Mitigating greenhouse gases – Agriculture’s role

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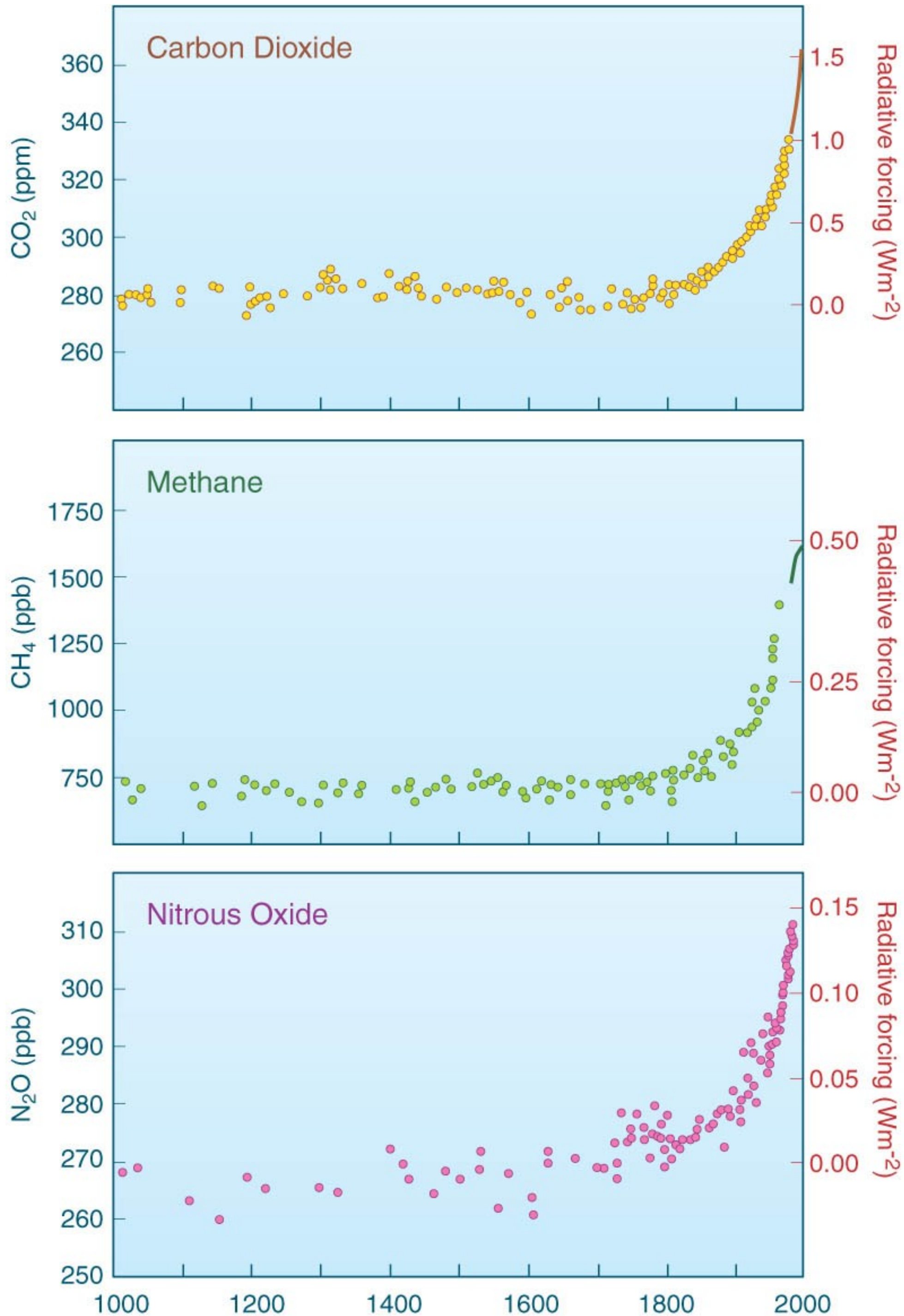
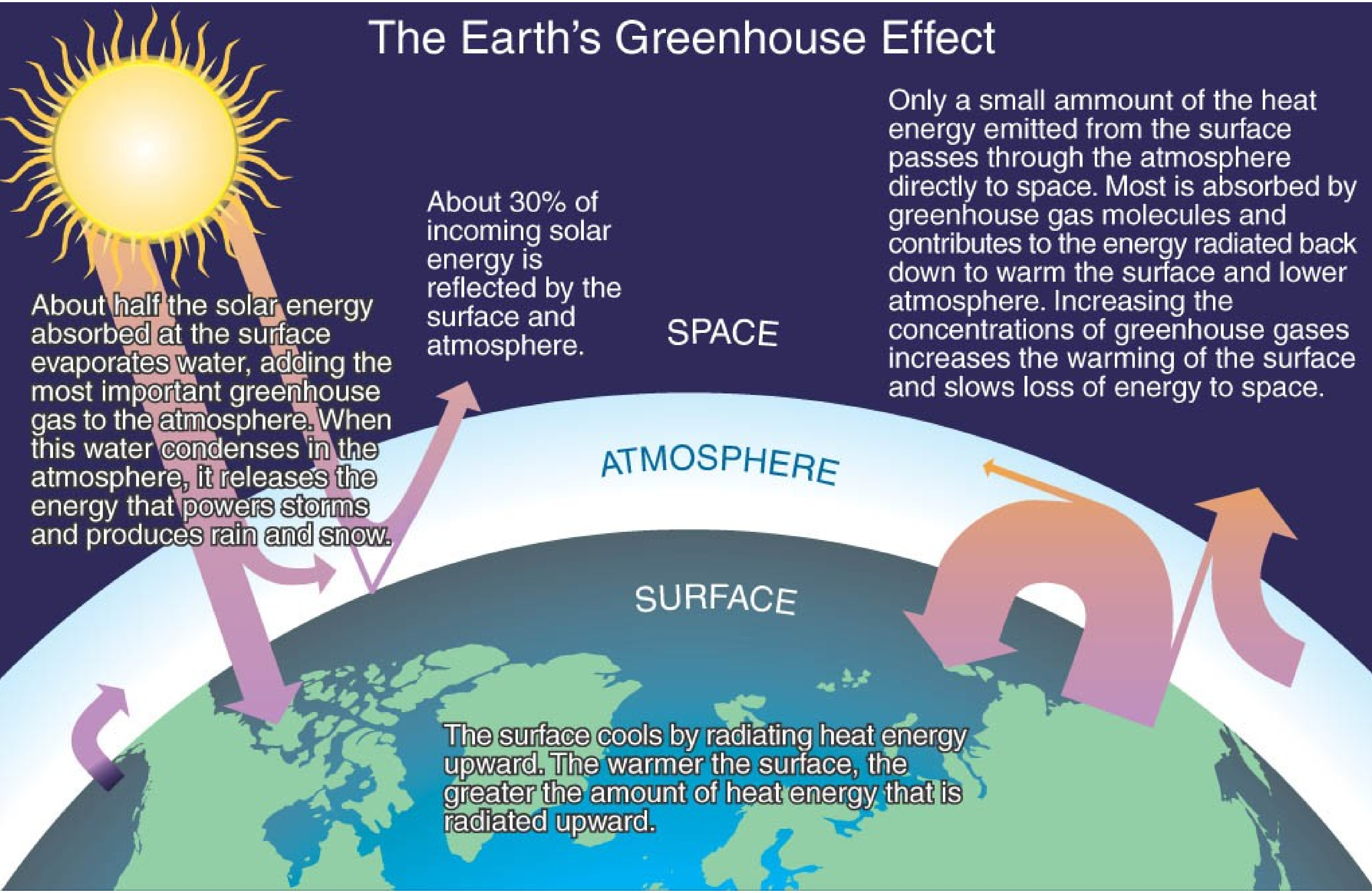
Plant Sciences

