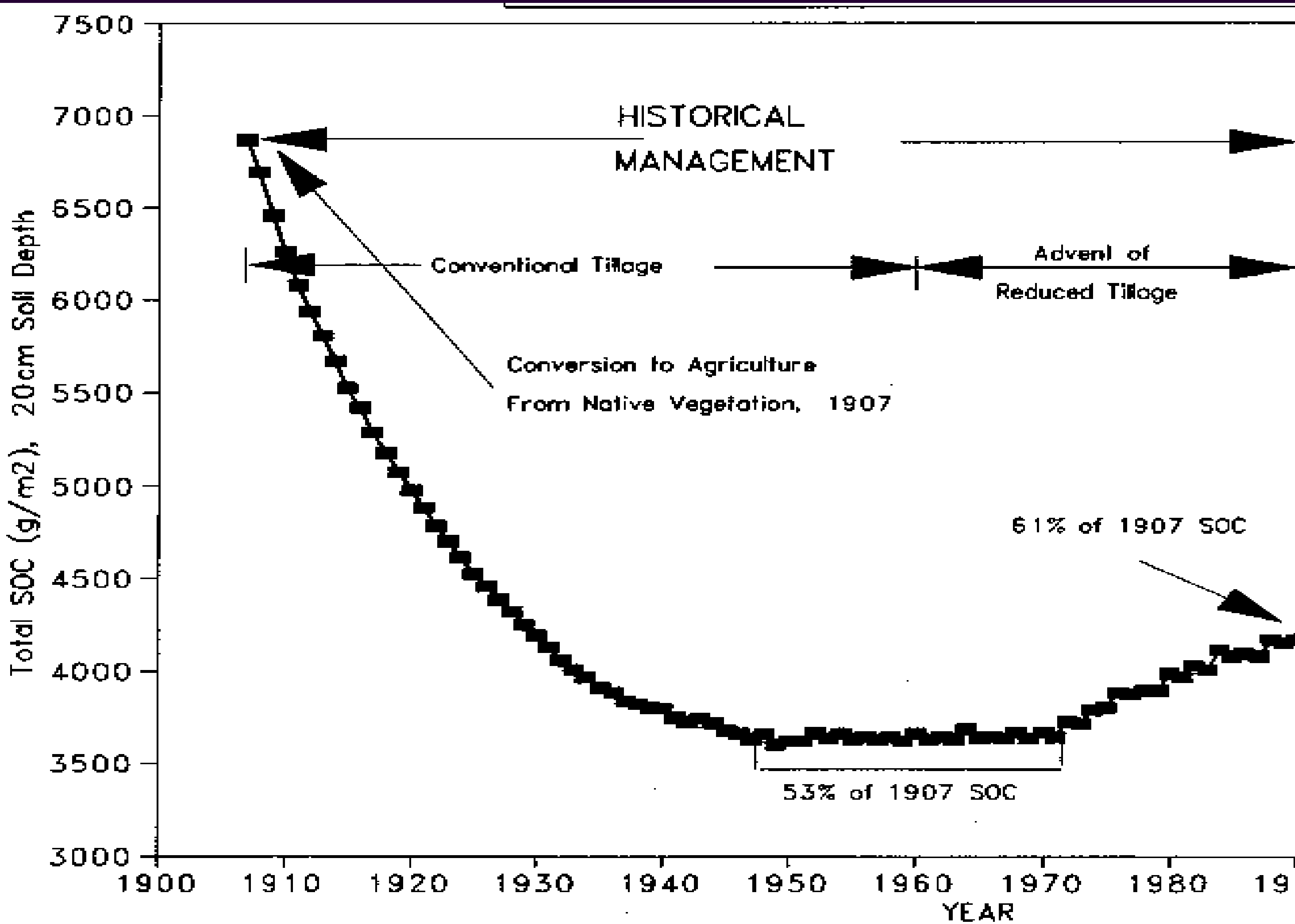
IPCC, 2007

Agriculture

- A large proportion of the mitigation potential of agriculture (excluding bioenergy) arises from soil C sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change.

