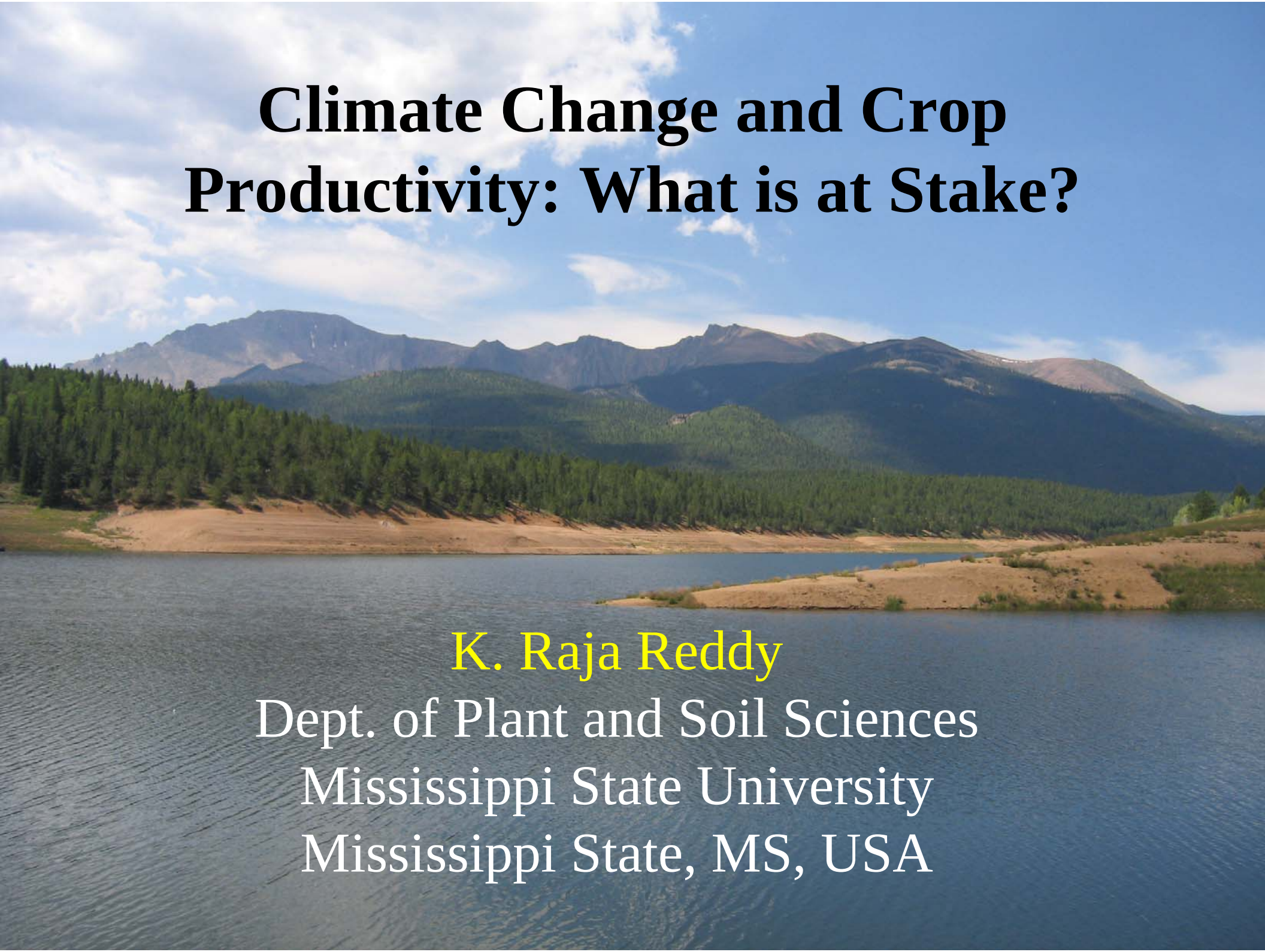


Climate Change and Crop Productivity: What is at Stake?

K. Raja Reddy
Dept. of Plant and Soil Sciences
Mississippi State University
Mississippi State, MS, USA

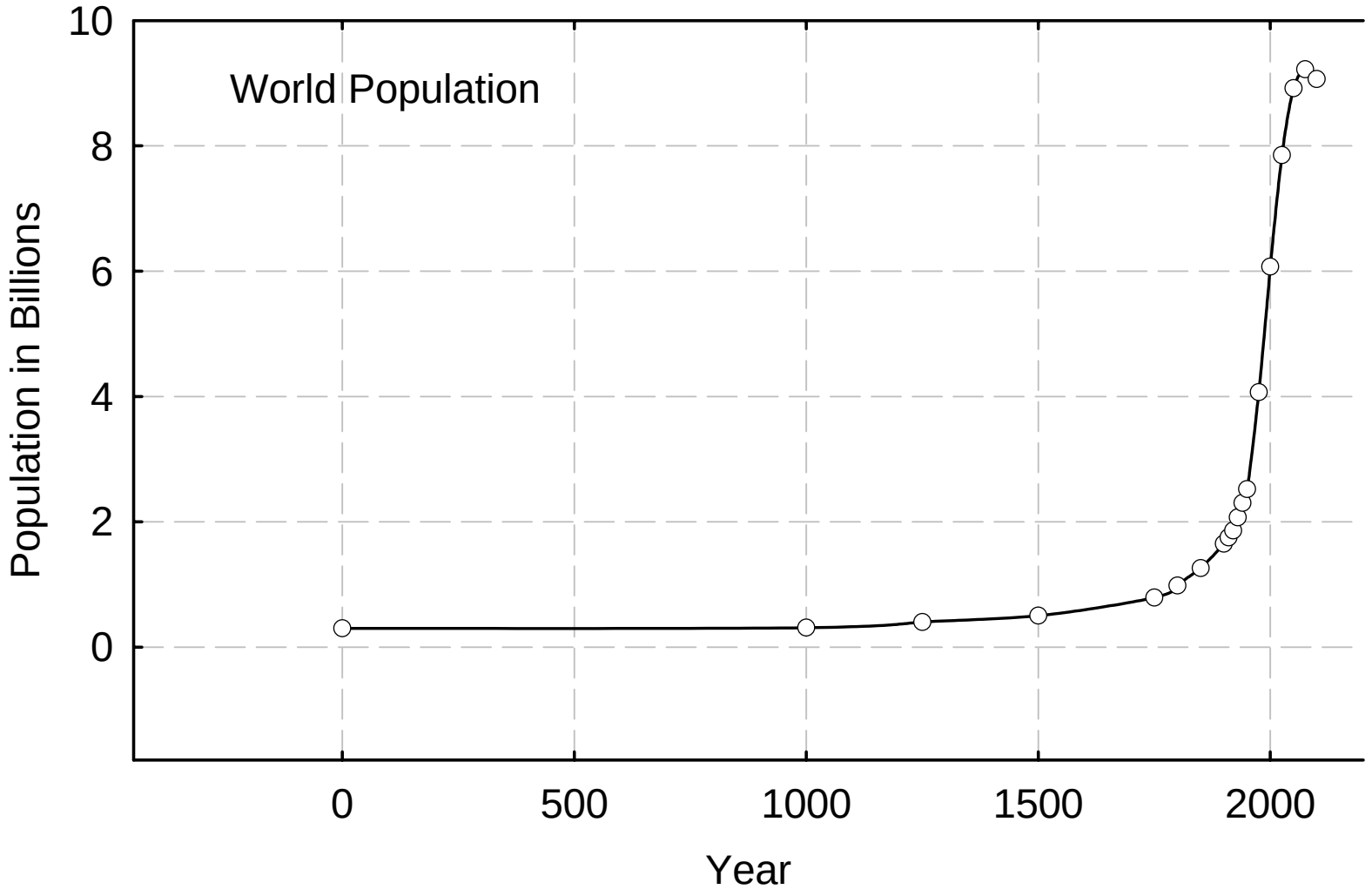
Outline

- Past and future trends in population, food production and climate change perturbations.
- Global environmental change and its impact on agriculture production systems.
- Role of crop simulation models in addressing future food security and climate change.

Trends That Shape Our Future

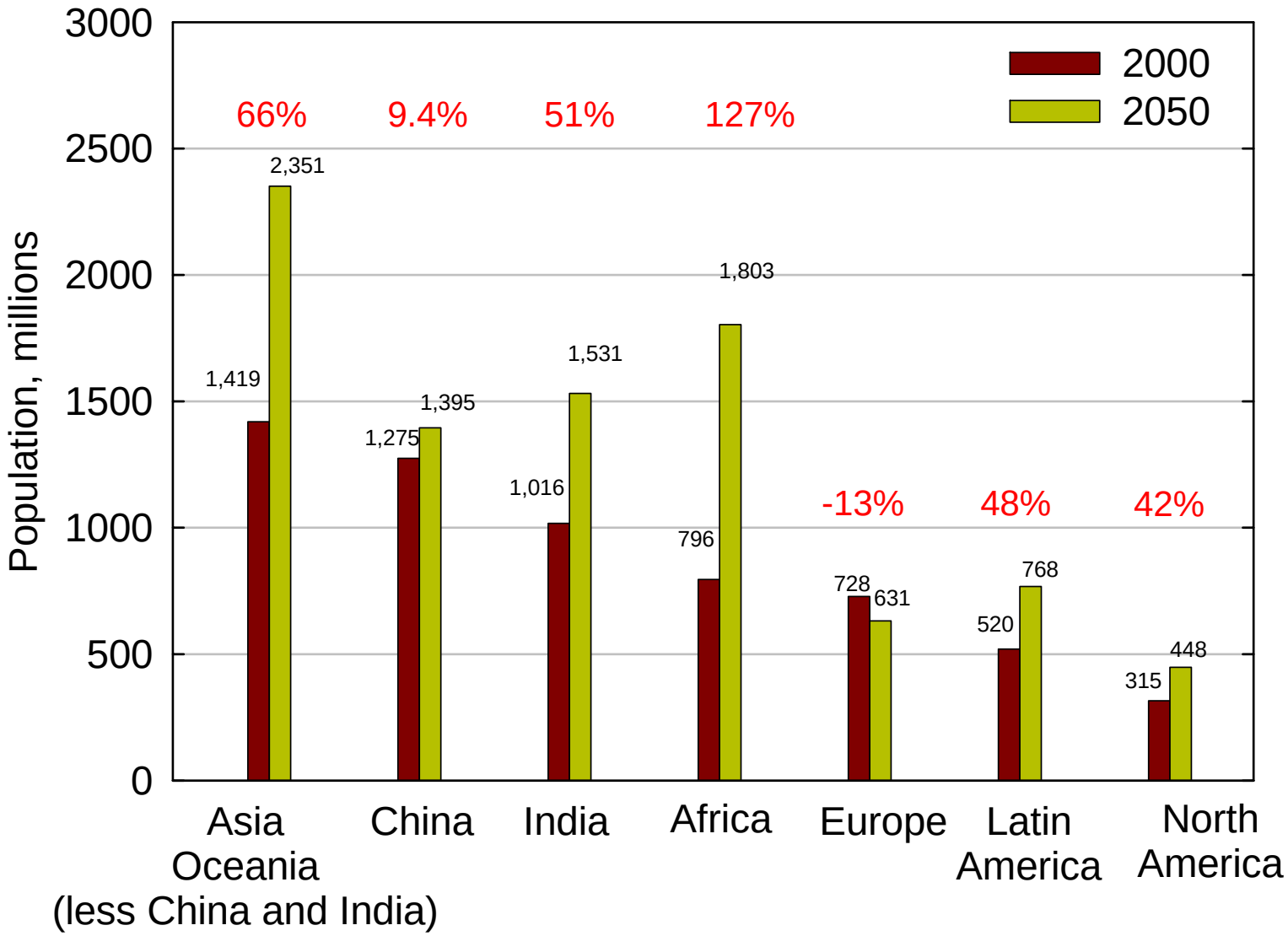
Trends, Signs and Signatures from the Earth