UCDavis


Carbon Dioxide
CO2 (ppm)
260
280
300
320
340
360
Radiative forcing (Wm-2)
0.0
0.5
1.0
1.5
Methane
CH4 (ppb)
750
1000
1250
1500
1750
Radiative forcing (Wm-2)
0.00
0.25
0.50
Nitrous Oxide
N2O (ppb)
250
260
270
280
290
300
310
Radiative forcing (Wm-2)
0.00
0.05
0.10
0.15
1000
1200
1400
1600
1800
2000

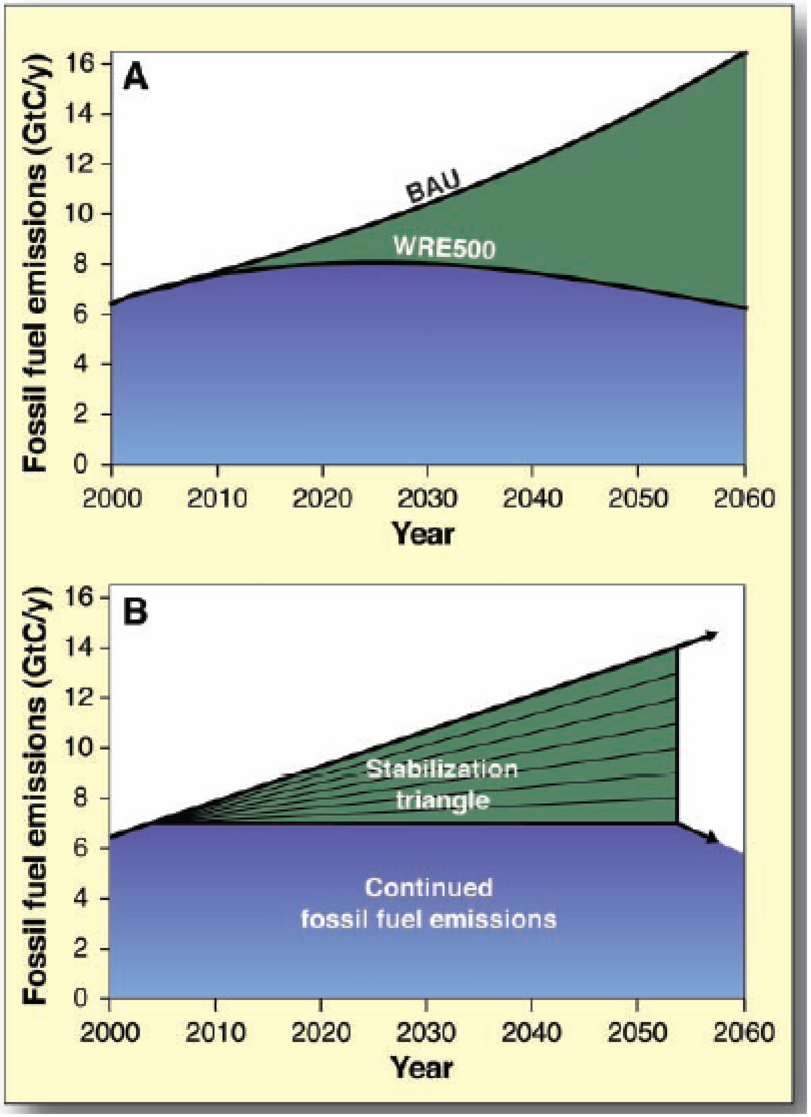

The Earth's Greenhouse Effect
Only a small ammount of the heat energy emitted from the surface passes through the atmosphere directly to space. Most is absorbed by greenhouse gas molecules and contributes to the energy radiated back down to warm the surface and lower atmosphere. Increasing the concentrations of greenhouse gases increases the warming of the surface and slows loss of energy to space.
About 30% of incoming solar energy is reflected by the surface and atmosphere.
About half the solar energy absorbed at the surface evaporates water, adding the most important greenhouse gas to the atmosphere. When this water condenses in the atmosphere, it releases the energy that powers storms and produces rain and snow.
SPACE
ATMOSPHERE
SURFACE
The surface cools by radiating heat energy upward. The warmer the surface, the greater the amount of heat energy that is radiated upward.

Projected Climate Change

- Global average temperatures predicted to increase by approx 2-5 ^{o}C by 2050
- Regional and local changes variable and difficult to predict
- California
  - 2-4^{o}C increase in temperatures (greatest in winter)
  - Regional precipitation changes vary (+ vs -) between models, difficult to predict.
  - Snowpack decreased
  - Increased variability in weather (most likely)

Likely consequences

- Effects on crop productivity
  - Maybe positive or negative in US depending on location/crop type
  - Likely increase in pest (weed, insect) pressure
  - ‘Migration’ of cropping systems necessary as an adaptive strategy (incurring relocation costs)
  - Greater problems for resource-poor farmers in tropics
- Potential for greater weather extreme
  - Drought, hurricanes, blizzards, floods



Pacala and Socolow 2004

Table 1. Potential wedges: Strategies available to reduce the carbon emission rate in 2054 by 1 GtC/year or to reduce carbon emissions from 2004 to 2054 by 25 GtC.

Option	Effort by 2054 for one wedge, relative to 14 GtC/year BAU	Comments, issues
	Energy efficiency and conservation	
Economy-wide carbon-intensity reduction (emissions/$GDP)	Increase reduction by additional 0.15% per year (e.g., increase U.S. goal of 1.96% reduction per year to 2.11% per year)	Can be tuned by carbon policy
1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg	Car size, power
2. Reduced use of vehicles	Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5000 miles per year	Urban design, mass transit, telecommuting
3. Efficient buildings	Cut carbon emissions by one-fourth in buildings and appliances projected for 2054	Weak incentives
4. Efficient baseload coal plants	Produce twice today's coal power output at 60% instead of 40% efficiency (compared with 32% today)	Advanced high-temperature materials
	Fuel shift	
5. Gas baseload power for coal baseload power	Replace 1400 GW 50%-efficient coal plants with gas plants (four times the current production of gas-based power)	Competing demands for natural gas
	CO_2 Capture and Storage (CCS)	
6. Capture CO_2 at baseload power plant	Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)	Technology already in use for H_2 production
7. Capture CO_2 at H_2 plant	Introduce CCS at plants producing 250 MtH_2/year from coal or 500 MtH_2/year from natural gas (compared with 40 MtH_2/year today from all sources)	H_2 safety, infrastructure
8. Capture CO_2 at coal-to-synfuels plant	Introduce CCS at synfuels plants producing 30 million barrels a day from coal (200 times Sasol), if half of feedstock carbon is available for capture	Increased CO_2 emissions, if synfuels are produced without CCS
Geological storage	Create 3500 Sleipners	Durable storage, successful permitting
	Nuclear fission	
9. Nuclear power for coal power	Add 700 GW (twice the current capacity)	Nuclear proliferation, terrorism, waste
	Renewable electricity and fuels	
10. Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times the current capacity) "occupying" 30×10^6 ha, on land or offshore	Multiple uses of land because windmills are widely spaced
11. PV power for coal power	Add 2000 GW-peak PV (700 times the current capacity) on 2×10^6 ha	PV production cost
12. Wind H_2 in fuel-cell car for gasoline in hybrid car	Add 4 million 1-MW-peak windmills (100 times the current capacity)	H_2 safety, infrastructure
13. Biomass fuel for fossil fuel	Add 100 times the current Brazil or U.S. ethanol production, with the use of 250×10^6 ha (one-sixth of world cropland)	Biodiversity, competing land use
	Forests and agricultural soils	
14. Reduced deforestation, plus reforestation, afforestation, and new plantations.	Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)	Land demands of agriculture, benefits to biodiversity from reduced deforestation
15. Conservation tillage	Apply to all cropland (10 times the current usage)	Reversibility, verification