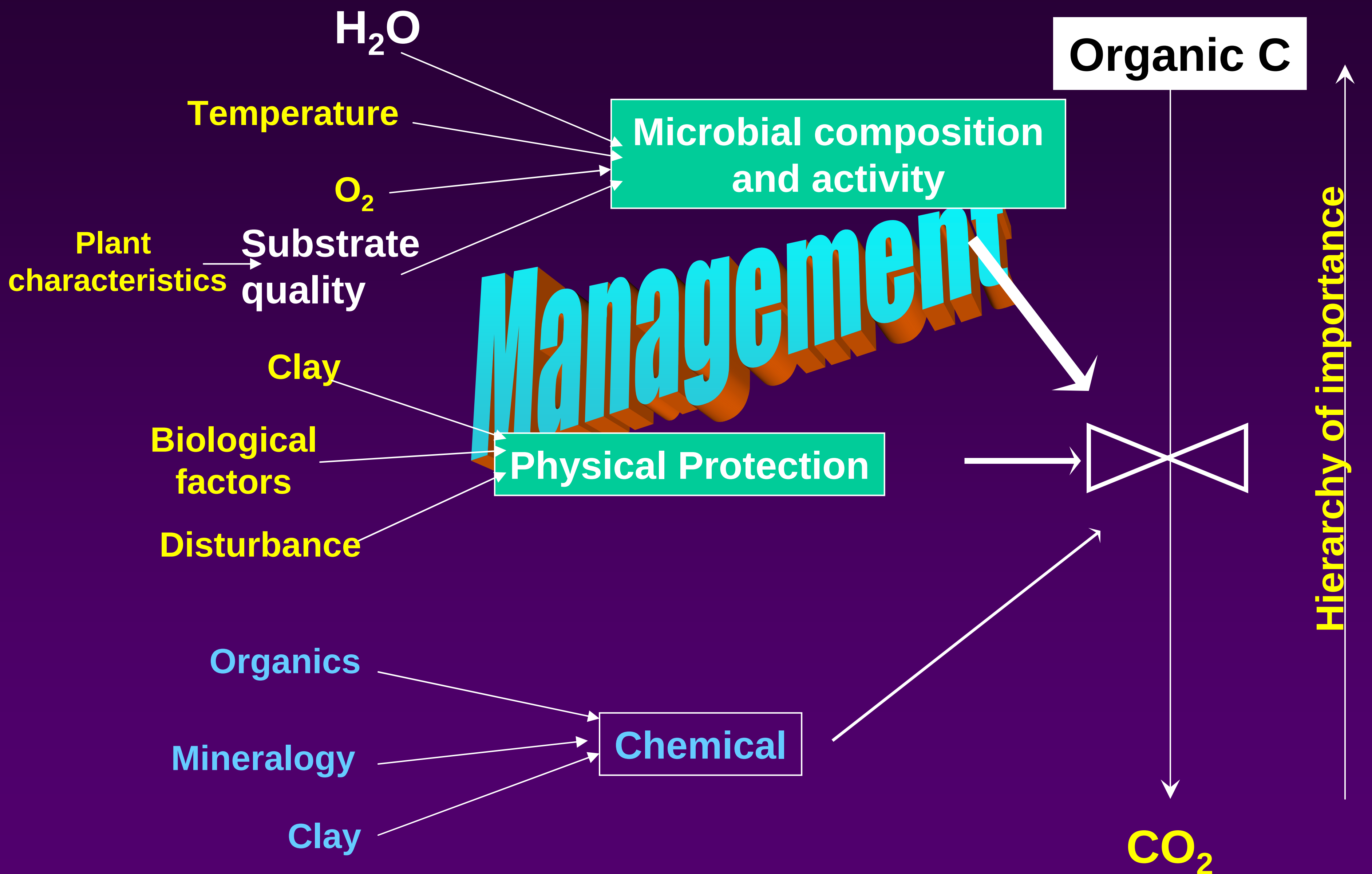
- Agricultural practices collectively can make a significant contribution at low cost
  - By increasing soil carbon sinks,
  - By reducing GHG emissions,
  - By contributing biomass feedstocks for energy use


Climate
Soils
Management
Sunlight
CO_2
Harvestable Yield
Soil Microbial Activity
Soil Organic Matter (C)



HISTORICAL
MANAGEMENT
Conventional Tillage
Advent of
Reduced Tillage
Conversion to Agriculture
From Native Vegetation, 1907
61% of 1907 SOC
53% of 1907 SOC
Total SOC (g/m2), 20cm Soil Depth
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
1900
1910
1920
1930
1940
1950
1960
1970
1980
YEAR