Past, Present and Future World Population



Trends, Signs and Signatures from the Earth

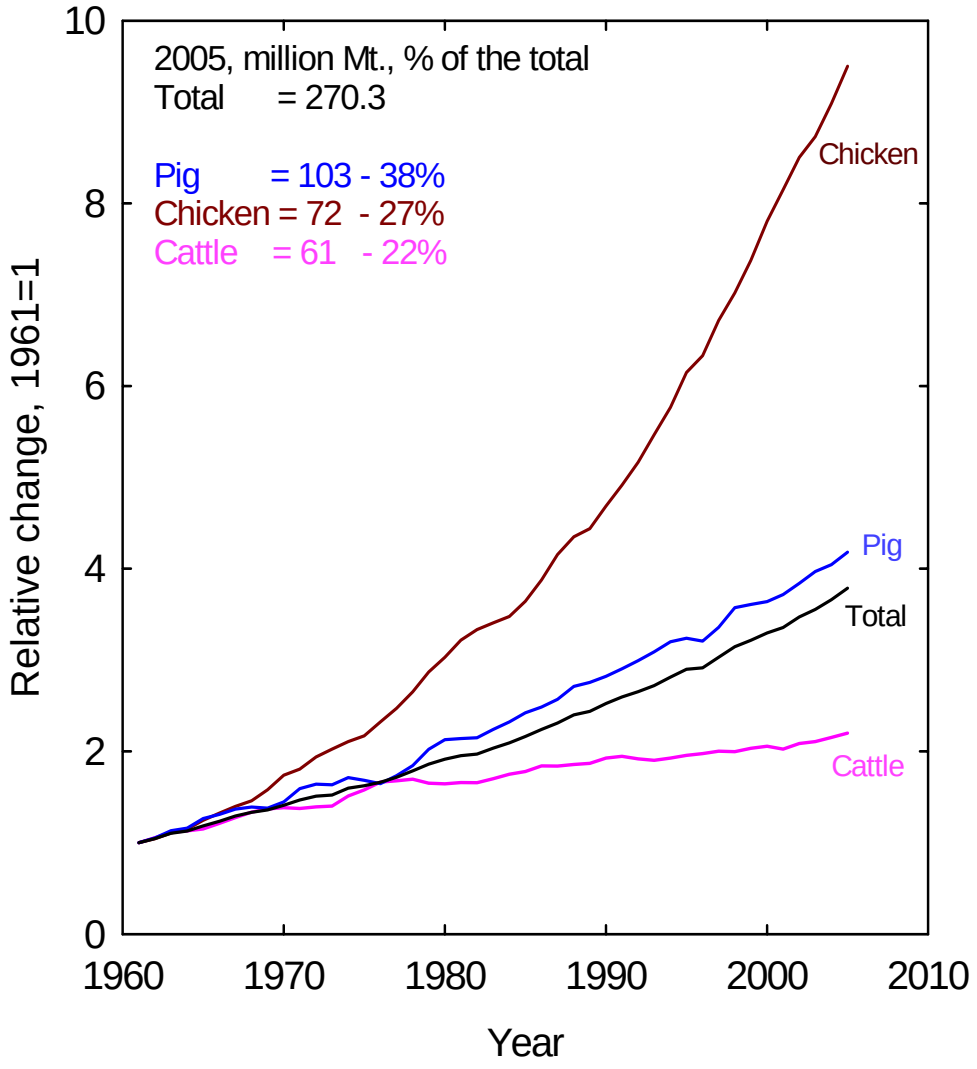
Past, Present and Future World Population Trends



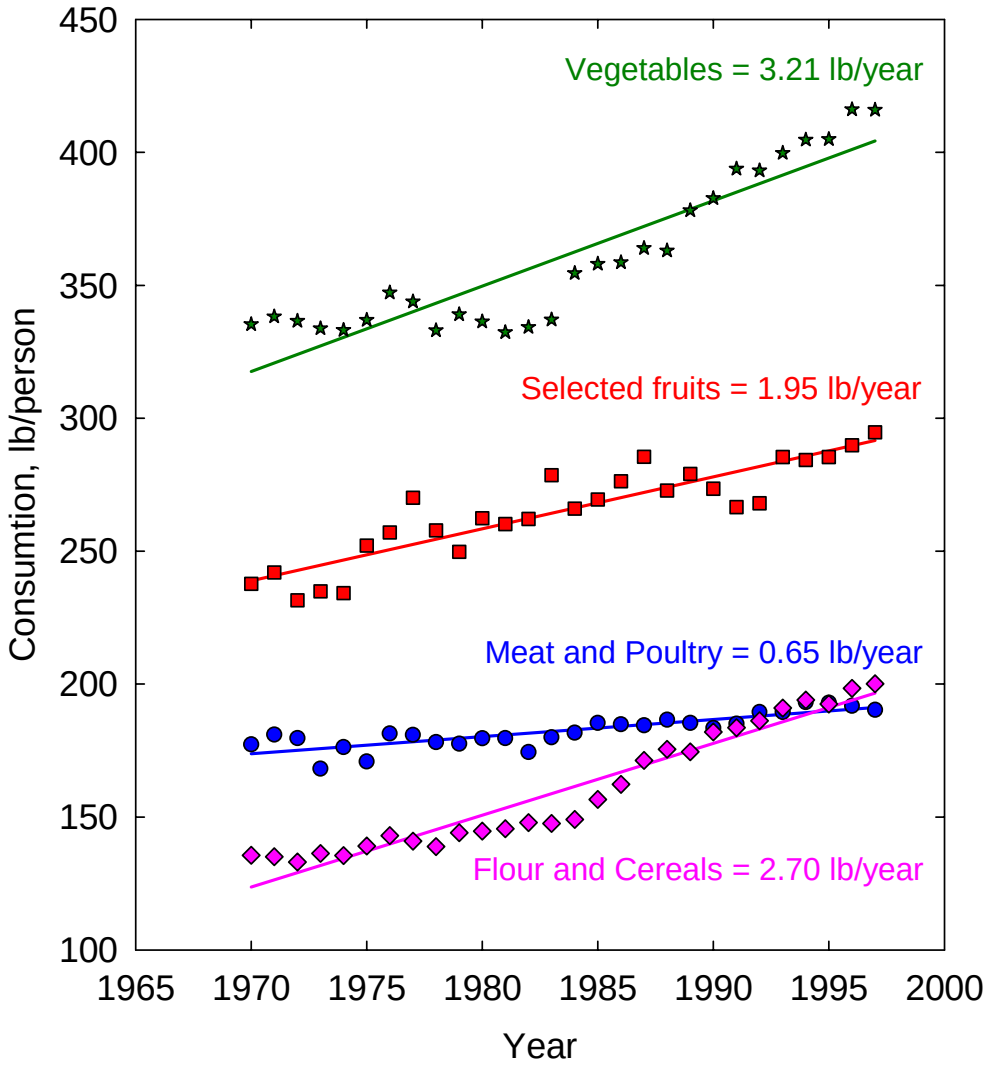
Trends, Signs and Signatures from the Earth