Pacala and Socolow 2004

What gases are of importance to agriculture ?

CO_2

Sources: Fossil fuels, biomass burning, soil degradation

Sinks: Buildup soil organic matter and plant biomass

GWP (Global Warming Potential) = 1

N_2O

Sources: Fertilizer, crop residues, manure

Sinks: No agricultural sinks

GWP = ~300

CH_4

Sources: Livestock, manure, anaerobic soils (rice)

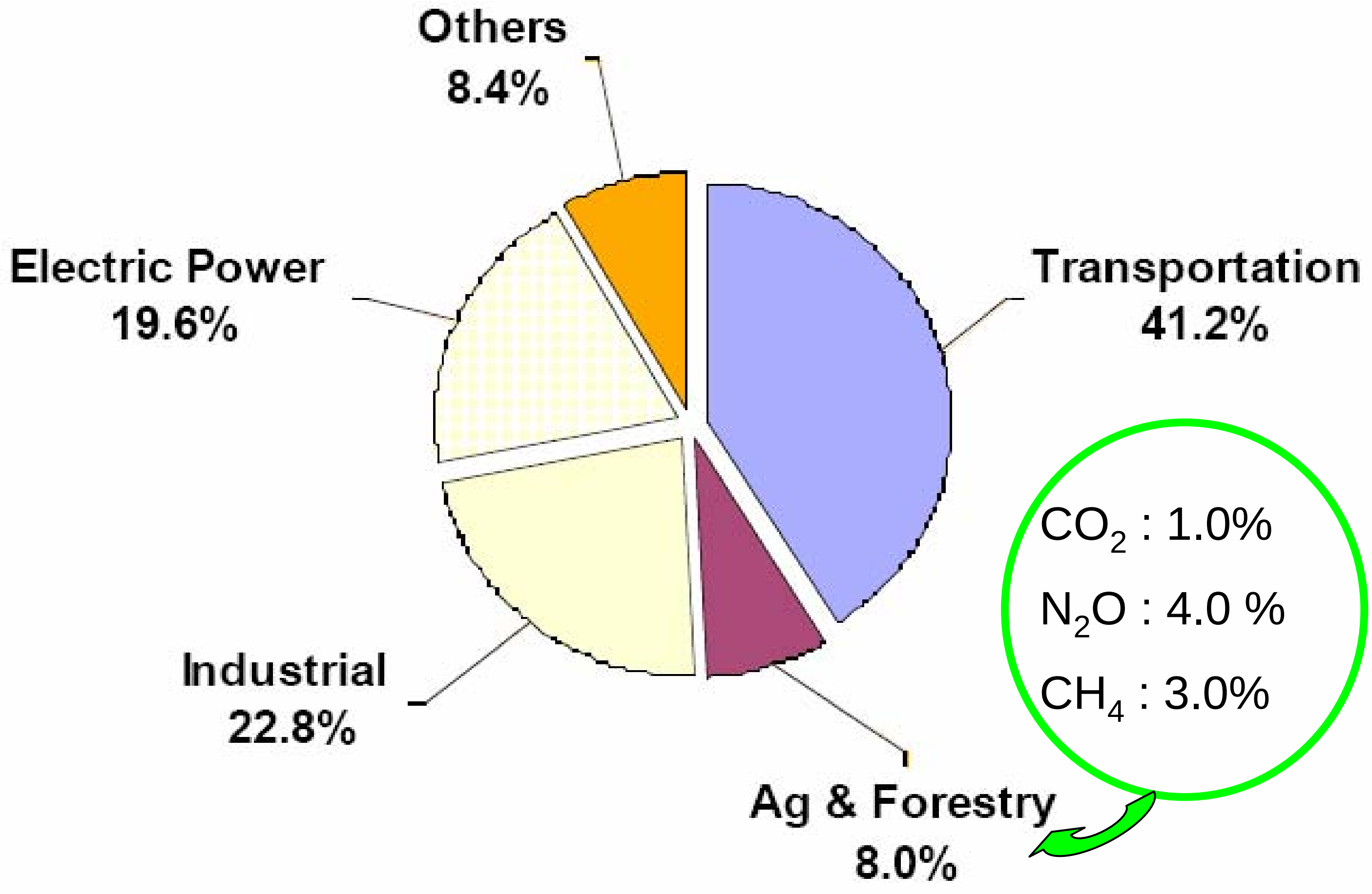
Sinks: Aerobic soils, especially forests and grasslands

