Environmental Plant Physiology
Introduction

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Personal - Education

Education: Ph.D. in Botany with Applied Plant Physiology as a major

Research areas: Environmental plant physiology including global change, crop modeling, remote sensing.

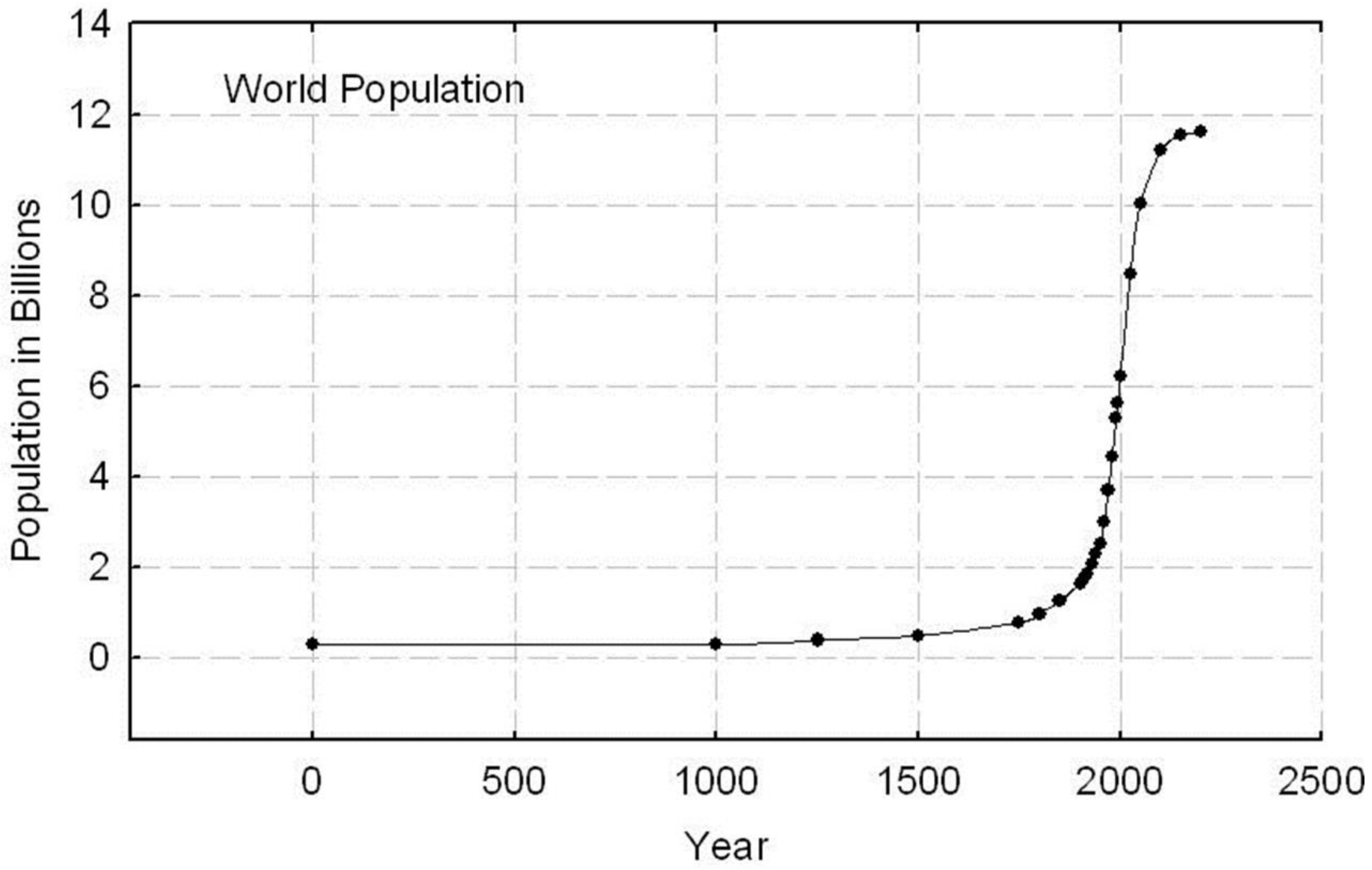
Years at MSU: 30

Taught the course since: 2000

Trends That Shape Our Future

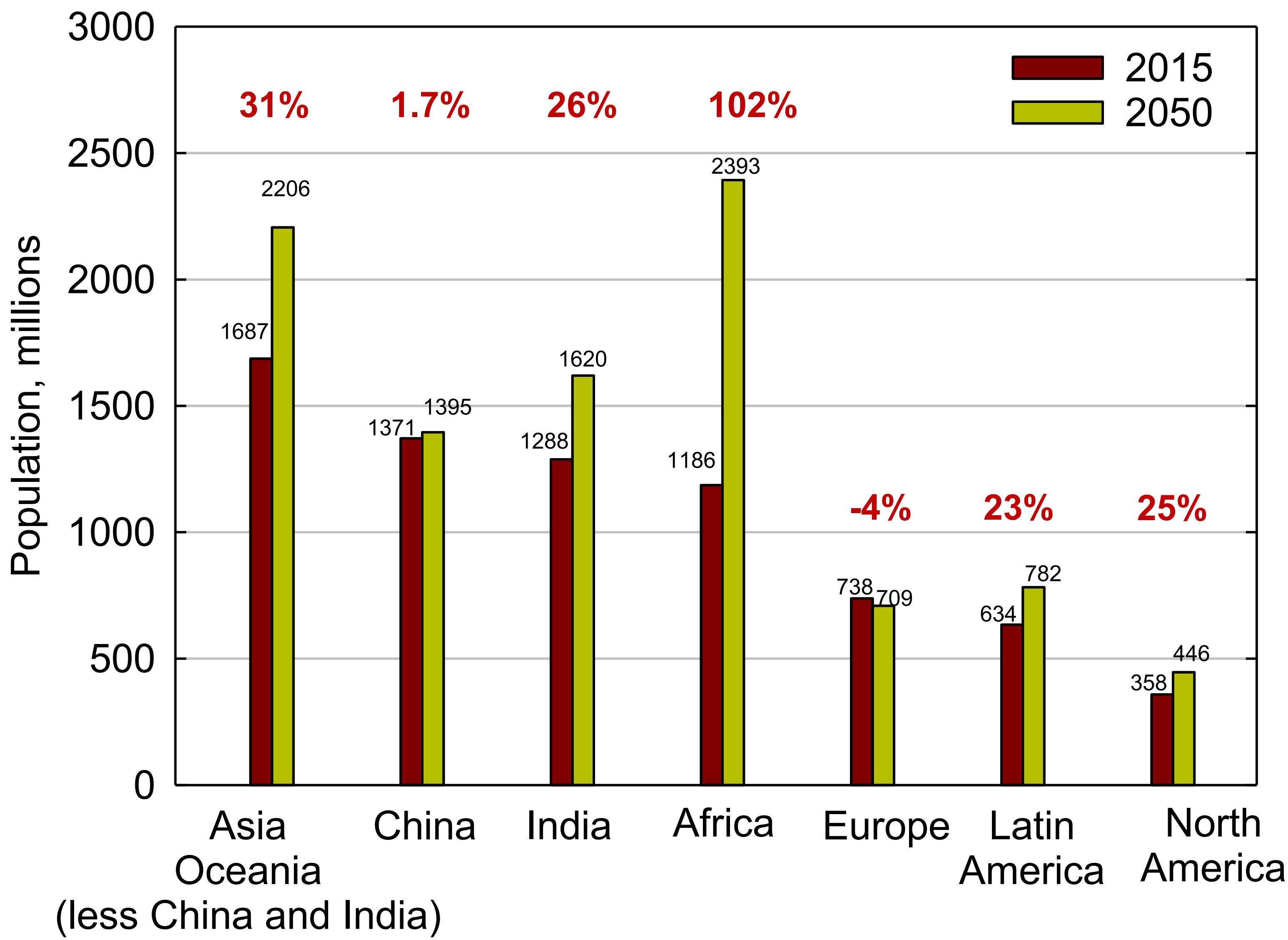
Trends, Signs and Signatures from the Earth