Global Major Foods Production and Consumption Trends

Production

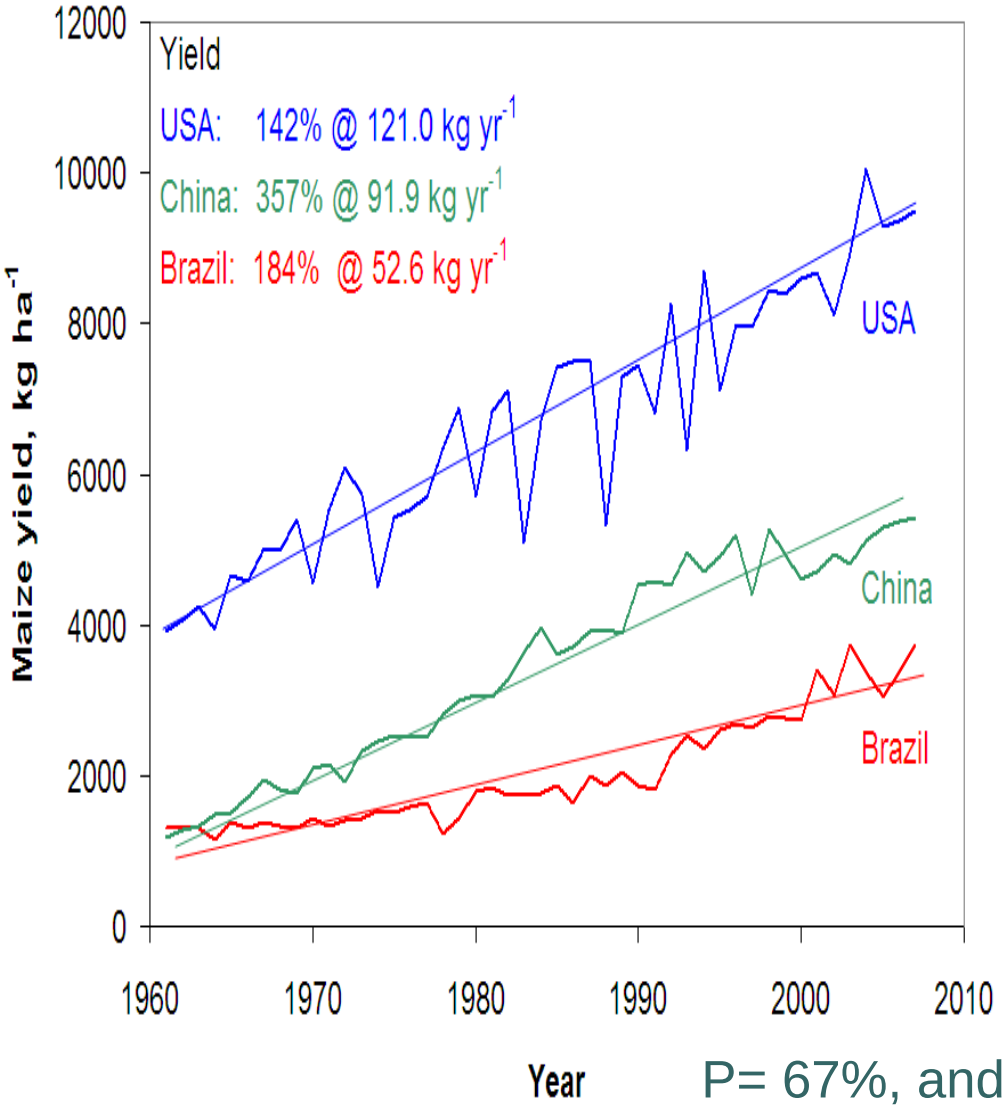


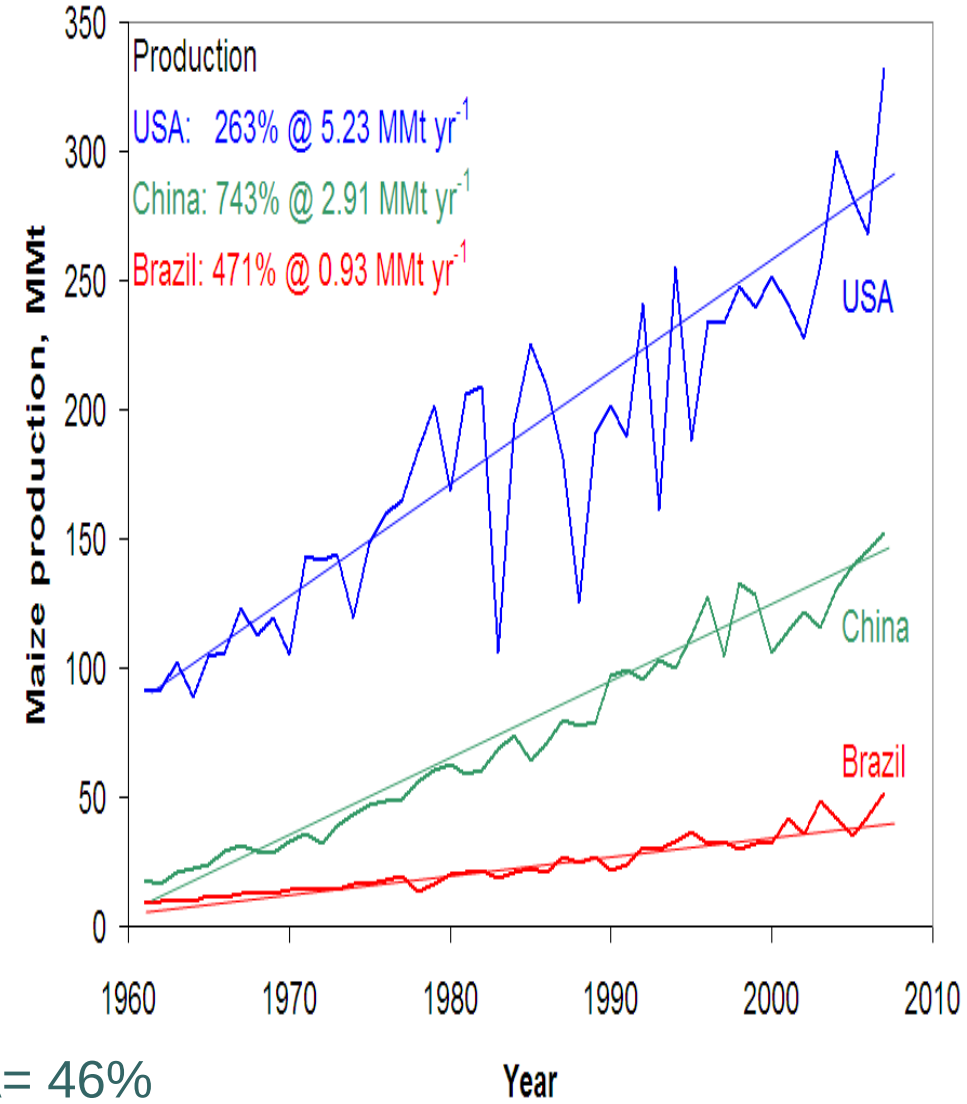
Consumption



Trends, Signs and Signatures from the Earth

Maize: Production and Yield - Selected Countries

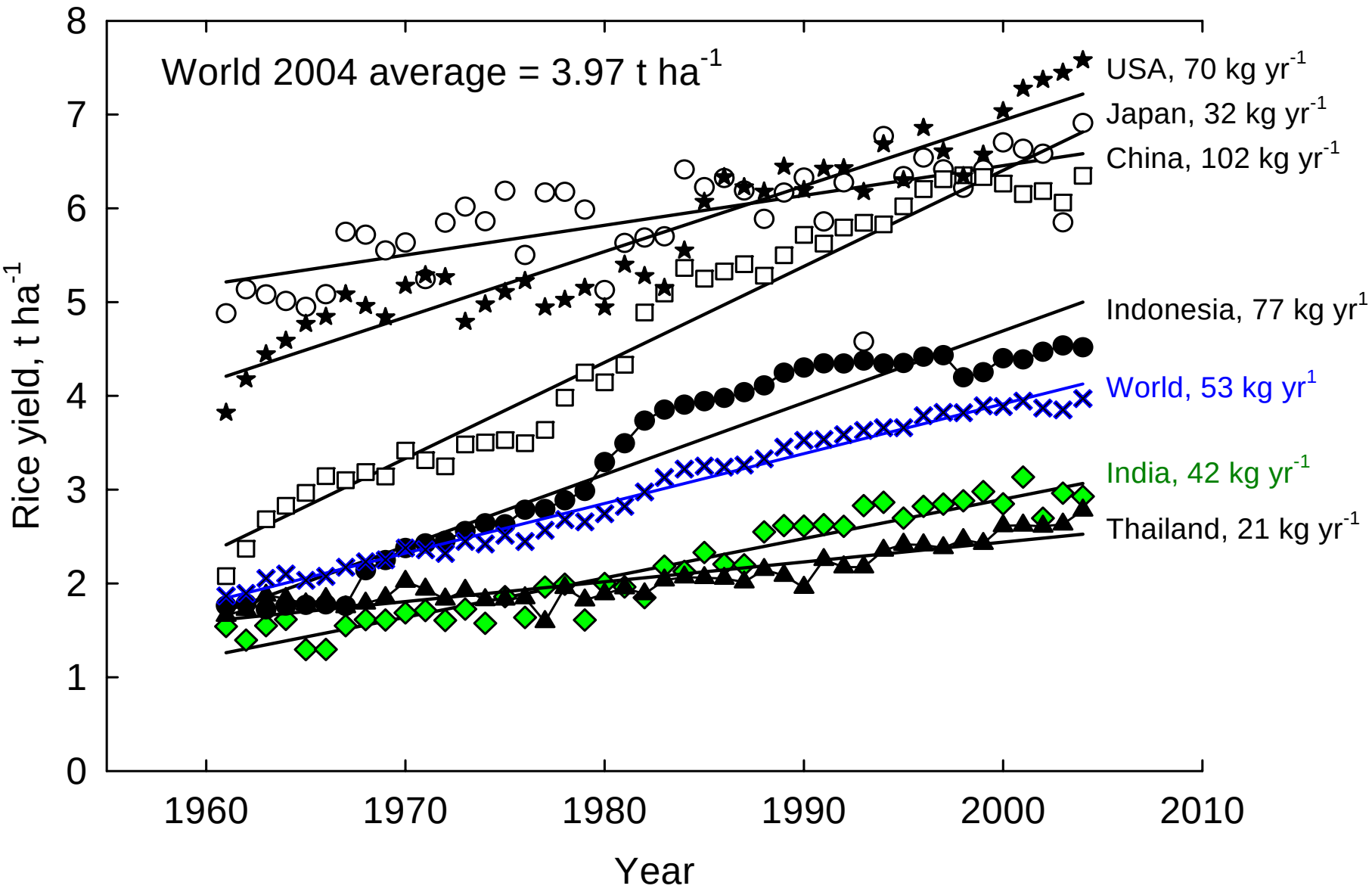




P= 67%, and A= 46%

Trends, Signs and Signatures from the Earth

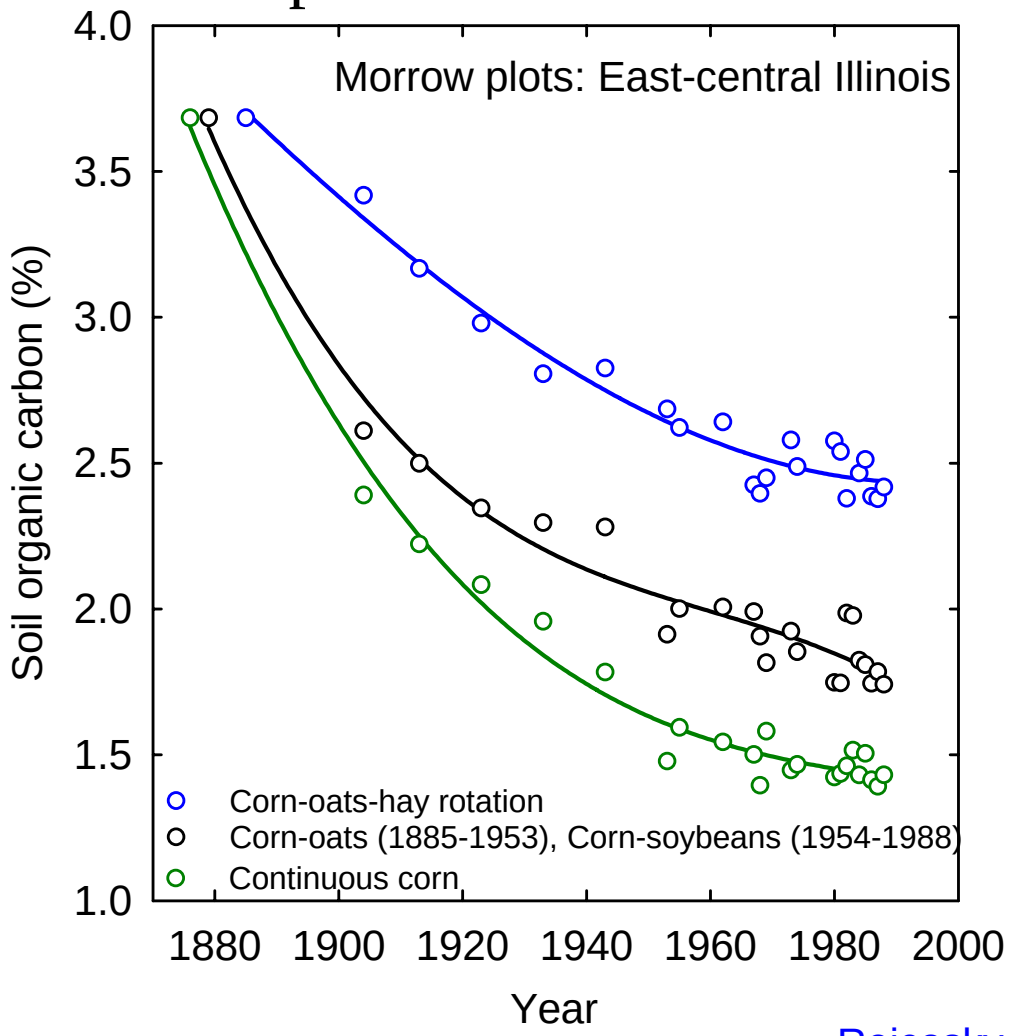
Rice: Production and Yield - Selected Countries



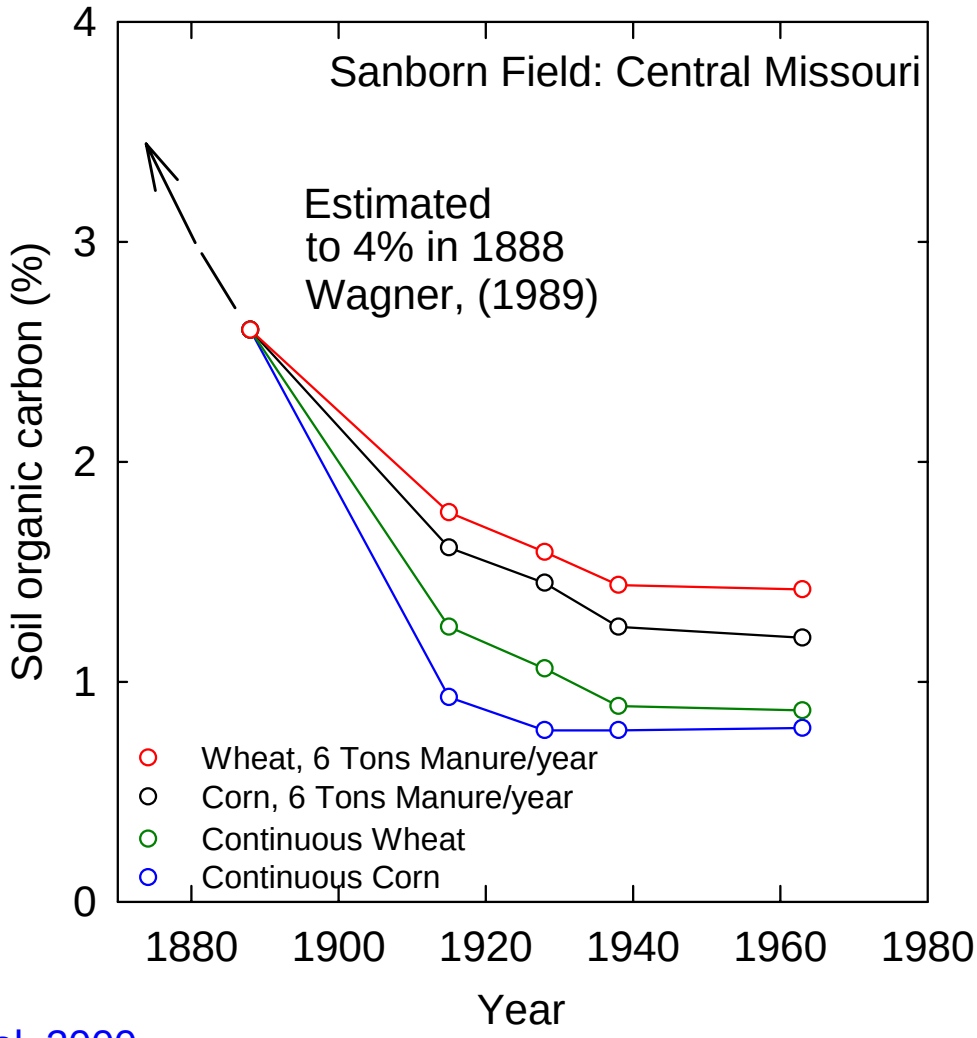
Trends, Signs and Signatures from the Earth

Management Practices on Soil Quality

Crop rotations



Fertility management



Reicosky et al. 2000

Trends, Signs and Signatures from the Earth

Cropland area, Irrigation and Salinization, and Management Practices on Soil Quality

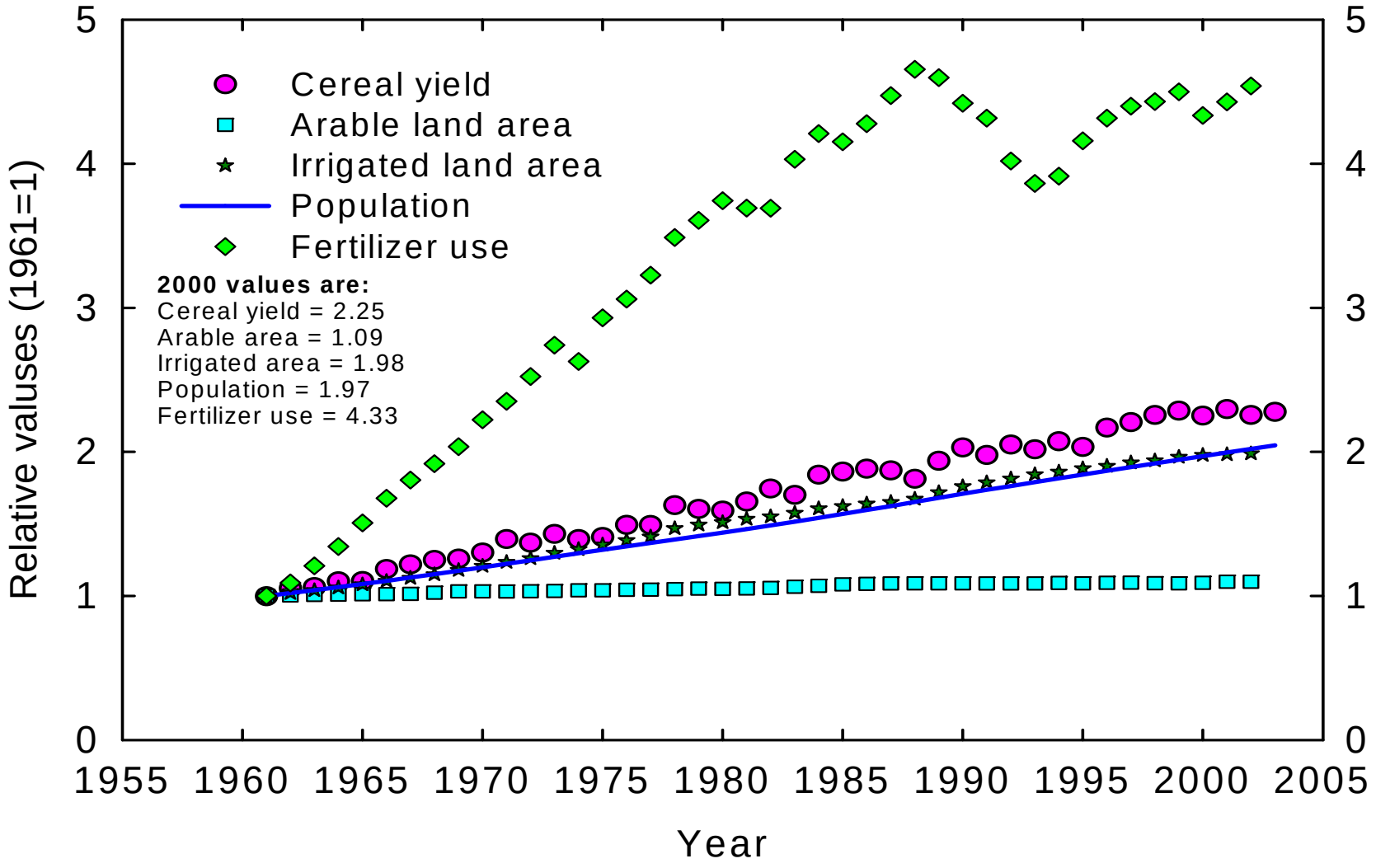
	Cropland area	Irrigated area		Salinized area	
	---------- Mha ----------				
China	124.0	54.4	(22%)	7-8	(14%)
India	161.8	54.8	(31%)	10-30	(50%)
USA	177.0	22.4	(13%)	4.5 -6	(15%)
USSR	204.1	19.9	(2%)	2.5-4.5	(21%)
World	1364.2	271.7	(21%)	62-82	(37%)

Percent change since 1985

S.G. Pritchard and J. S. Amthor, 2005

Trends, Signs and Signatures from the Earth

Population, Cereal Yield, Arable and Irrigated Area, N Use



Feeding 10 Billion Mouths

- We must develop the capacity to feed 10 billion people within the next 40 to 50 years.
- The average world current cereal yield is about 3 tons per ha for about 6 billion people.
- We need about 4 tons per ha for 8 billion (33 % more than the current), and 5 tons per ha for 10 billion (67 % more than the current).