Conservation of Soil Carbon



Konza Ecosystems Experiment

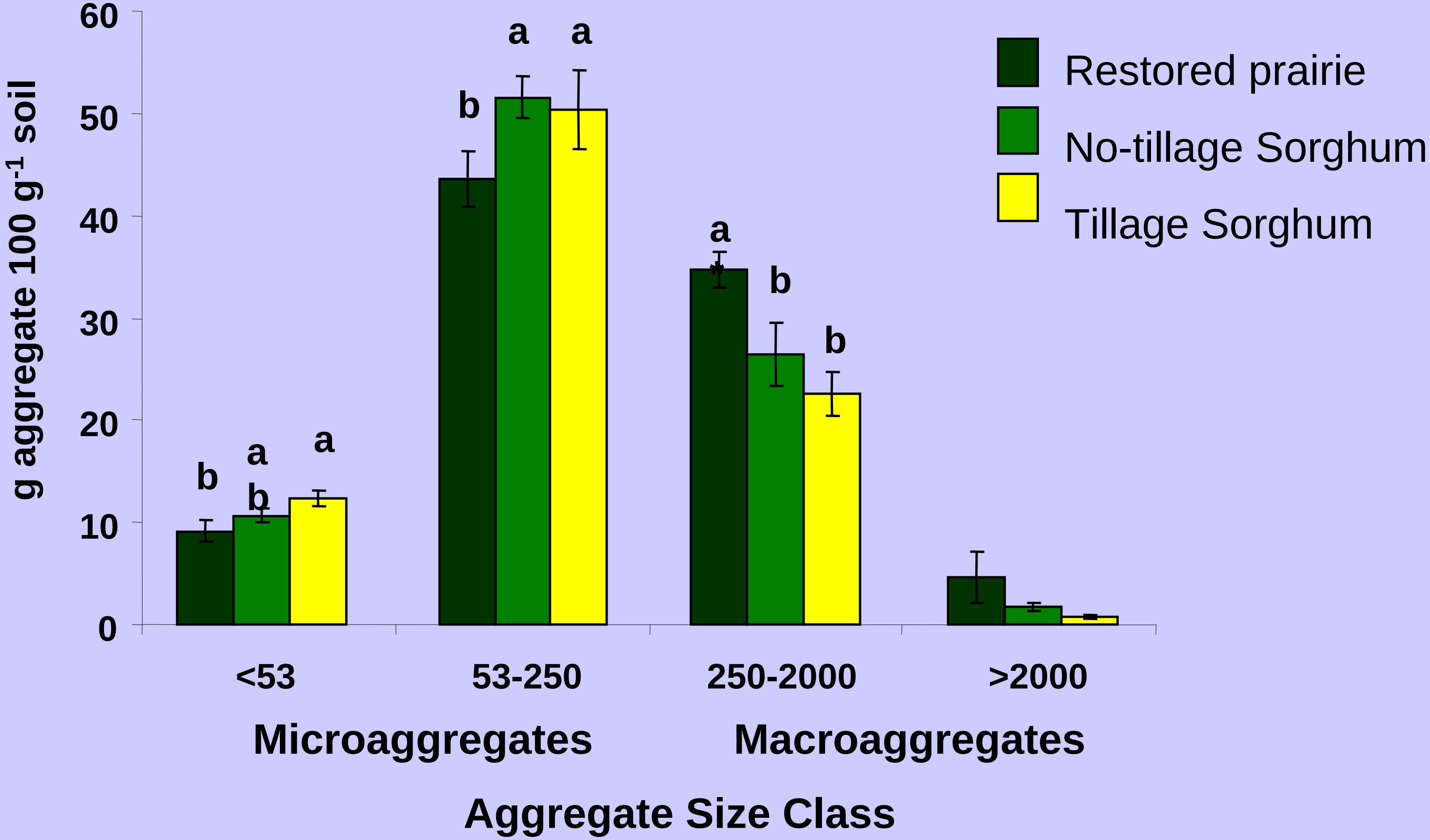
1. Tilled Grain Sorghum
2. No-Till Grain Sorghum
3. Native Warm Season Tallgrass Prairie