Past, Present and Future World Population



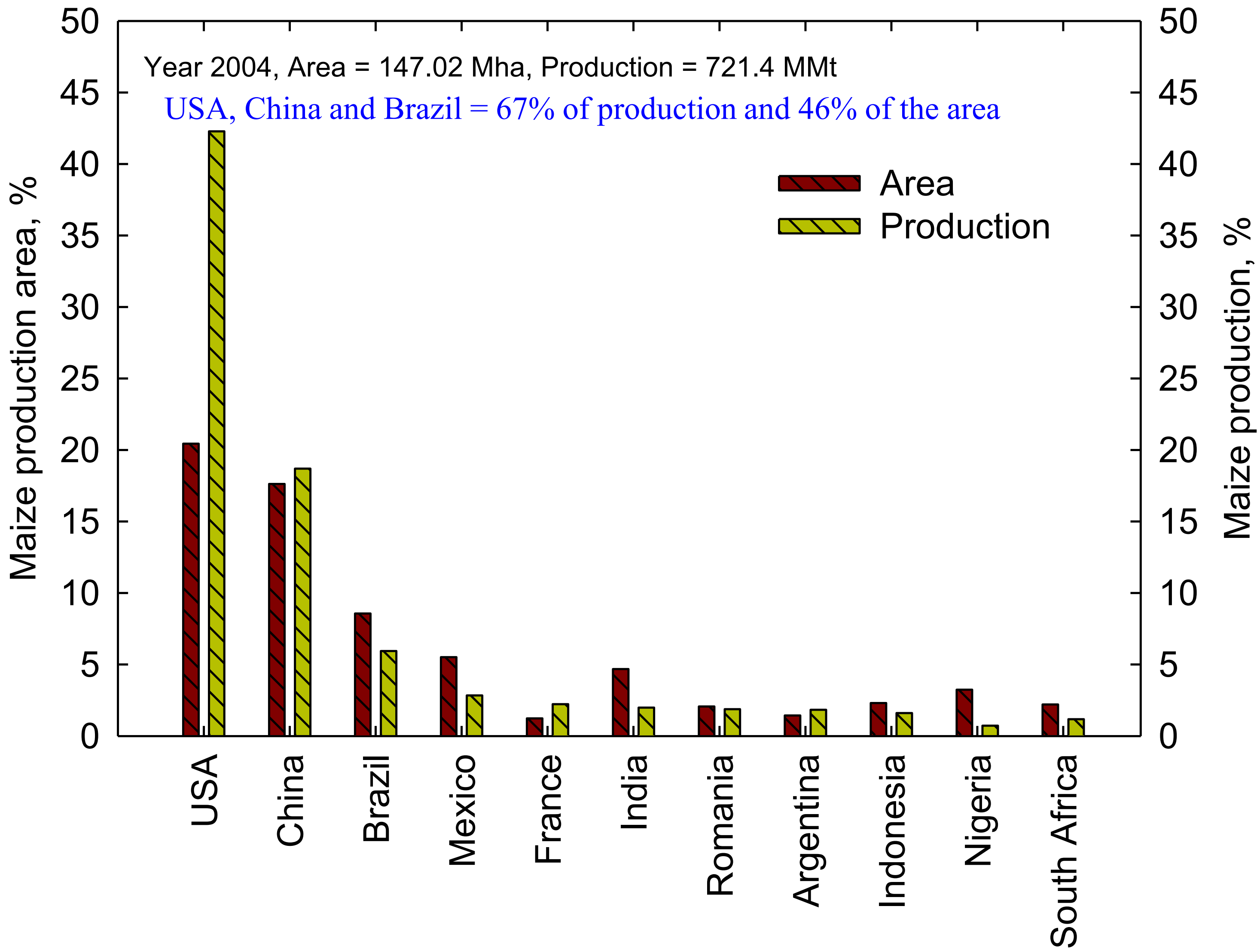
Trends, Signs and Signatures from the Earth

Present and Future World Population Trends



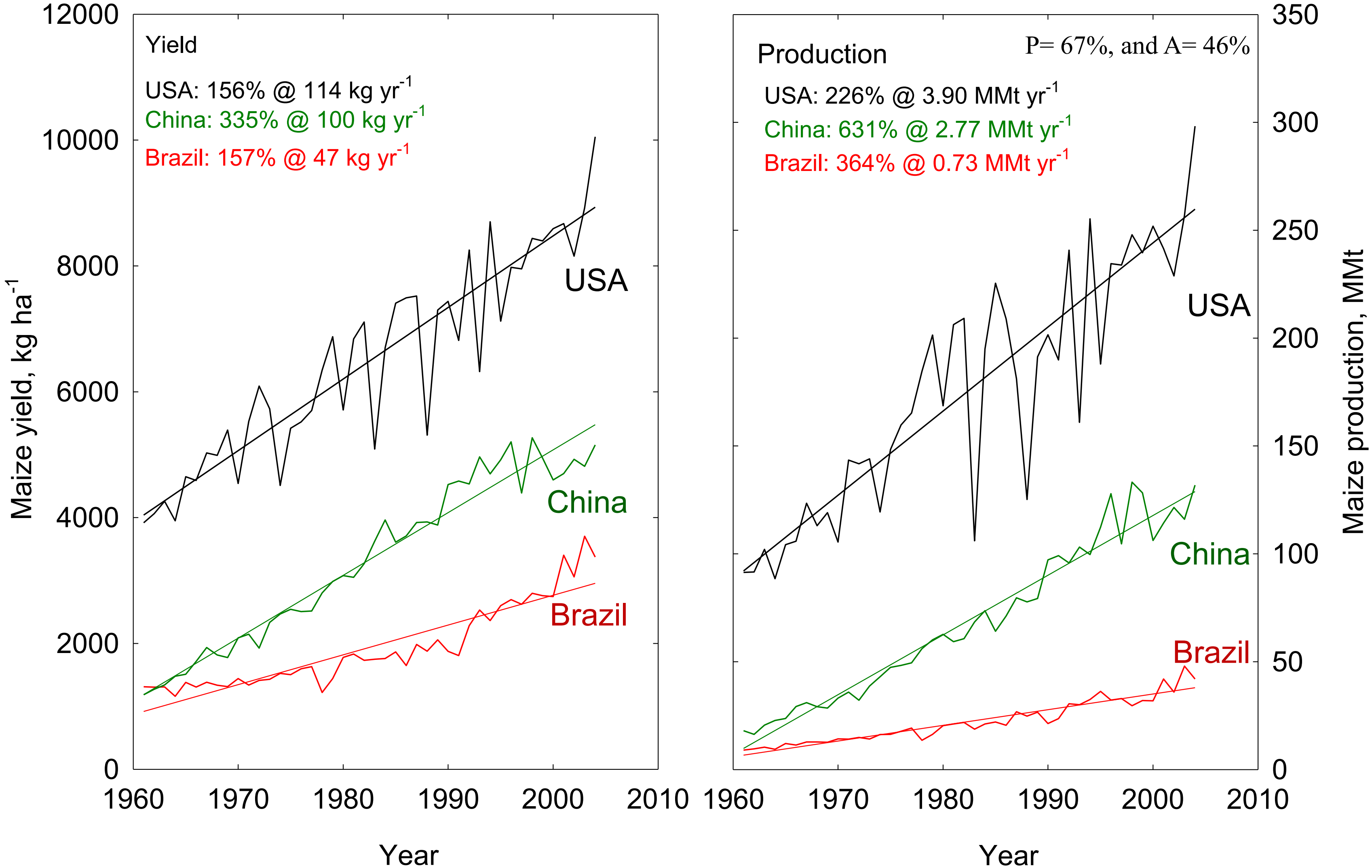
Trends, Signs and Signatures from the Earth