Routes to Greater Food Production

- Increase in the area of land under cultivation.
- Displacement of lower yielding crops by higher yielding ones (done since the dawn of domestication).
- Efficiency of crop production in terms of:
  - Per unit of land area (yield per ha)
  - Per unit of time
  - Per unit of inputs such as fertilizers, water and labor etc.

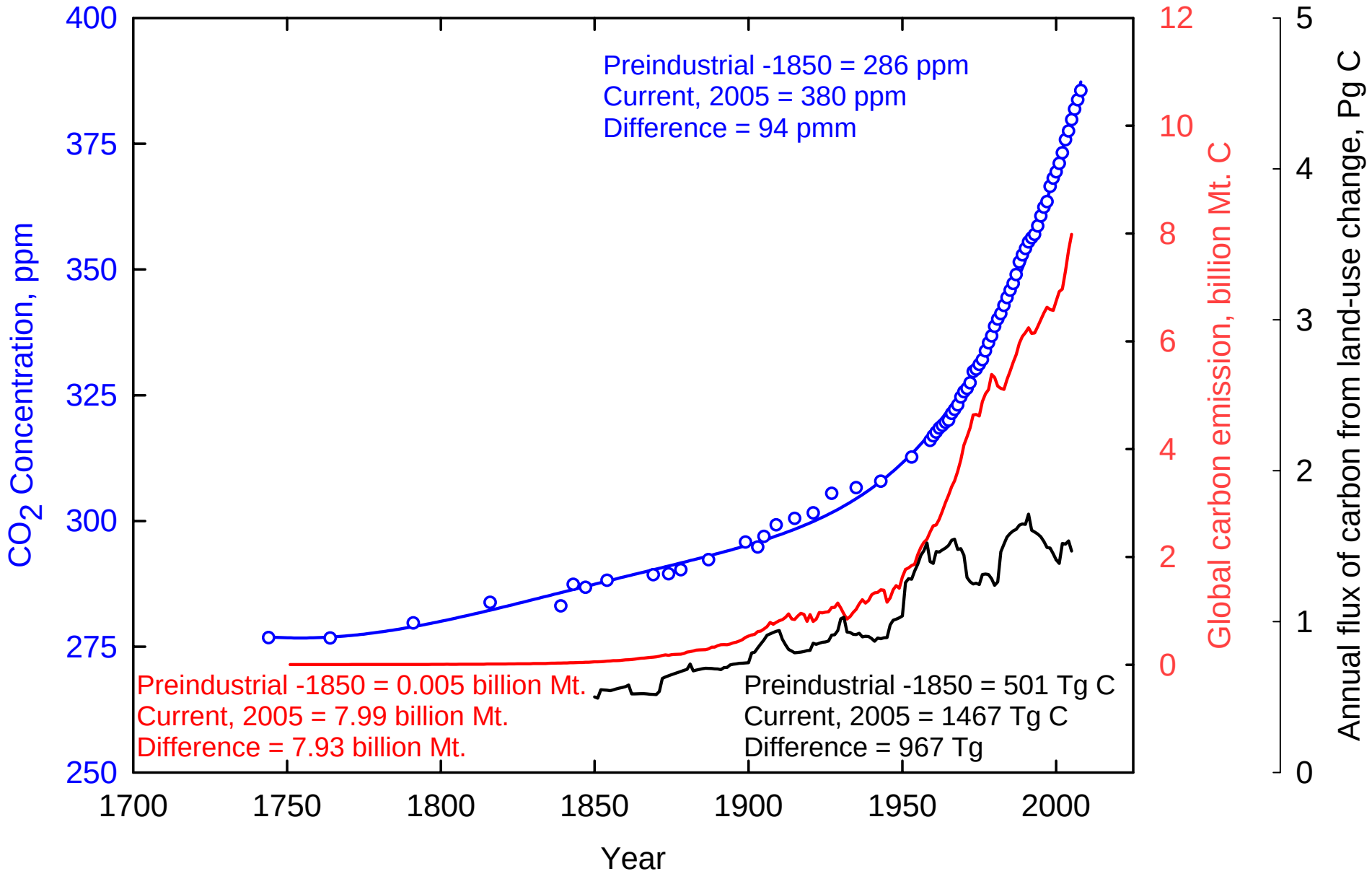

Here Comes the Greatest
Challenge of our Time,
The Global Climate Change

Trends, Signs and Signatures from the Earth

- Greenhouse gases (CO_2, CH_4, N_2O etc.)
- Temperatures
- Glaciers, oceans and sea-levels
- Precipitation patterns and drought intensities
- Extreme events
- Higher ozone and UV-B radiation

Trends, Signs and Signatures from the Earth

Global Carbon Emissions and Fluxes



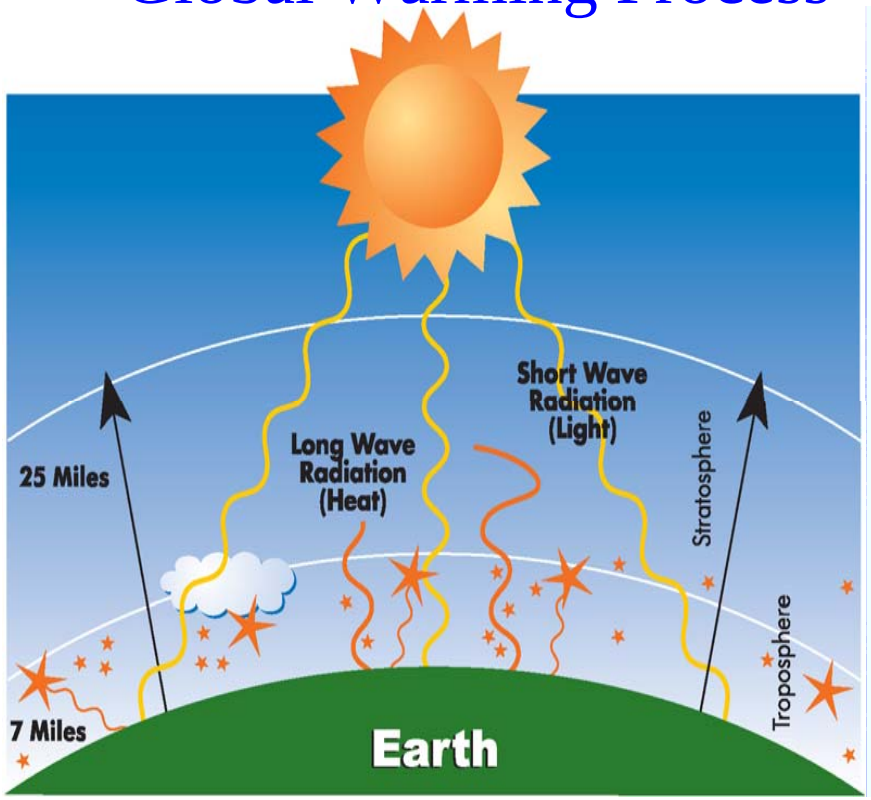
Trends, Signs and Signatures from the Earth

Past and Current Levels in GHG Concentrations, Rates of Change and Atmospheric Lifetime

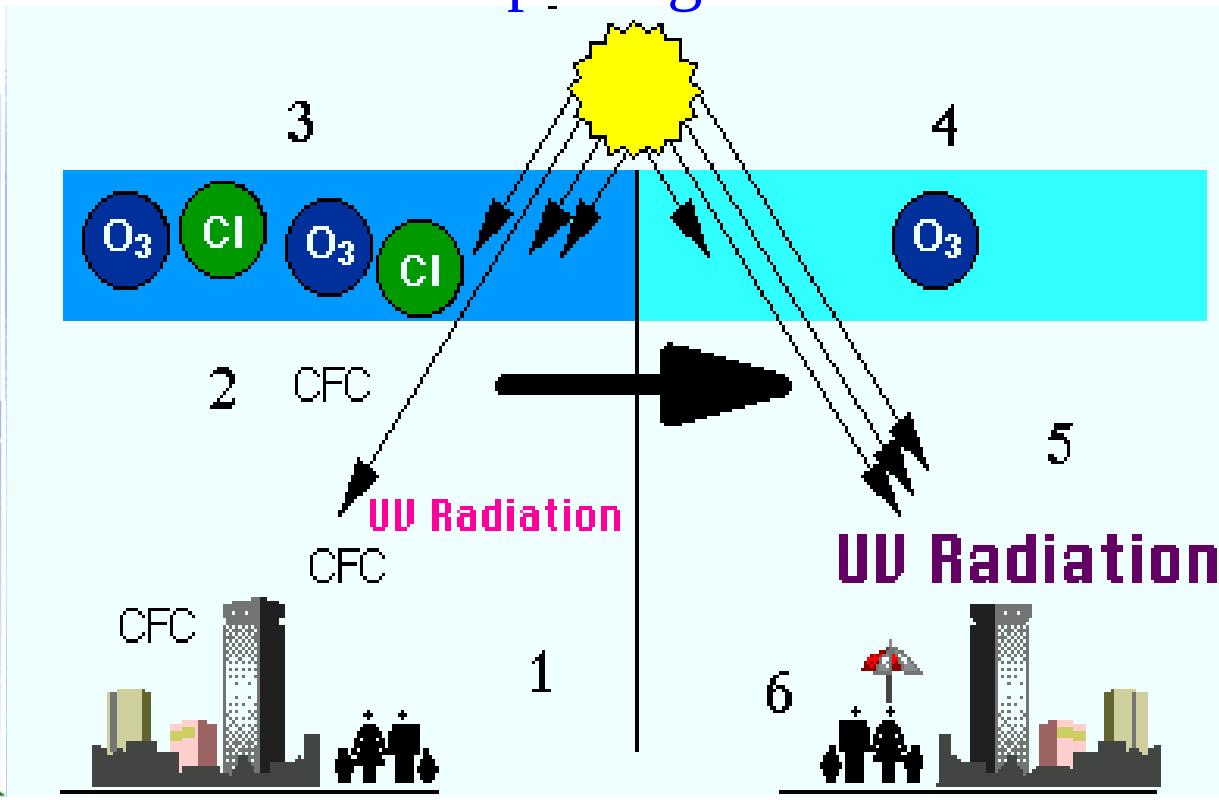
	Global warming gases			Ozone depleting chemicals		
Period	CO_2	Methane	Nitrous oxide	CFC-11	HFC-23	Perfluro-methane
Pre-industrial concentration (1850)	about 280 ppm	about 700 ppb	about 270 ppb	0	0	40 ppt
Current Concentration in 2008	386 ppm	1857 ppb	321 ppb	244 ppt	18 ppt	74 ppt
Rate of change	1.43 ppm/yr	7.0 ppb/yr	0.8 ppb/yr	-1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
Atmospheric lifetime	5 to 200 years	12 years	114 years	45 years	260 Years	>50,000 years

Global Warming and the Ozone Story

Global Warming Process



Ozone Depleting Process



CFCs are commonly used as refrigerants, solvents, and foam blowing agents. The most common CFCs are CFC-11, CFC-12, CFC-113, CFC-114, and CFC-115.