C_3 Soil δ ^{13}C = -19.0 ‰ and C_4 plant δ ^{13}C ~ -12 to -14‰

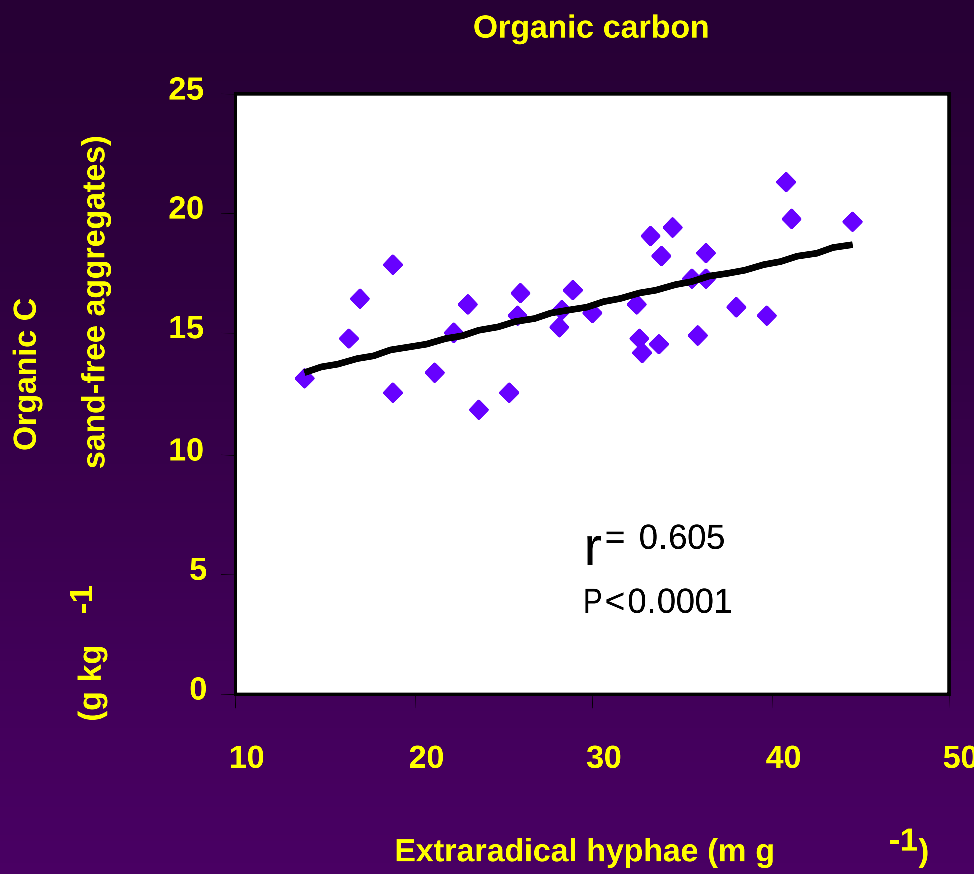
Monitor soil C turnover over time (Gregorich et al., 2005).

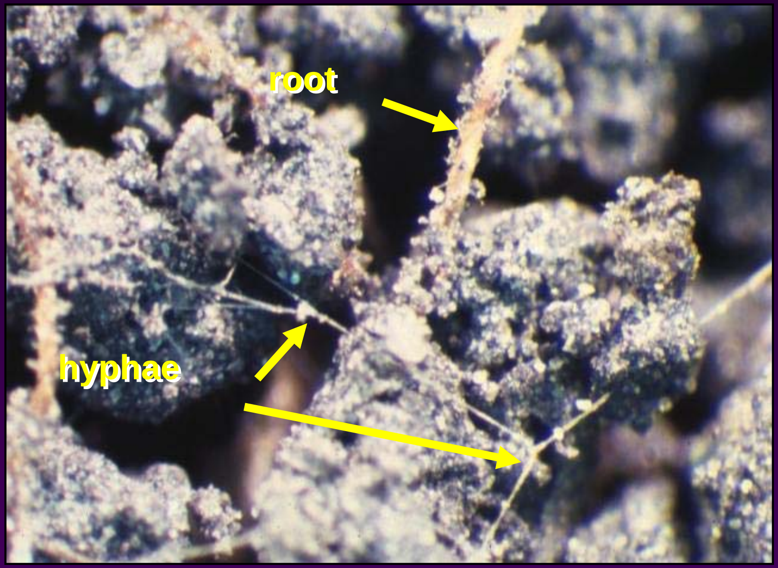
White and Rice, 2007

Soil Aggregation



White and Rice, 2007





Increases in fungal hyphae increases the amount of carbon sequestered in the soil. Formation of soil aggregates physically protects soil carbon from decomposition.