Maize - Production and Yield – Selected Countries



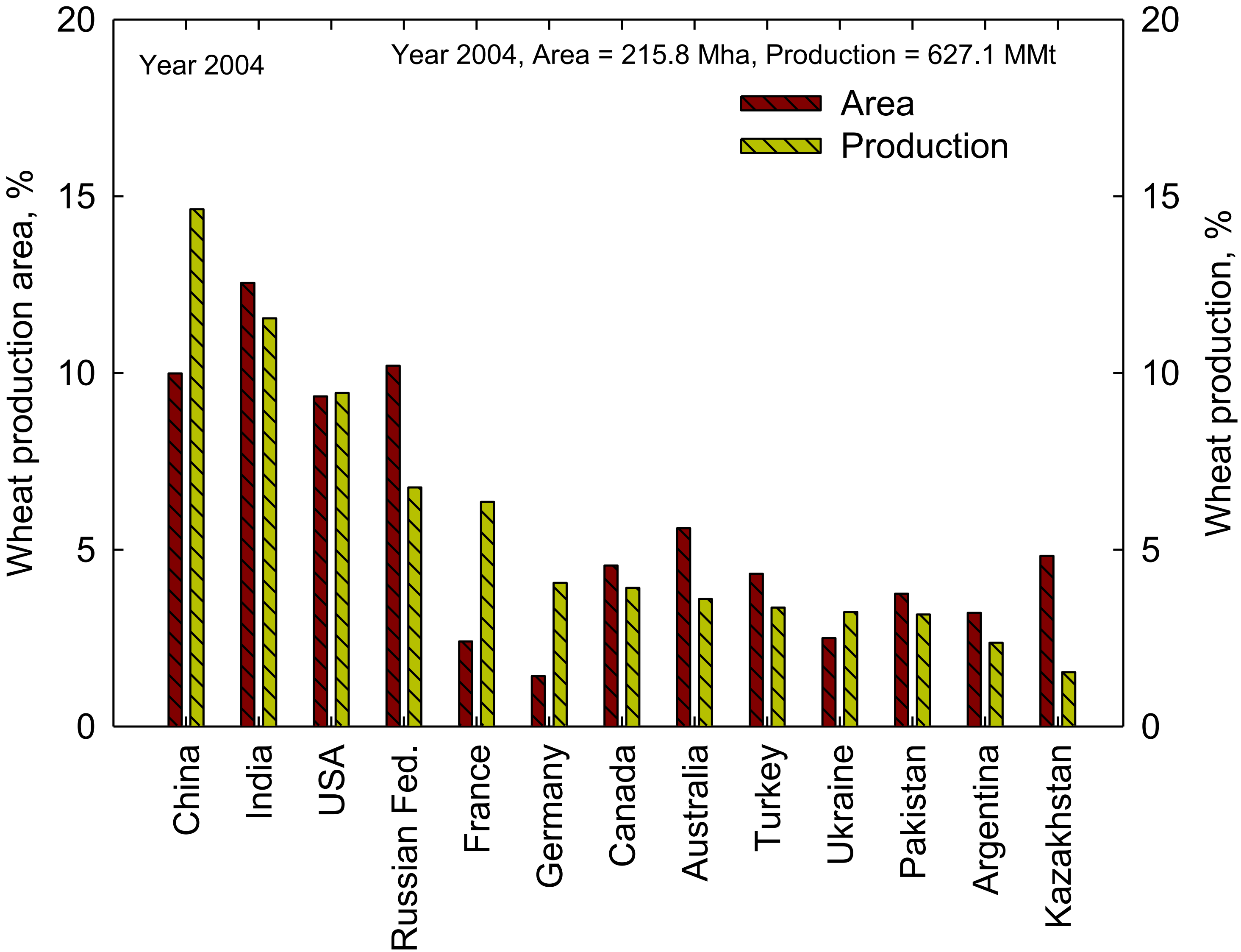
Trends, Signs and Signatures from the Earth