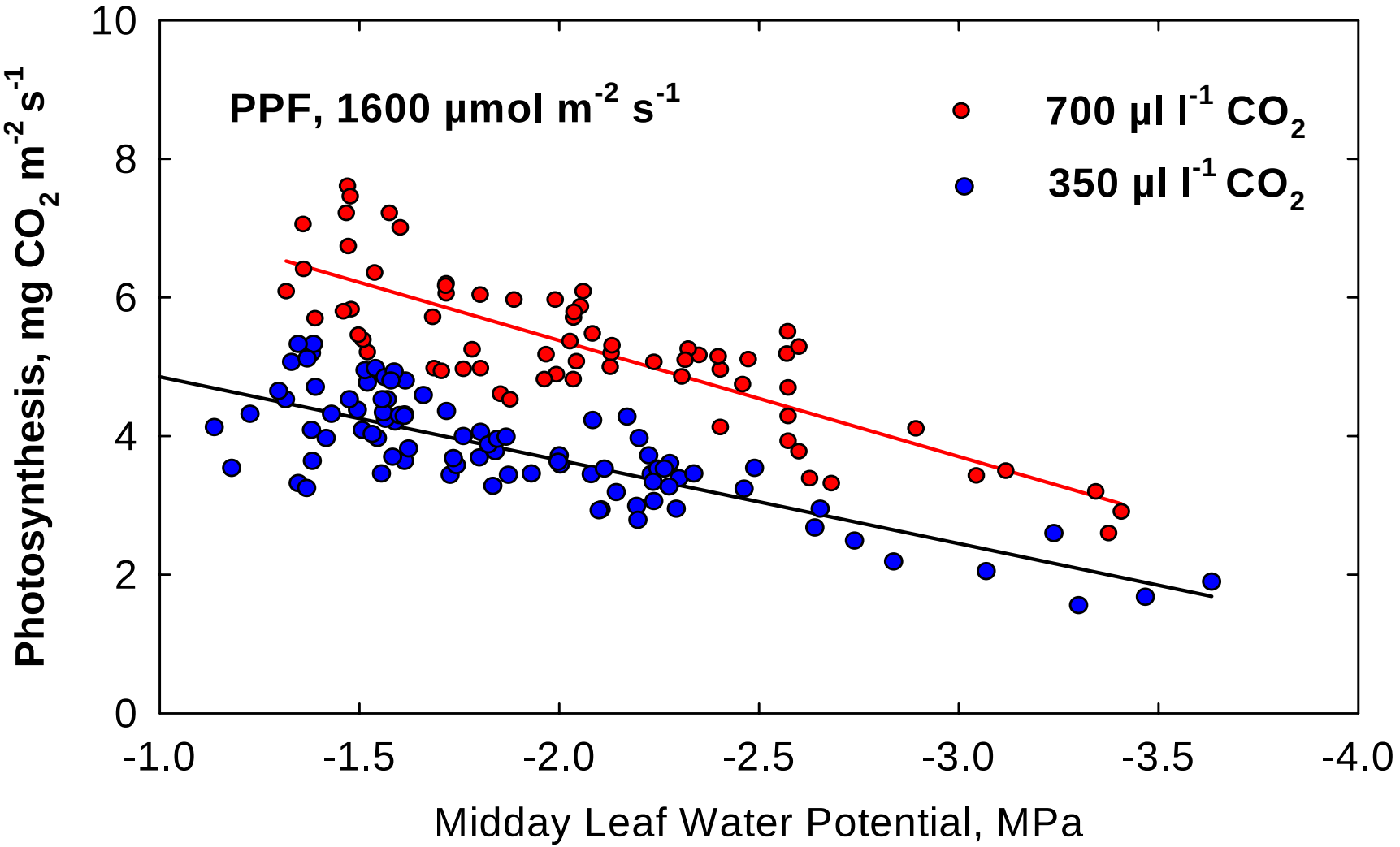
Trends, Signs and Signatures from the Earth

Future trends in global carbon dioxide concentration and associated climate change, if no interventions are made

Climate variable	**2025**	**2050**	**2100**
Carbon dioxide concentration	405-460 ppm	445-640 ppm	720-1020 ppm
Global mean temperature change from the year 1990	0.4-1.1 ^{o}C	0.8-2.6 ^{o}C	2.4-6.4 ^{o}C
Global mean sea-level rise from the year 1990	3-14 cm	5-32 cm	26-59 cm