Data from Wilson and Rice; Photo from Mike Miller and Julie Jastrow


5 cm
From: Juca Sá

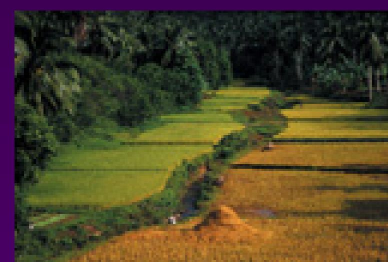
Agricultural management plays a major role in greenhouse gas emissions and offers many opportunities for mitigation

- **Cropland**
  - Reduced tillage
  - Rotations
  - Cover crops
  - Fertility management
  - Erosion control

ment

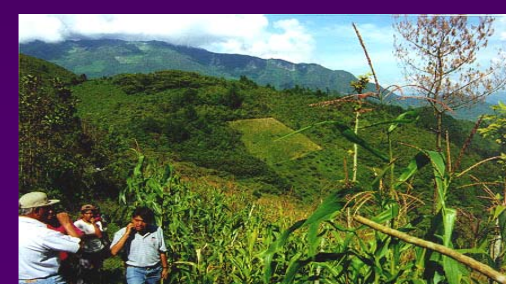
No-till seeding in USA

- **Rice paddies**
  - Irrigation
  - Chemical and organic fertilizer
  - Plant residue management