Maize - Production and Yield – Selected Countries



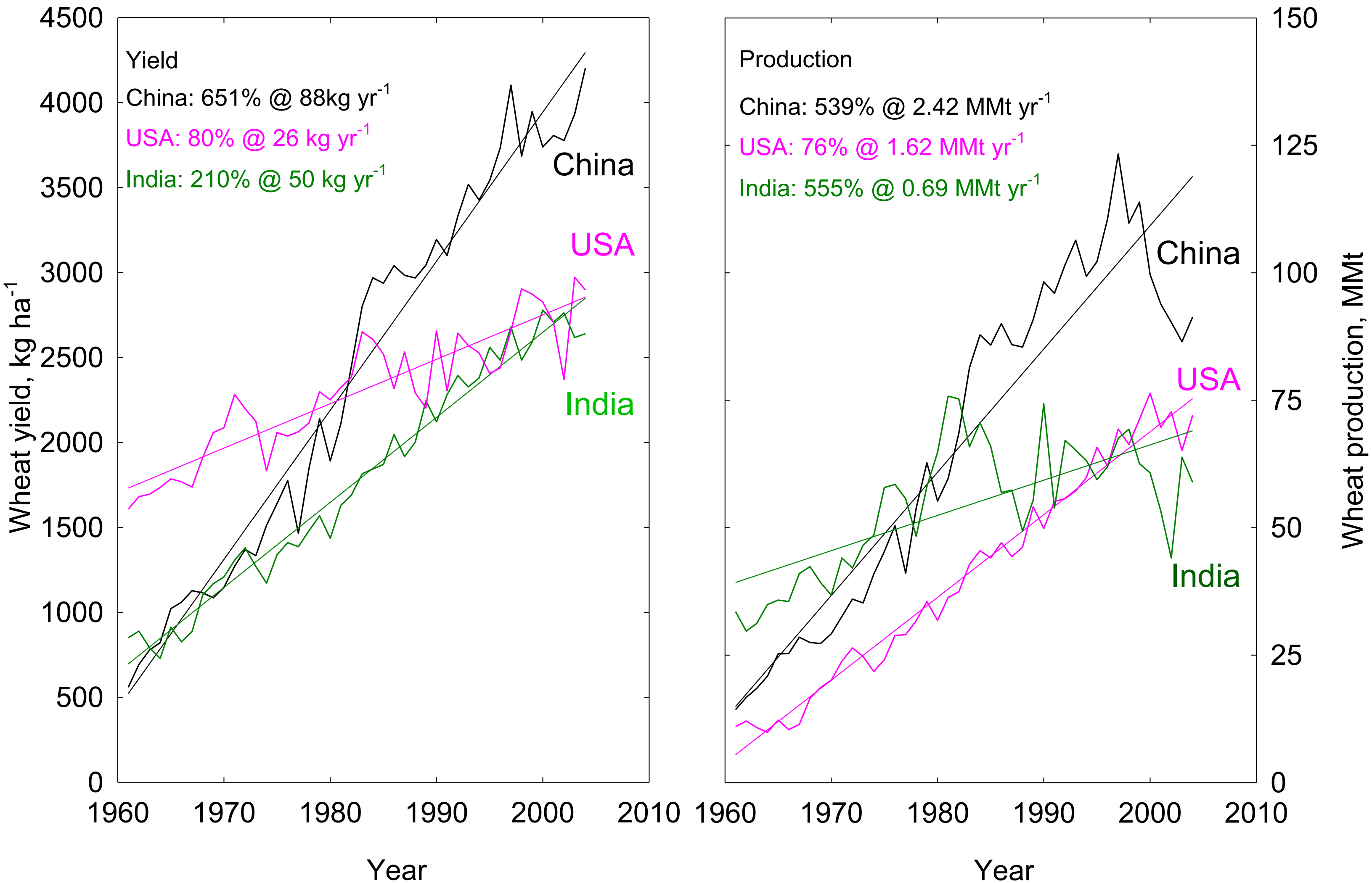
Trends, Signs and Signatures from the Earth