Climate Change and Crop Productivity

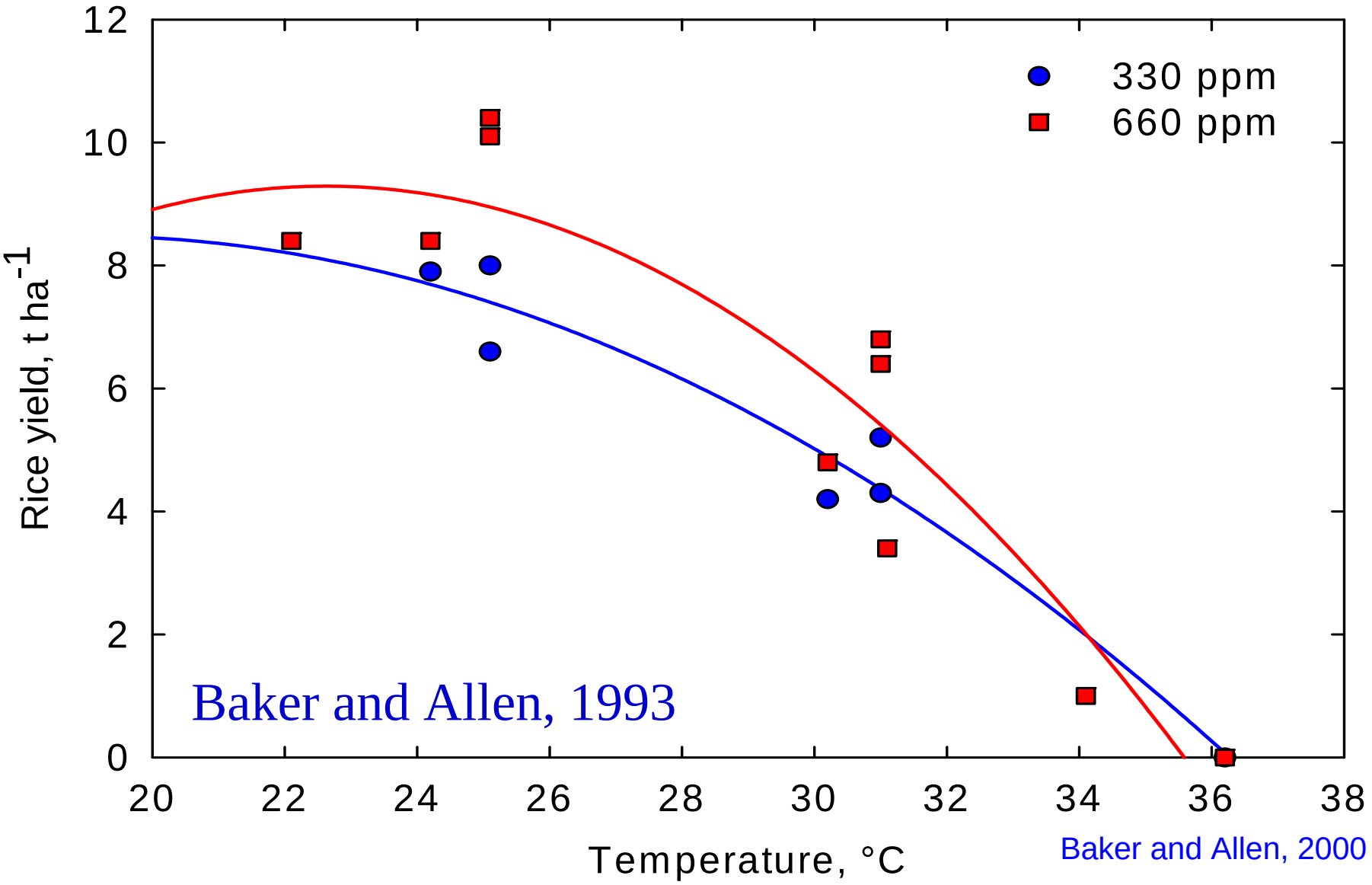
Photosynthesis - Leaf Water Potential



Well-watered ⟷ Water stressed

Climate Change and Crop Productivity

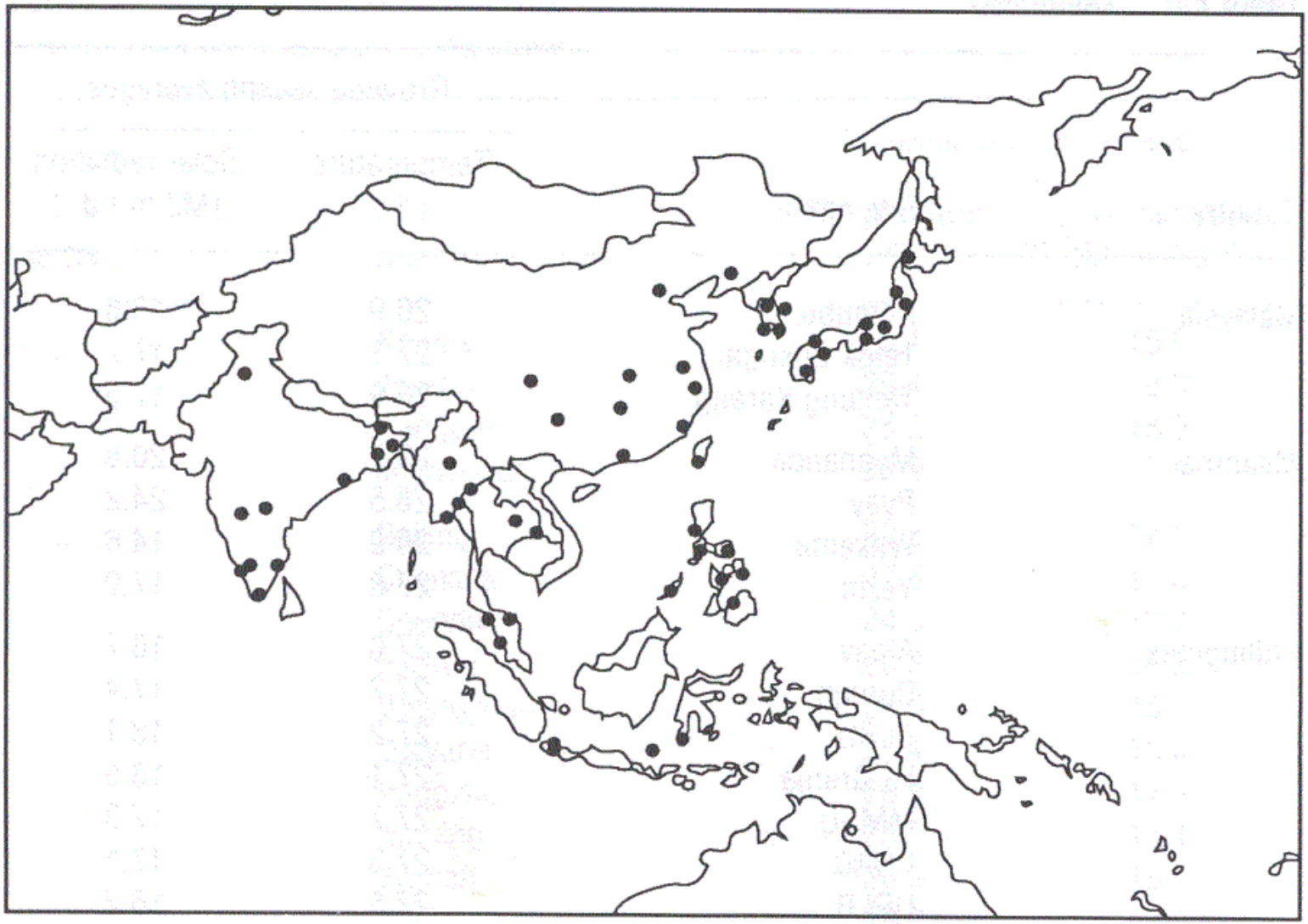
Temperature and CO2 - Rice Yield



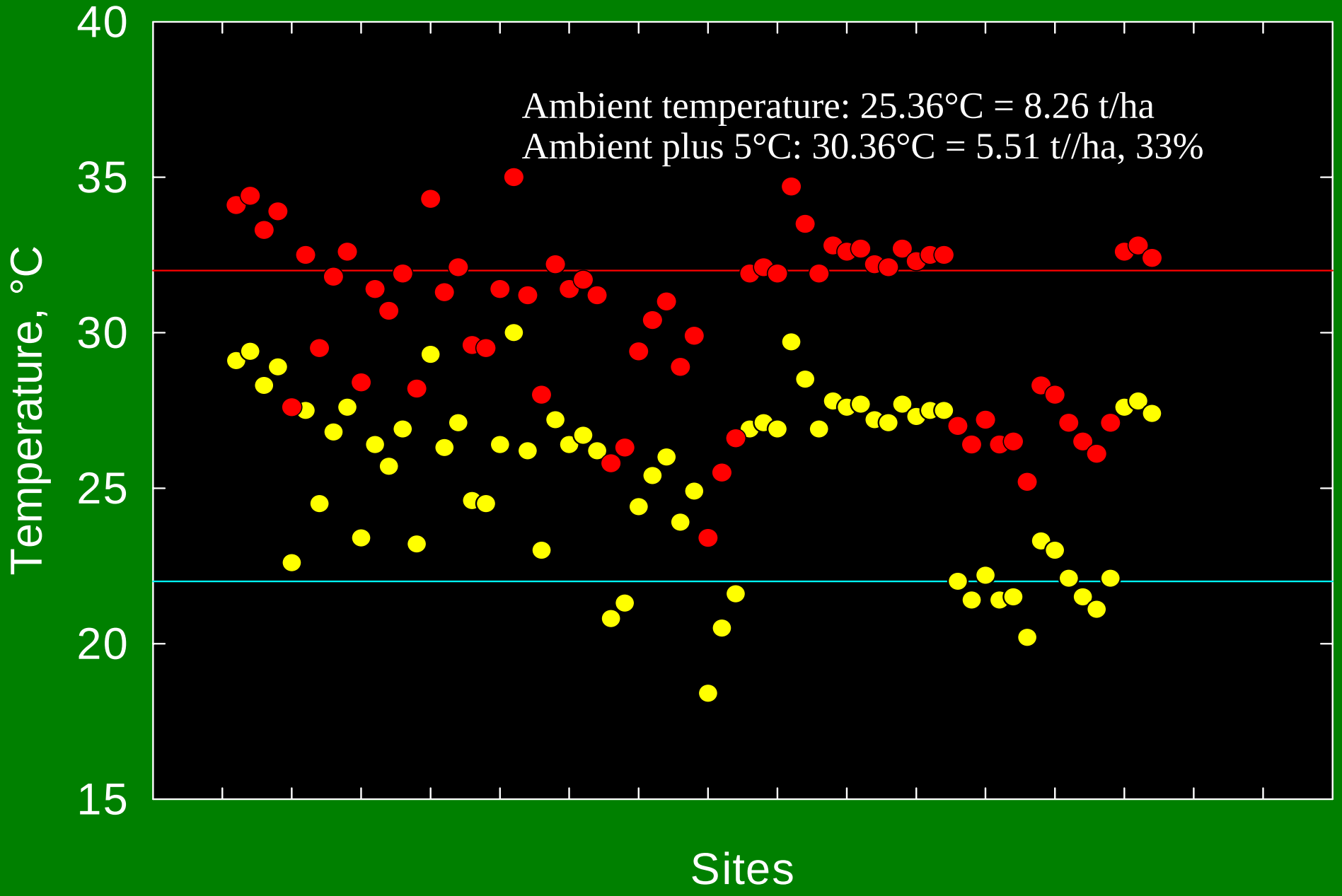
Baker and Allen, 2000

Climate Change and Crop Productivity

Rice Growing Areas and Variety trial Experiments

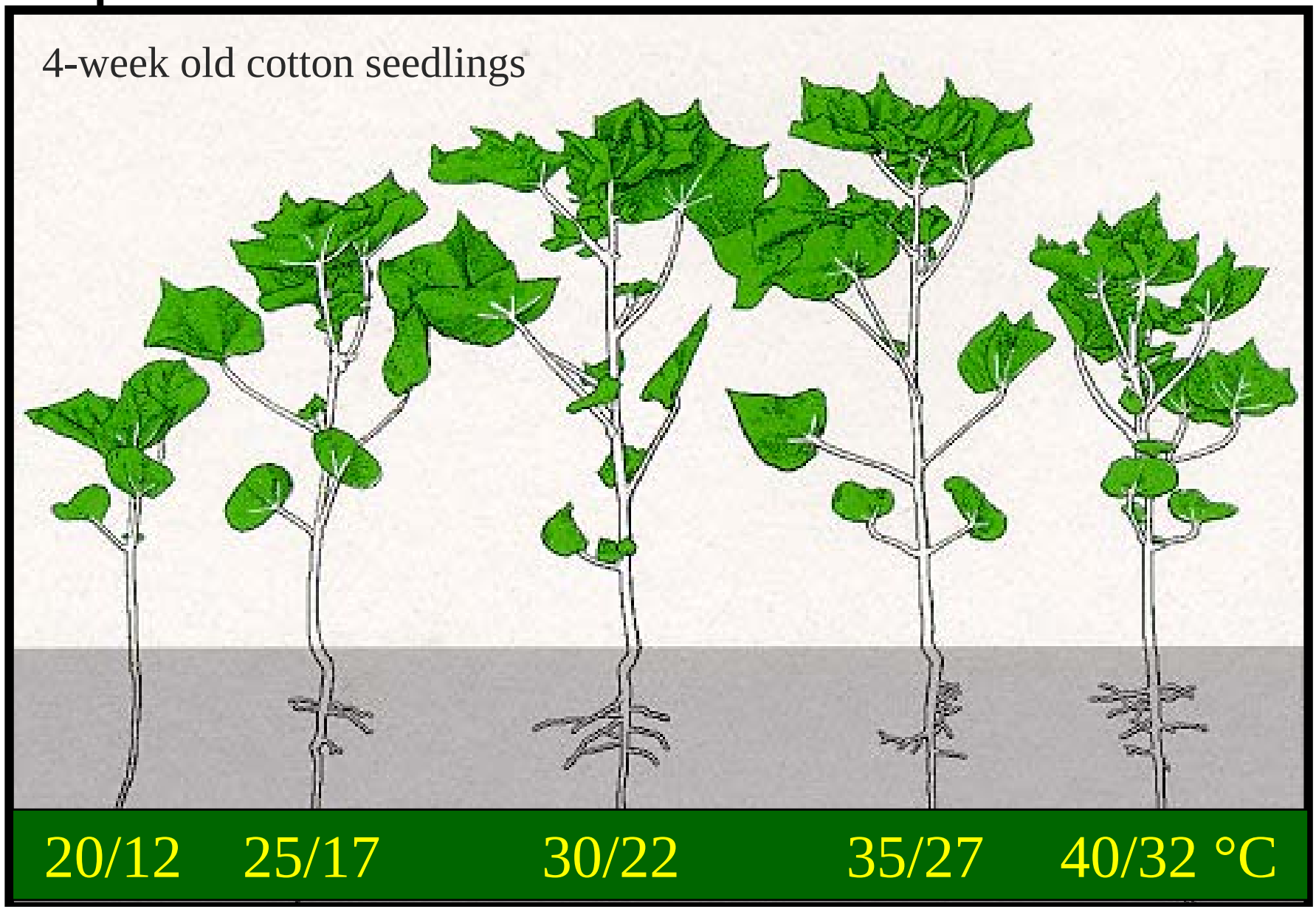


Growing season temperatures from those locations listed in the previous slide and with an additional 5°C added to those temperatures relative to optimum and marginal conditions



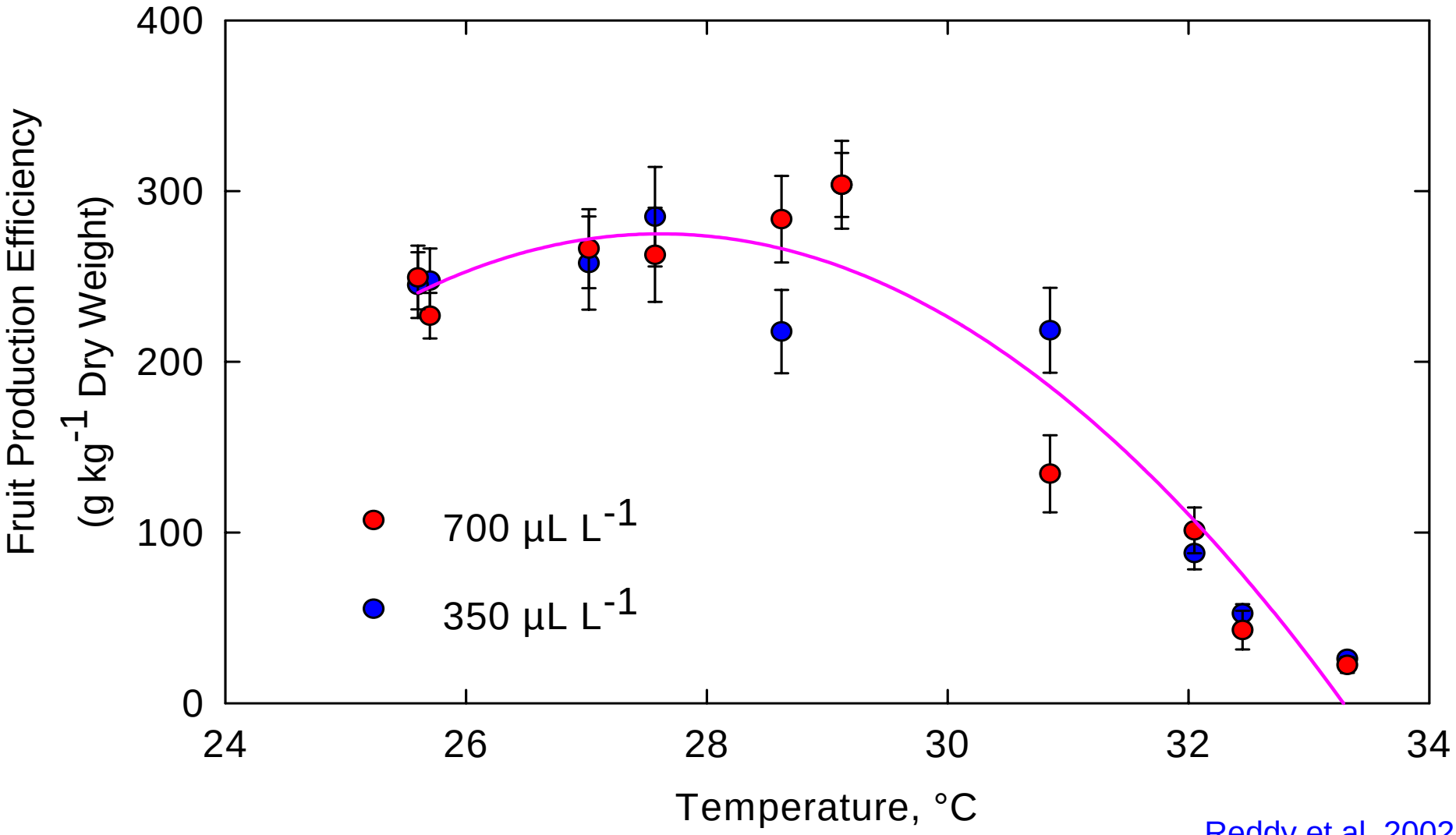
Climate Change and Crop Productivity

Temperature and Cotton Growth



Climate Change and Crop Productivity

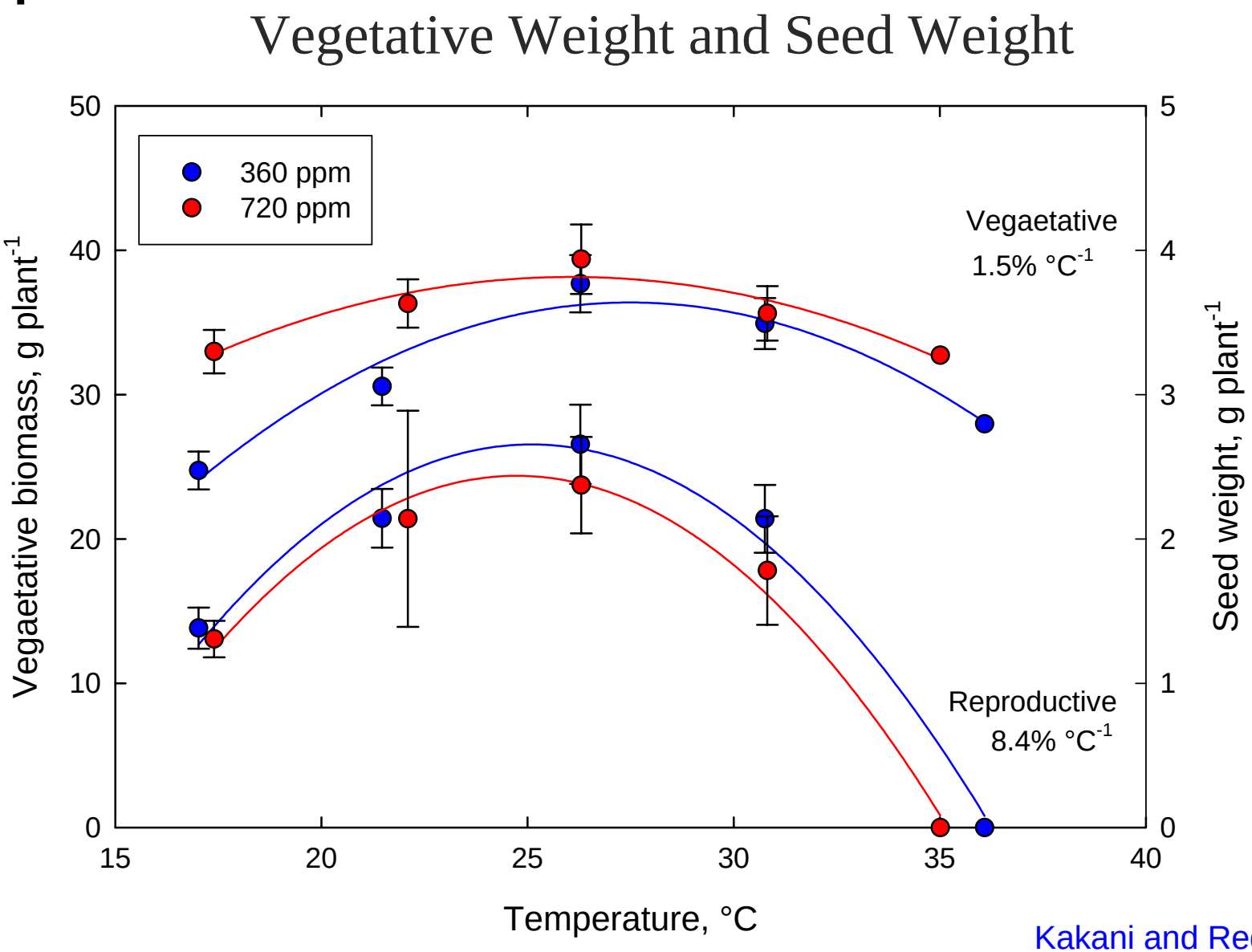
Temperature and CO_2 - Cotton Reproductive Growth