GWP = ~20

Globally, agriculture (20%) and land use change (14%) contribute about **1/3** of the total GHG emissions (as ‘radiative’ forcing) from **all** anthropogenic sources.

In the US, agriculture accounts for about 8% of total GHG emissions (forestry is a substantial sink).

California



Source: California Energy Commission

Practices for C sequestration

- Reduced and zero tillage
- Set-asides/conversions to perennial grass
- Reduction in cultivated organic soils
- Reduction/elimination of summer-fallow
- Winter cover crops
- More hay in crop rotations
- Higher residue (above- & below-ground) yielding crops

Technical potential = 80-200 MMTC/yr

Practices for N_2O & CH_4 emission reduction

N_2O mitigation

- Better match of N supply to crop demand
- Better organic N (e.g. manure) recycling
- Advanced fertilizers (e.g. controlled release, nitrification inhibitor)

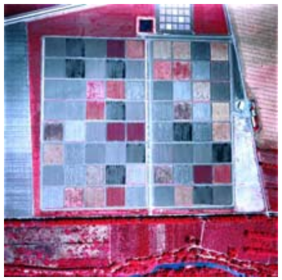
CH_4 mitigation

- Improved livestock breeding and reproduction
- Nutrition (e.g. forage quality, nutrient balance, additives)
- Methane capture from manure
- Manure composting
- Rice (water and nutrient management)