Wheat - Production and Yield – Selected Countries



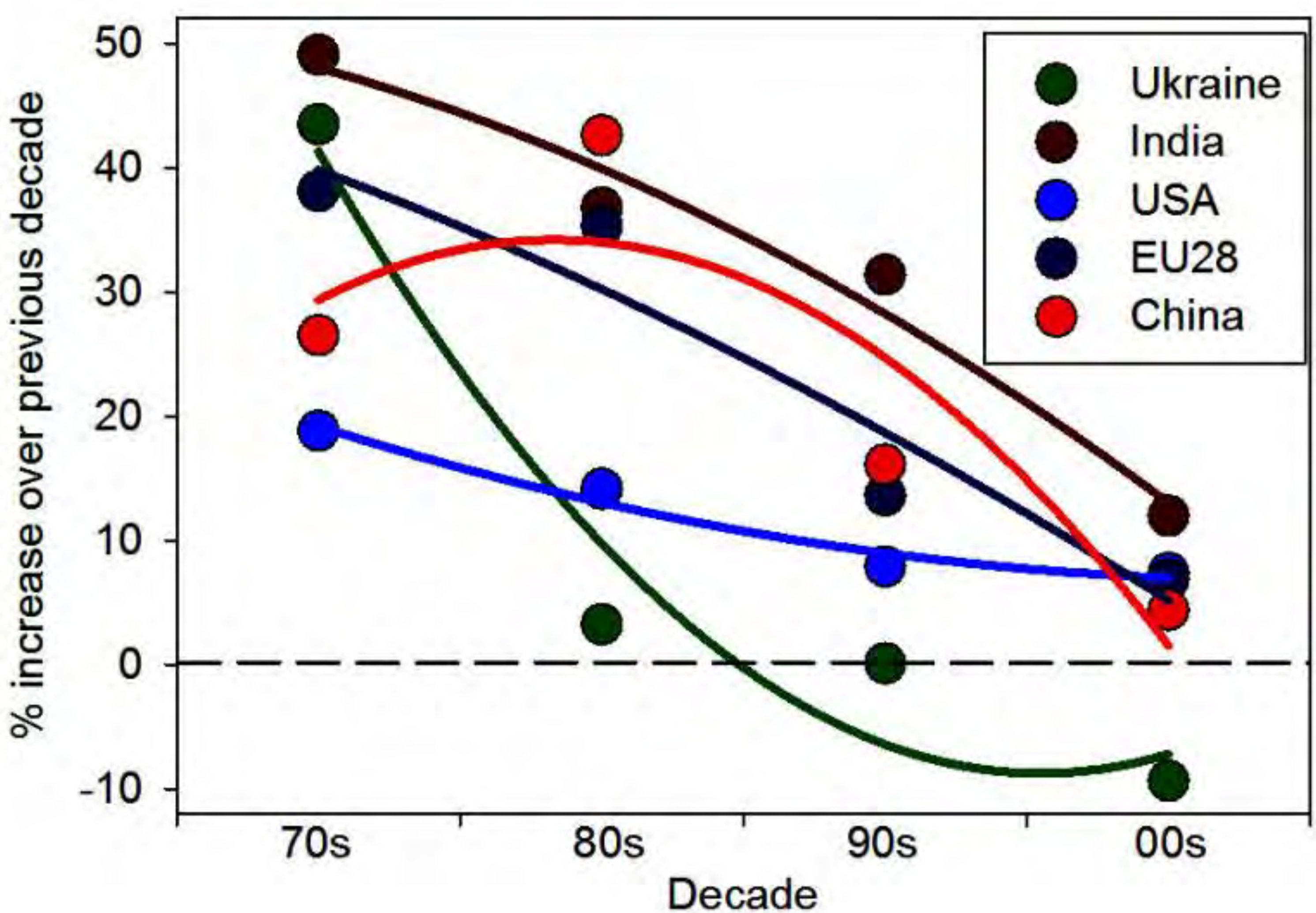
Trends, Signs and Signatures from the Earth

Wheat - Production and Yield – Selected Countries



Trends, Signs and Signatures from the Earth

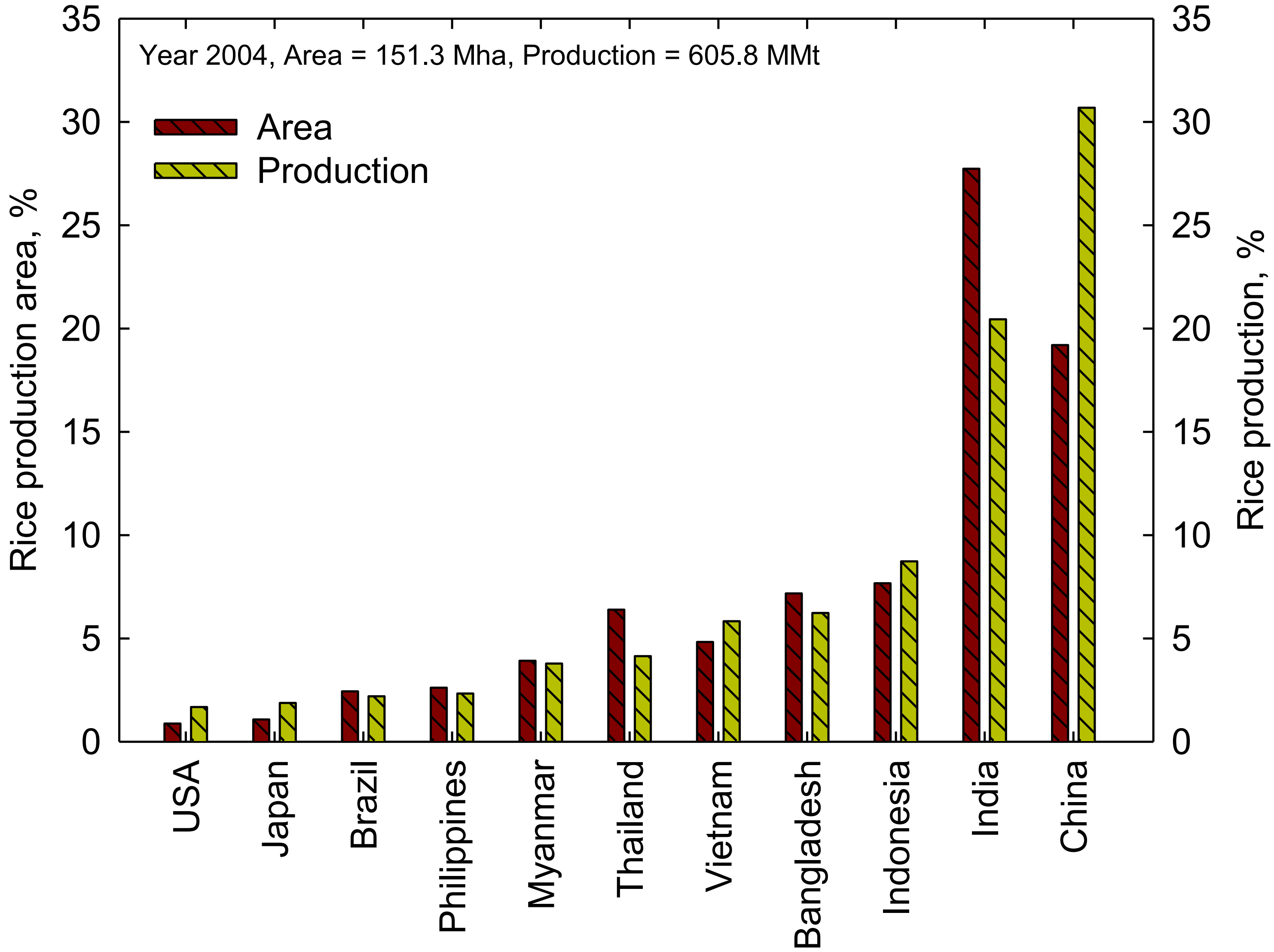
Rate of improvement in wheat yield per unit land area is declining