Reddy et al. 2002

Climate Change and Crop Productivity

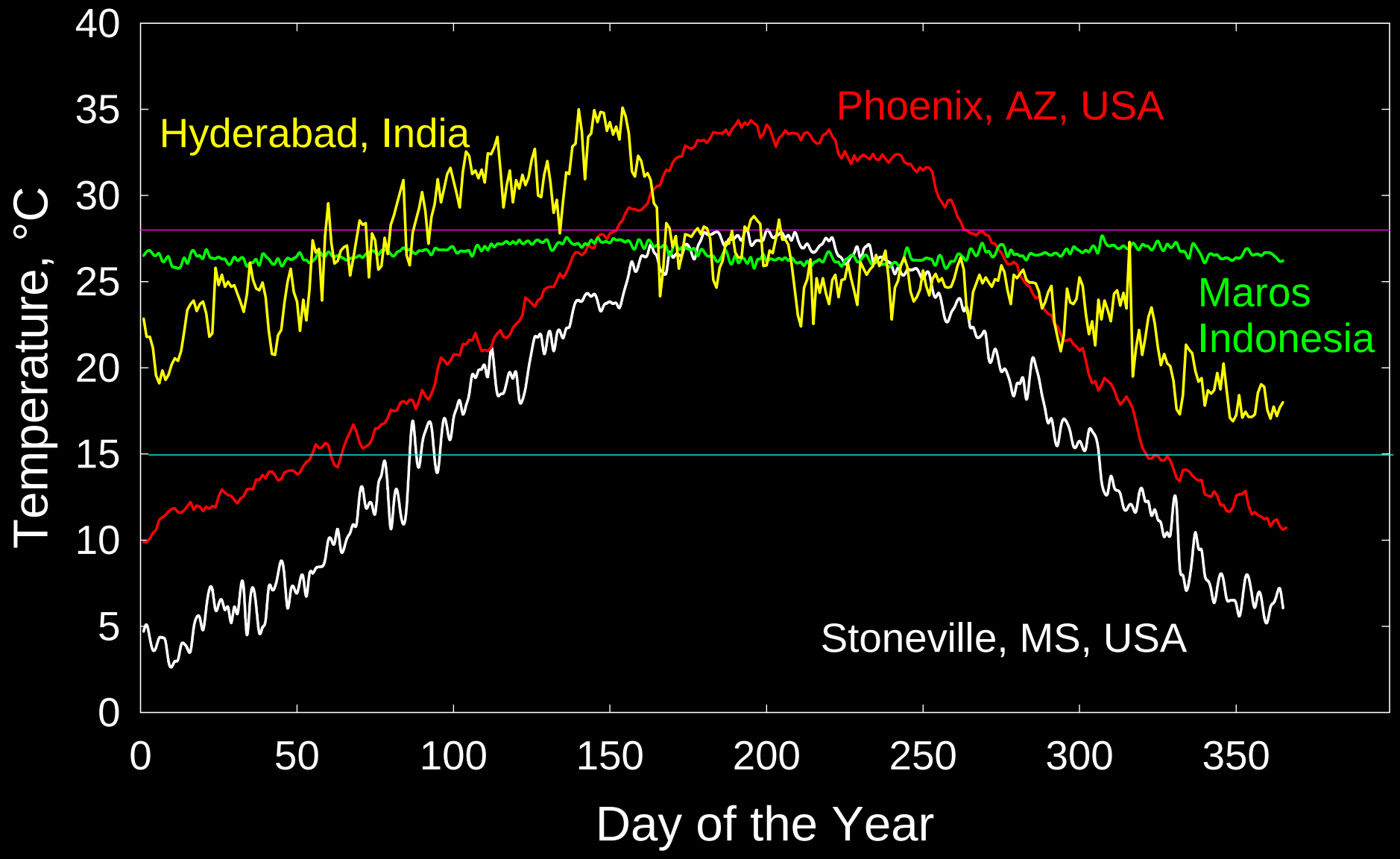
Temperature and CO2 – Rangeland C4 Grass: Big Bluestem



Kakani and Reddy, 2004

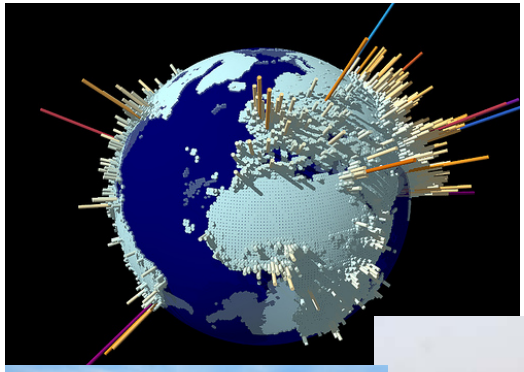
Climate Change and Crop Productivity

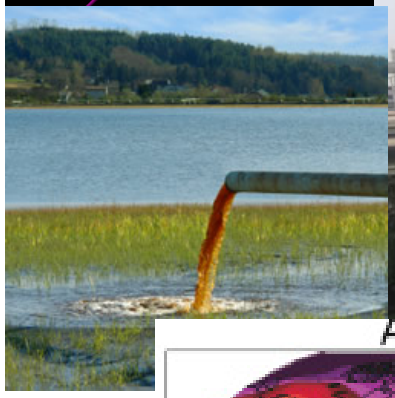
Long-term Temperatures across Regions

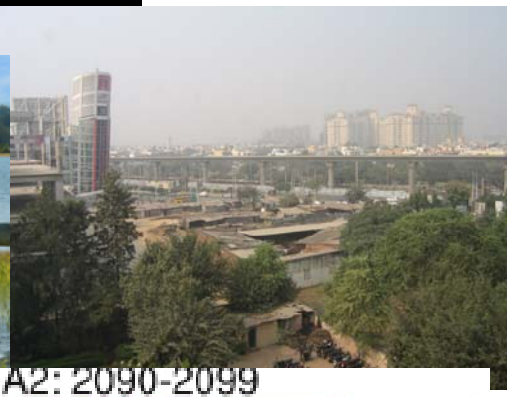


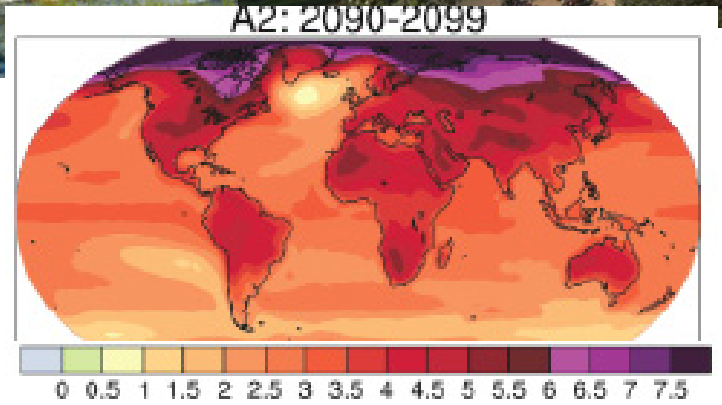
Issues of 21st Century, Particularly in Developing Countries

- Meeting food demands for the growing population.
- Reducing the risks of soil and ecosystem degradation.
- Minimizing the risks of eutrophication and contamination of natural waters.
- Developing scientific capacity and system tools to assess the impacts of climate change on food and fiber security.



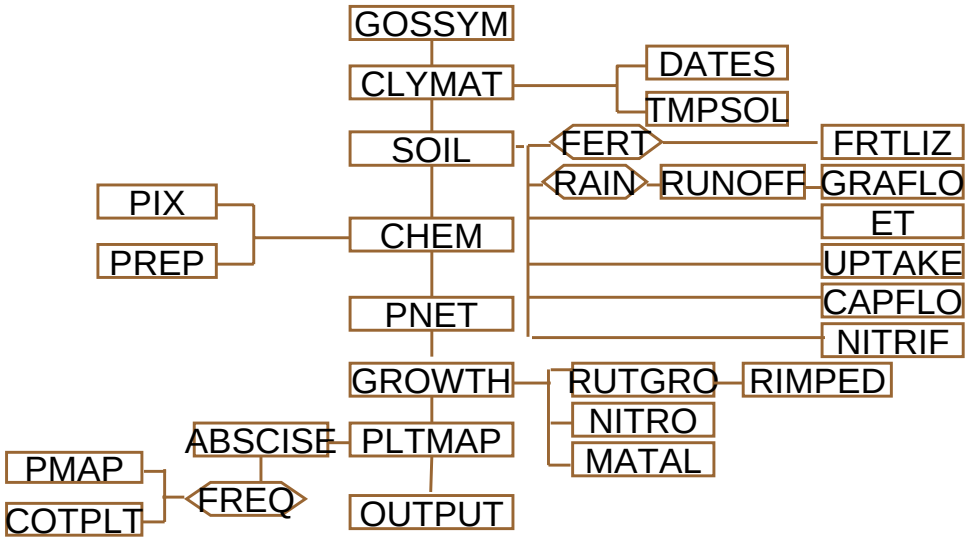


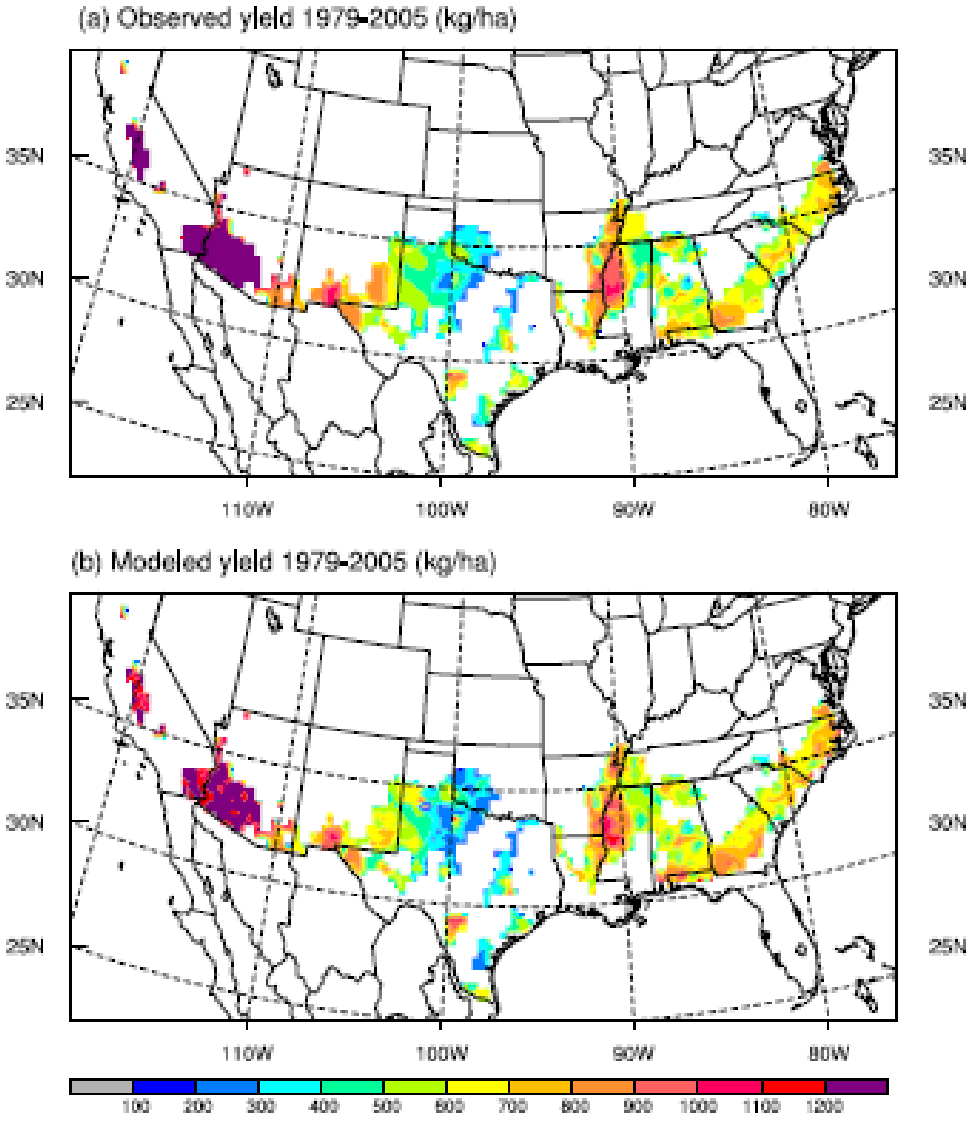




Can We Use Crop Models for Regional and Global Food and Fiber Security and Assist in Policy Decisions?