Technical potential = 40-50 MMTC Equivalent per year

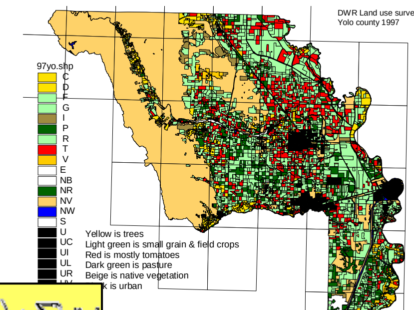
Integrated modeling approach

Field experiments

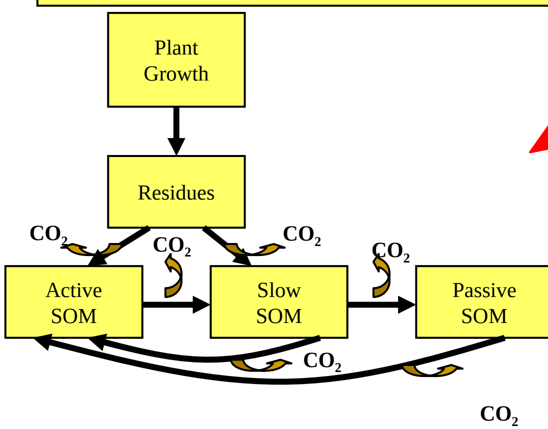


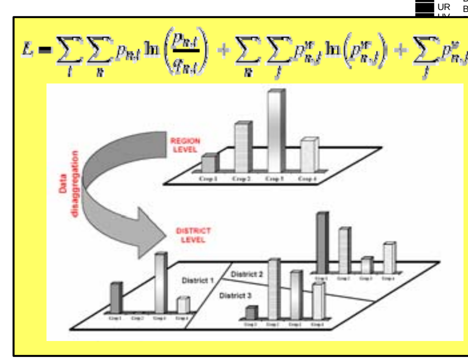
Land use and
management identification

Spatial Information



Ecosystem model





Dynamic economics

Decision support

With uncertainty
estimates

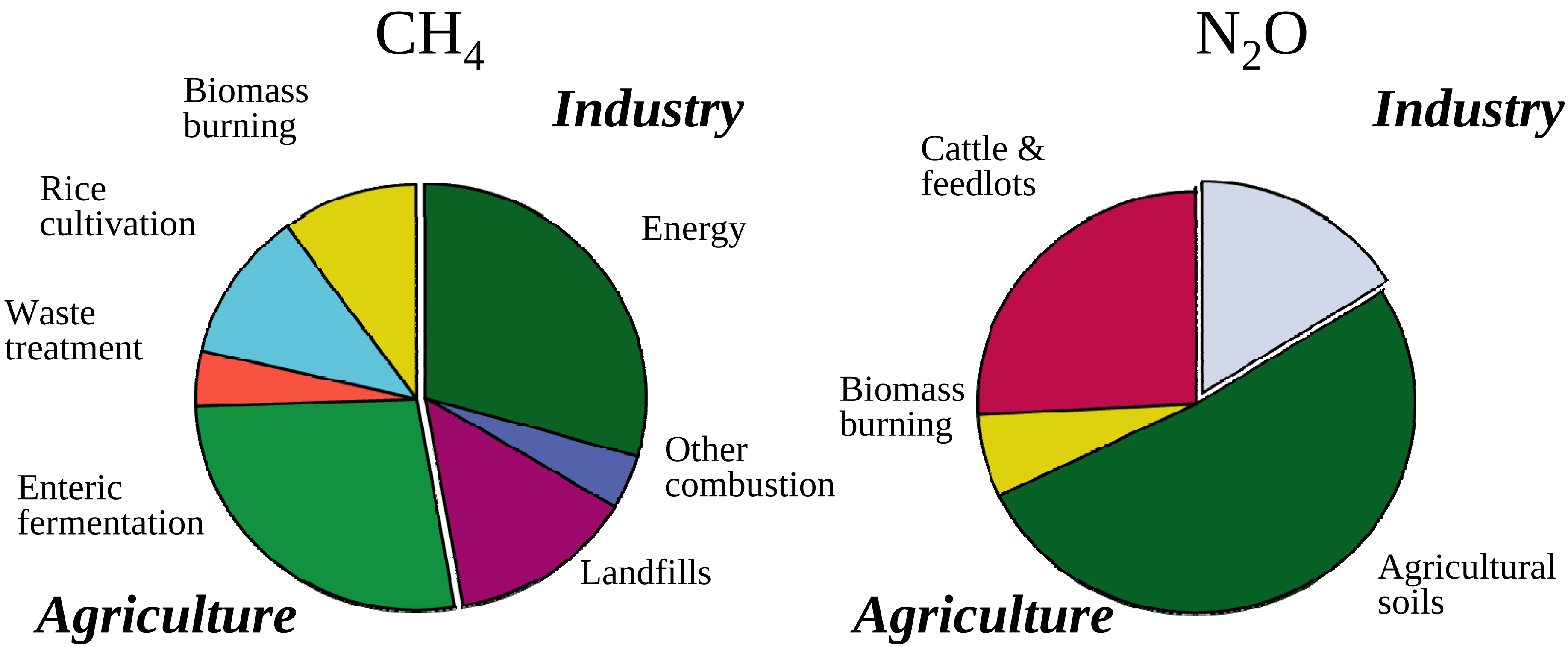
Greenhouse gas budget: Five Points

- Reduced tillage can cut fuel-CO_2 emissions by half
- Integration of reduced tillage with cover cropping!

		$tCO_2e\ ha^{-1}$			
		STNO	**STCC**	**CTNO**	**CTCC**
SOC					
	Cotton	-0.11	-2.42	-0.92	-4.20
	Tomato	-0.65	-2.53	-0.87	-3.71
N_2O	297				
	Cotton	1.62	1.04	1.33	0.80
	Tomato	1.69	1.63	1.36	1.17
CH_4	31				
	Cotton	-0.11	-0.12	-0.11	-0.11
	Tomato	-0.11	-0.11	-0.11	-0.11
Fuel-C					
	Cotton	0.51	0.57	0.25	0.27
	Tomato	0.63	0.85	0.30	0.34
SUM					
	Cotton	1.91	-0.93	0.54	-3.25
	Tomato	1.56	-0.17	0.68	-2.31
	system	**1.73**	**-0.55**	**0.61**	**-2.78**