Stephen Long, CSA News, 2014

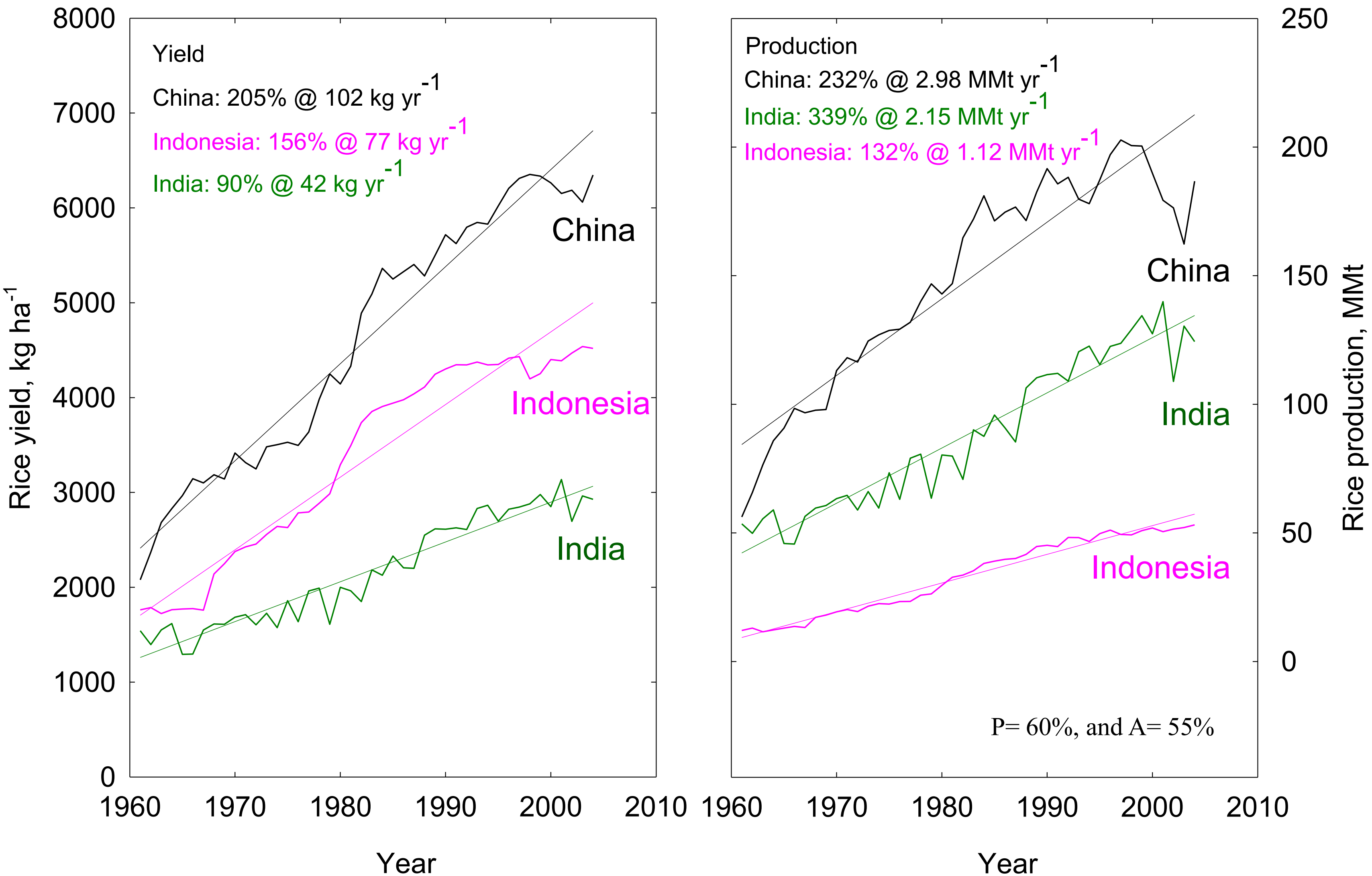
Trends, Signs and Signatures from the Earth