Rice fields in The Philippines

- **Agroforestry**
  - Improved management of trees and cropland

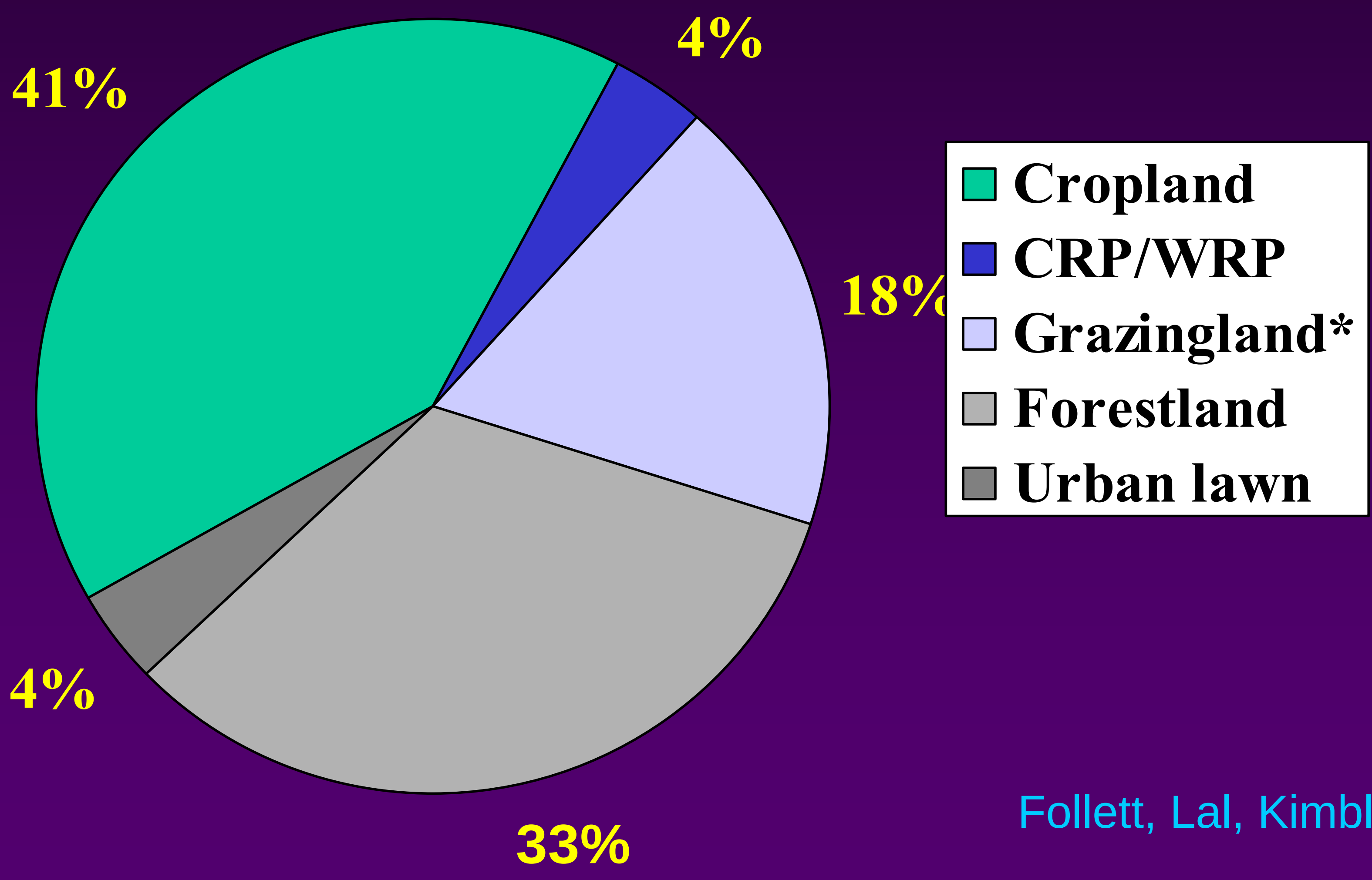


Maize / coffee fields in Mexico

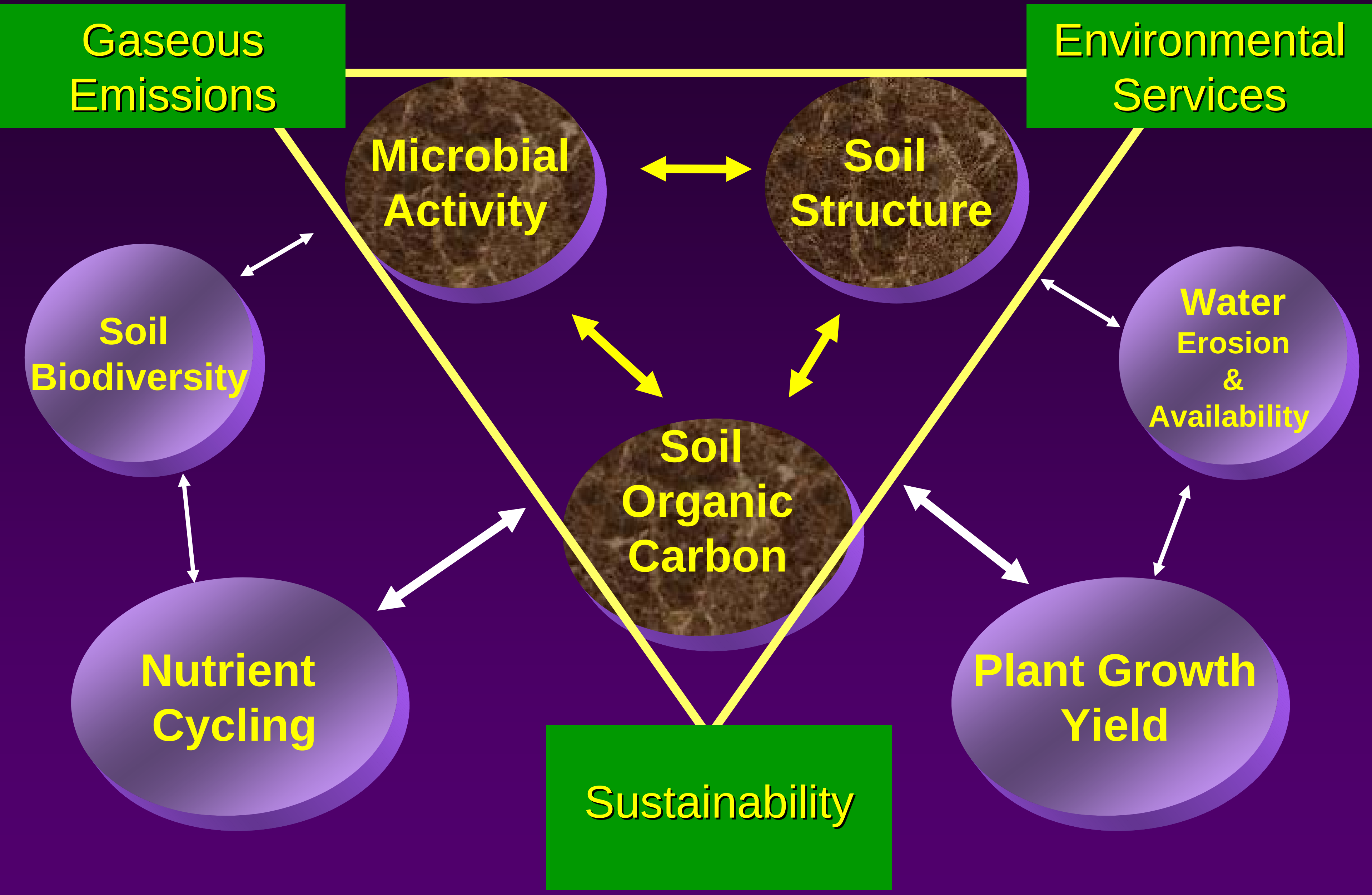
No-Tillage Cropping Systems
Conservation Agriculture