- Simple models can't simulate complex problems.
- Robust and process-rich models are needed to study the impacts of climate change perturbation on agro-ecosystem goods and services.





Liang et al. 2009

Crop Model Applications for Natural Resource Management

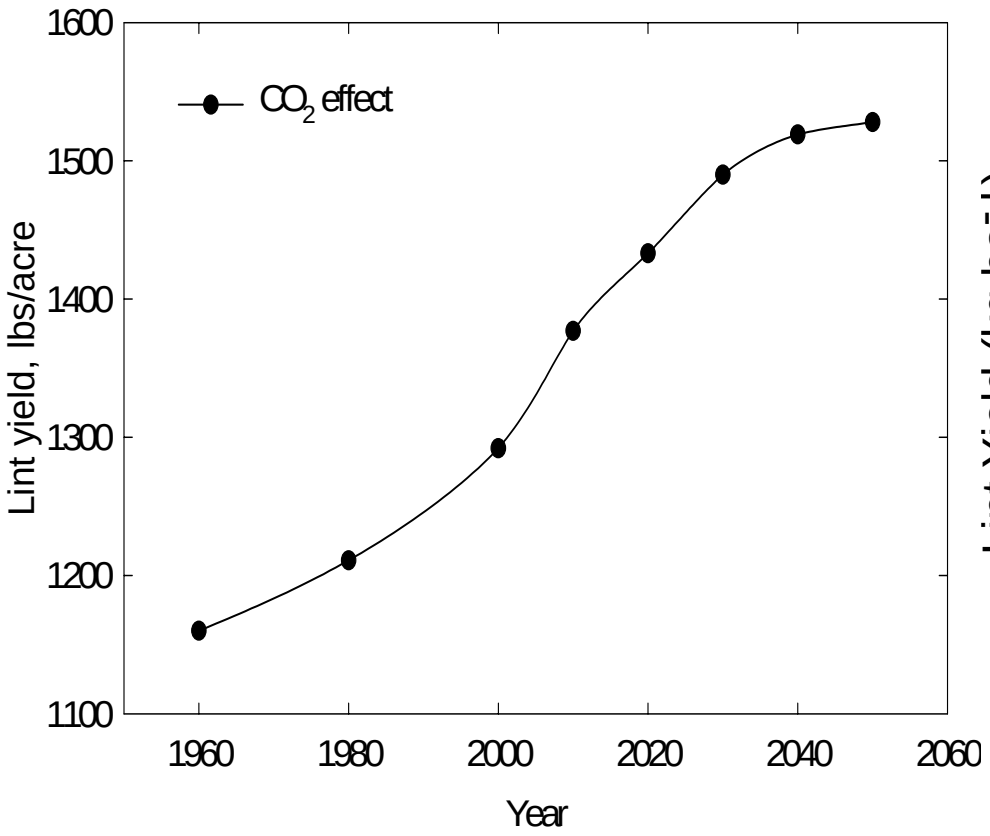
- ✓ Farm management (e.g. planting, irrigation, fertilization and harvest scheduling).
- ✓ Resource management (e.g. several Govt. agencies and private comp. use).
- ✓ Climate change and policy analysis.
- ✓ Production forecasts (e.g. global, regional and local forecasts).
- ✓ Research and development (e.g. research priorities and guide fund allocations).
- ✓ Turning information into knowledge (e.g. information overflow in every area including agricultural research).

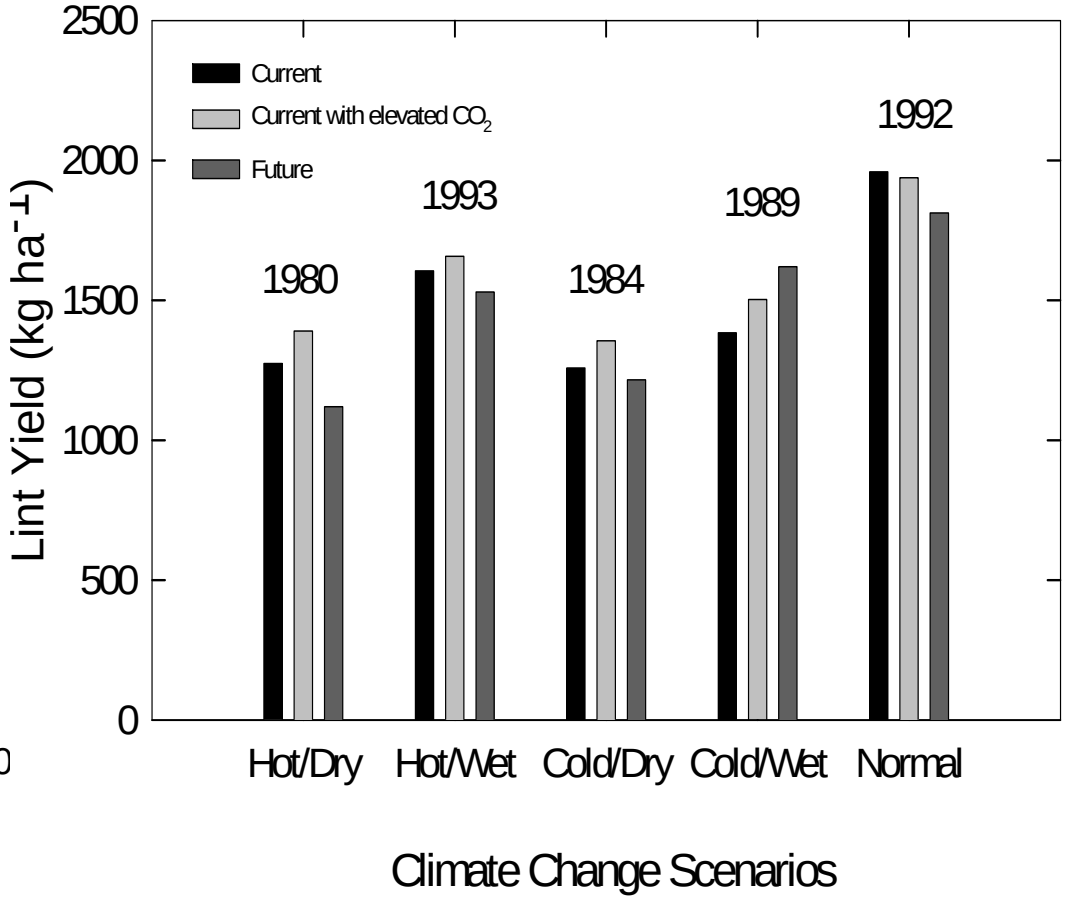
Crop Model Applications for Adaptation to Global Climate Change

- ✓ What production strategies have the least risk of economic loss?
- ✓ How can natural resource quality be best managed while achieving production goals?
- ✓ What are the consequences of climate change on production, gaseous emissions, pest populations, etc.?
- ✓ What would be the effect of regional drought on agricultural-based energy production?
- ✓ What are the adaptation and mitigation approaches to agricultural production in 21st Century?

Crop Model Applications for Climate Change Scenarios: A Case Study

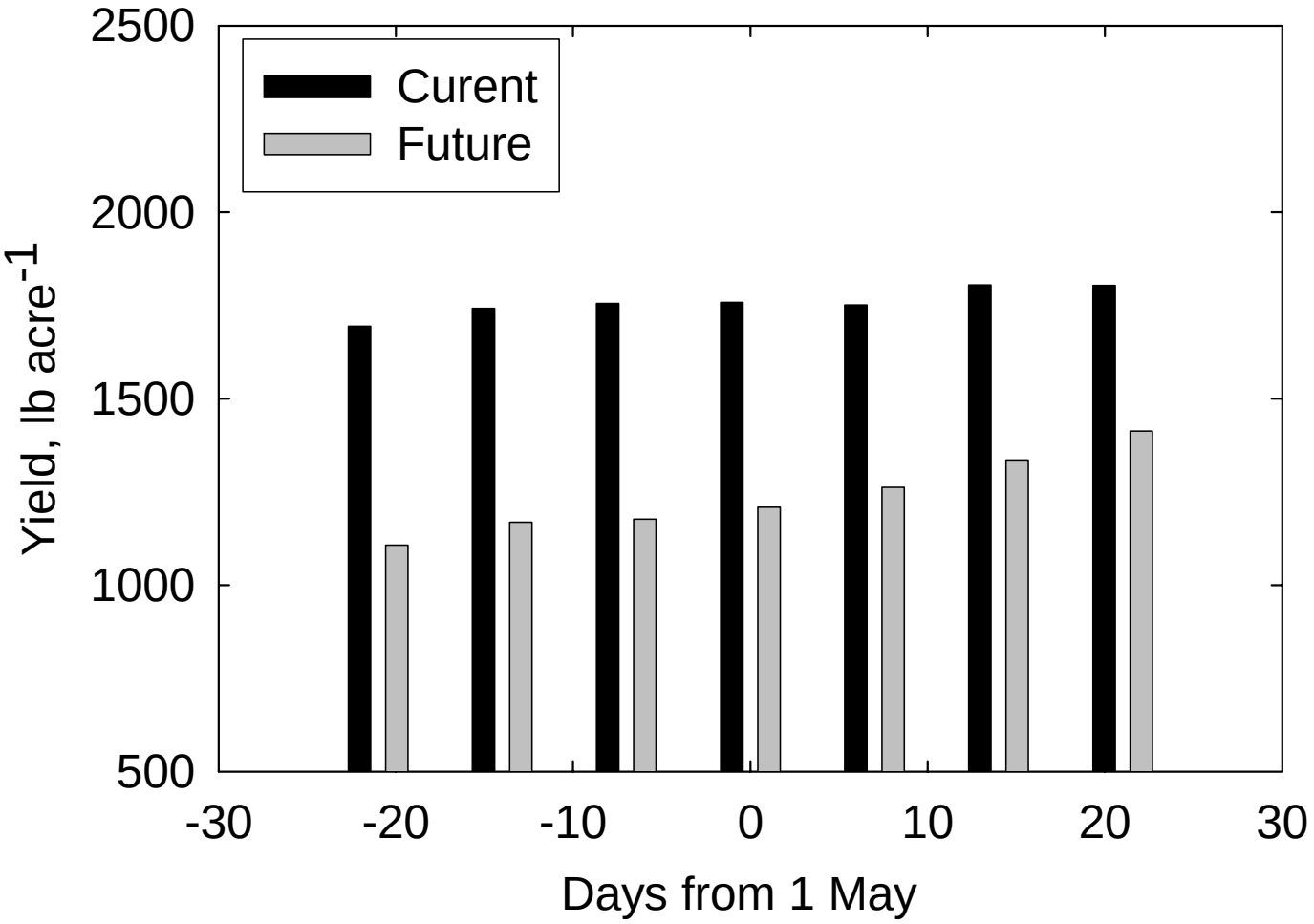
Potential as Well as Stress Interactions





Crop Model Applications for Climate Change Scenarios: A Case Study

Planting date Adaptations



Climate Change and Crop Productivity

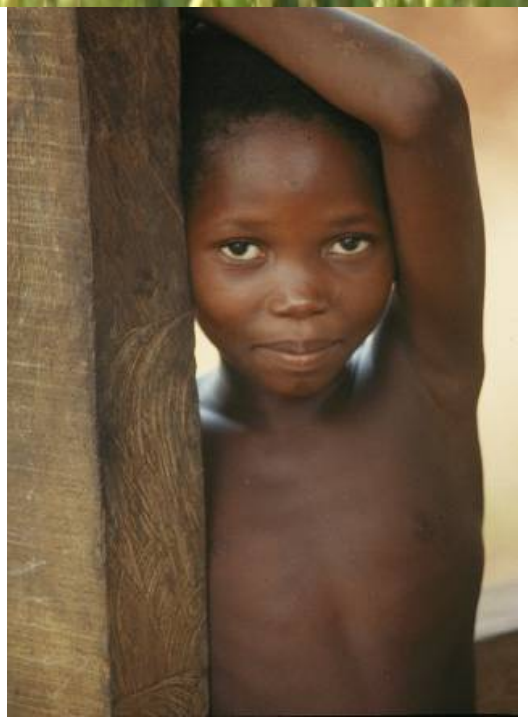
Some Considerations

- Except limiting the causes of climate change, there are no other long-term strategies
- For a shorter-term, we must develop crop varieties which can withstand changes projected in climate to meet the growing demands for food.
  - Cold, heat- and drought-tolerant varieties for temperate
  - Heat- and drought tolerant varieties for tropics
- We must also develop models that provide adequate warning or guidance for policy makers to act proactively rather than reactively.
- Everybody and every nation should participate in the process, and opportunities are there for everyone.


We will be > 10 billion by 2050 in a much different climate than what we have today
We need to produce enough goods and services in a sustainable way
We need tools to provide information to policy makers

Questions?

"You can't eat the potential yield, but need to raise the actual by combating the stresses"
Norman E. Borlaug
Nobel Peace Laureate



"You can't build peace on empty stomachs"
John Boyd Orr
Nobel Peace Laureate
First FAO Director General