Slide courtesy
Robertson

Anthropic Sources of Methane and Nitrous Oxide Globally



Total Impact 2.0 Pg C_{equiv} 1.2 Pg C_{equiv}

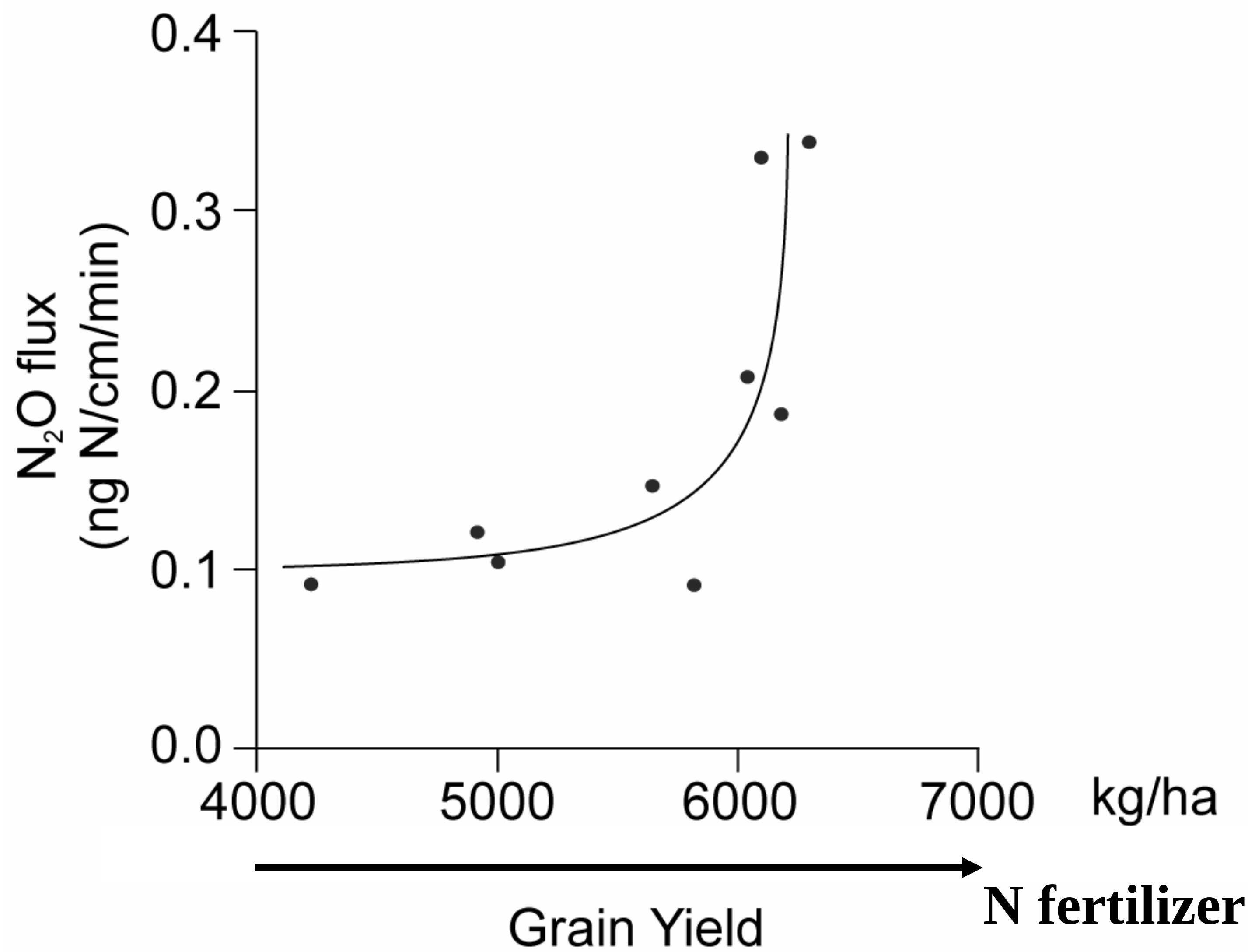
(compare to fossil fuel CO_2 loading = 3.3 Pg C per year)

(compare to soil C sequestration of 0.3-0.5 Pg C per year)