- Restores soil carbon
- Conserves moisture
- Saves fuel
- Saves labor
- Lowers machinery costs
- Reduces erosion
- Improved soil fertility
- Controls weed
- Planting on the best date
- Improves wildlife habitat

Soil C sequestration potential of different US land Categories (% of 322 MMT C/yr) **



Follett, Lal, Kimble


Gaseous Emissions
Environmental Services
Microbial Activity
Soil Structure
Soil Biodiversity
Water Erosion & Availability
Soil Organic Carbon
Nutrient Cycling
Plant Growth Yield
Sustainability

Mitigation Opportunities for Agriculture

- Offsets
  - **Soil Carbon**
    - **Cropping systems: No-tillage, rotations**
    - **Grasslands**
    - **Rangelands**
  - **Methane reduction**
    - **livestock facilities**
    - **landfills**
  - Nitrous oxide reductions from fertilizers
  - Fuel reductions (no-till)
- Biofuel offsets
  - Production
  - Consumption
- Wind energy
- Energy efficiency

BIODIVERSITY CREDITS

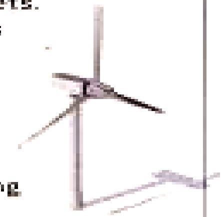
Conservation organizations are leasing development rights from the owners of undisturbed forests and other habitats that host threatened endemic species and fast-vanishing ecosystems.

CO_2 OFFSET CREDITS

When landowners plant new forests and promise never to cut or burn the trees, they can receive carbon dioxide offset credits that industries will buy to help them comply with restrictions on greenhouse gas emissions.