IPCC 2001; Robertson 2004

Slide courtesy Robertson

N_2O - Yield Threshold

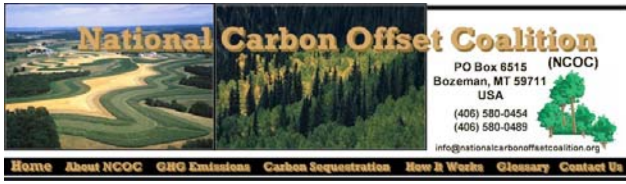


McSwiney and Robertson, submitted

Implementation

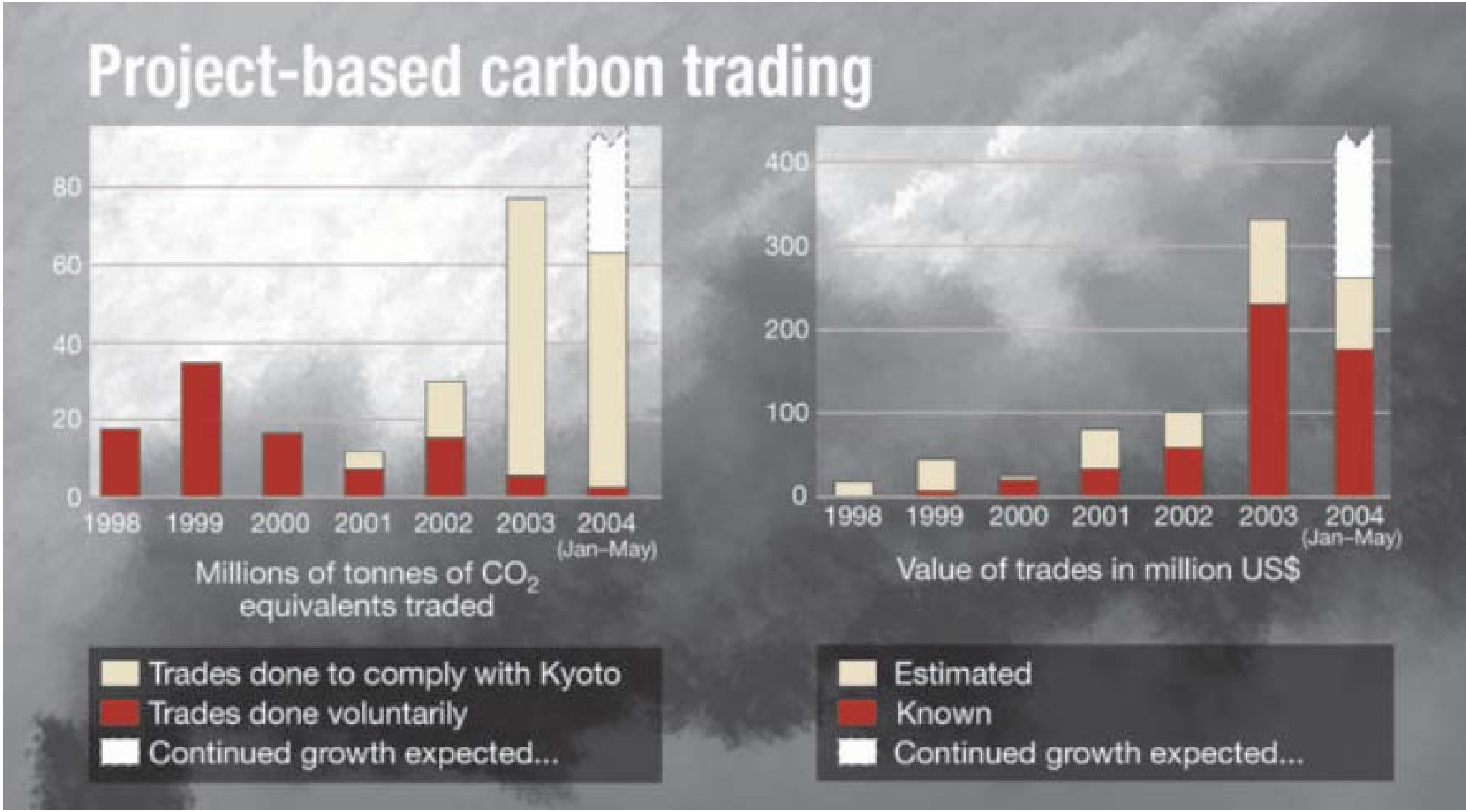
US Trading Initiatives and Activities

- Chicago Climate Exchange
- National Carbon Offset Coalition
- Commodity brokerage firms
  - Natsource
  - Cantor Fitzgerald
- Consultants
- NGOs
- State Initiatives



Economics

Slide courtesy
Paustian



Hopkins 2004

Cost to Mitigate

Five Points	STNO -> STCC	$35
	STNO -> CTNO	$0
	STNO -> CTCC	$35

European Market: $34/tCO_2e$

Issues

- Measurement and monitoring costs
  - Preliminary estimates of ‘large project’ measurement costs, suggest values < 5% of cost of C credits.
  - Transaction costs?
- ‘Temporary’ carbon storage – who assumes the liability?
  - Long-term contracts
  - Leasing
- Additionality
  - Credit for ‘early’ adopters?
  - ‘Fairness’ vs economic efficiency

N_2O -> no issue

Ancillary benefits of GHG mitigation

C sequestering practices

- Reduced erosion
- Improved soil quality and fertility
- Improved water quality
- Conservation Reserve lands - Wildlife habitat and biodiversity
- Biofuel production

N_2O emissions reductions

- Reduced leaching and ammonia volatilization
- Improved water quality (well nitrate, hypoxia, algae blooms)
- Less fertilizer waste

CH_4 emission reductions

- Improved water and air quality (manure handling, odors, runoff)

Conclusions

- Cover cropping and/or reduced tillage seem to have potential in California.

    What about manure, compost, drip irrigation and set-aside?

- Fuel C and N_2O are major player in greenhouse gas budgets; especially in California

    But measurements and modeling issues with N_2O

Conclusions

- Use of improved management practices show a significant technical potential for GHG mitigation, but agriculture is **only part** of the solution.

- Various issues need to be resolved with respect to implementation. However, no ‘show-stoppers’ so far.

- Bundling’ GHG mitigation with other environmental goals should increase benefit and cost-efficiency of agricultural GHG policies.