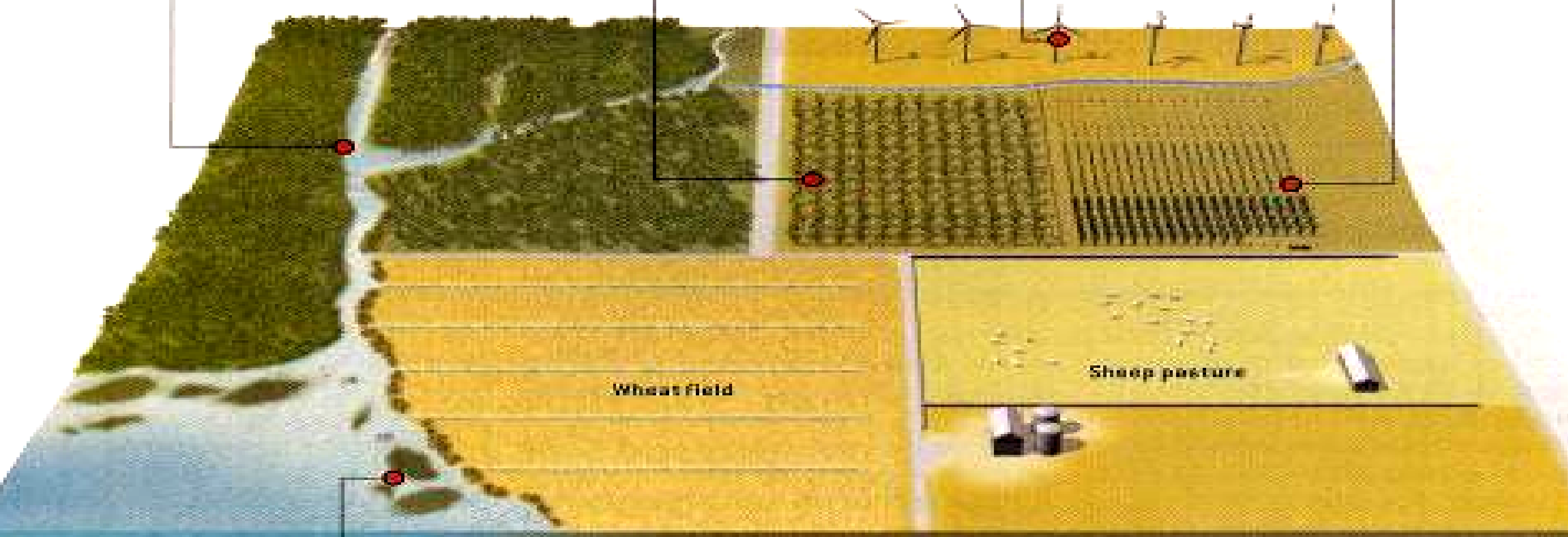
RENEWABLE ELECTRICITY

Wind farms generate nonpolluting electricity that commands premium prices in deregulated power markets. The turbines can also garner tax credits that subsidize their capital and operating costs.



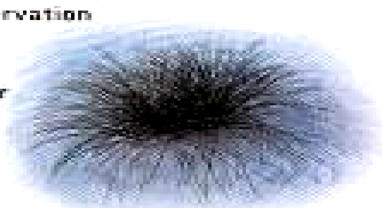
CERTIFIED SUSTAINABLE TIMBER

Sustainably harvested timber is now one of numerous "eco-labeled" products that are certified as ecologically sound and sold at a premium in specialty markets.



WATER CREDITS

Careful management of water and wetlands is economically valuable for many reasons. Urban water authorities purchase water filtration credits to protect the quality of their watersheds; wetland owners can also receive compensation from government agencies for flood-control services, from conservation organizations for the preservation of migratory waterfowl breeding areas, and from agricultural cooperatives for the prevention of soil salinity increases caused by overdrawn groundwater aquifers.



COMMODITY	PERCENT OF FARM'S INCOME	CUSTOMER
Biodiversity credits	5	Conservation trust
CO_2 offset credits	10	Steelmaker
Renewable electricity	15	Power market
Certified sustainable timber	20	Specialty market
Water credits	20	Urban water market
Wheat	15	World market
Wool	15	World market

Scientific American's Vision of the Future Farm
Scientific American, 2005

Conclusions
Adaptation

- Competition for water resources
- Stress on human, animal and plant systems from infectious diseases
- Stress on natural resources
  - Soil
  - Water
  - Natural ecosystems
- Agriculture may adapt but at some costs

Conclusions: Mitigation

- Agriculture has a significant role to play in climate mitigation
- Agriculture is cost competitive with mitigation options in other sectors
- Bio-energy crops and improved energy efficiency in agriculture can contribute to further climate mitigation
- Agricultural mitigation should be part of a portfolio of mitigation measures to reduce emissions / increase sinks whilst new, low carbon energy technologies are developed.

Summary

- Agricultural soil C sequestration
  - Keeps land in production
  - Improves soil quality
  - In many cases increases profitability for the farmer
  - Provides other environmental benefits to society
    - Water quality (less runoff, less erosion)
    - Flood control
    - Wildlife habitat
  - May help adapt to climate change as well as mitigate

Chuck Rice
Phone: 785-532-7217
Cell: 785-587-7215
cwrice@ksu.edu

- Websites

  www.oznet.ksu.edu/kccm

  www.soilcarboncenter.k-state.edu/

  www.oznet.ksu.edu/ctec

  www.casmgs.colostate.edu/

K-State Research and

Potential CO_2 Stabilization Options

	Rapidly Deployable	Not Rapidly Deployable
Minor Contributors <0.2 PgC/y	• **Biomass co-fire electric generation** • Cogeneration (small scale) • Hydropower • Natural Gas Combined cycle • Niche options (geothermal, solar)	• Integrated photovoltaics • **Forest management (fire suppression)** • Ocean fertilization
Major Contributors >0.2 PgC/y	• **C sequestration in ag. soils** • Improved appliance efficiency • Improved buildings • Improved vehicle efficiency • Non-CO_2 gas abatement from industry • **Non-CO_2 gas abatement from agriculture** • **Reforestation** • Stratospheric sulfates	• **Biomass to hydrogen** • **Biomass to fuel** • **Cessation of deforestation** • Energy-efficient urban and transportation systems • Fossil-fuel C separation with geologic or ocean storage • High efficiency coal technology • Large-scale solar • Next generation nuclear fission • Wind with H_2 storage • Speculative technologies

Caldeira et al. 2004. A portfolio of carbon management options, p. 103-130,
In C. B. Field and M. R. Raupach, eds. The Global Carbon Cycle. Island Press, Washington, DC.