Rice - Production and Yield – Selected Countries



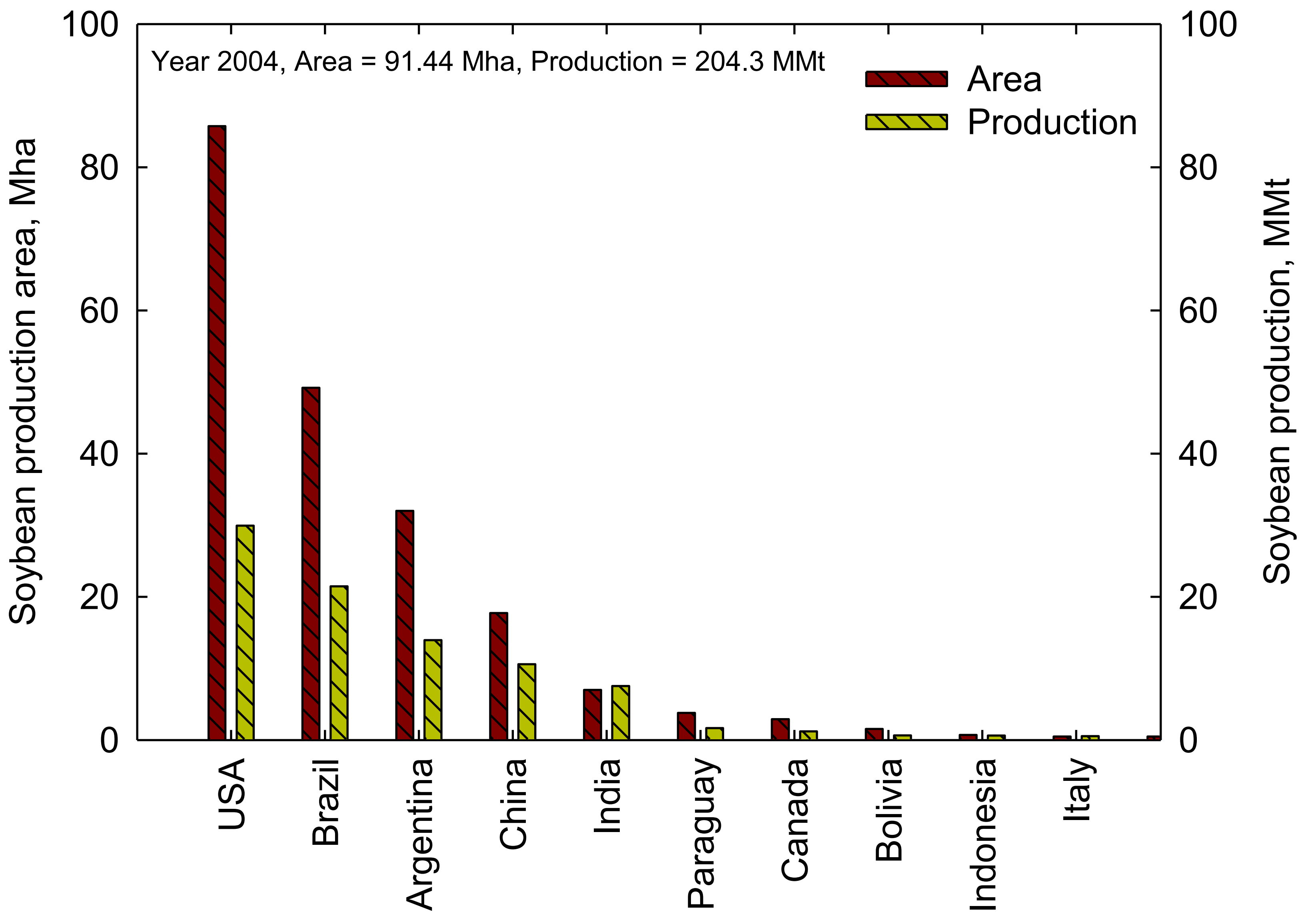
Trends, Signs and Signatures from the Earth

Rice - Production and Yield – Selected Countries



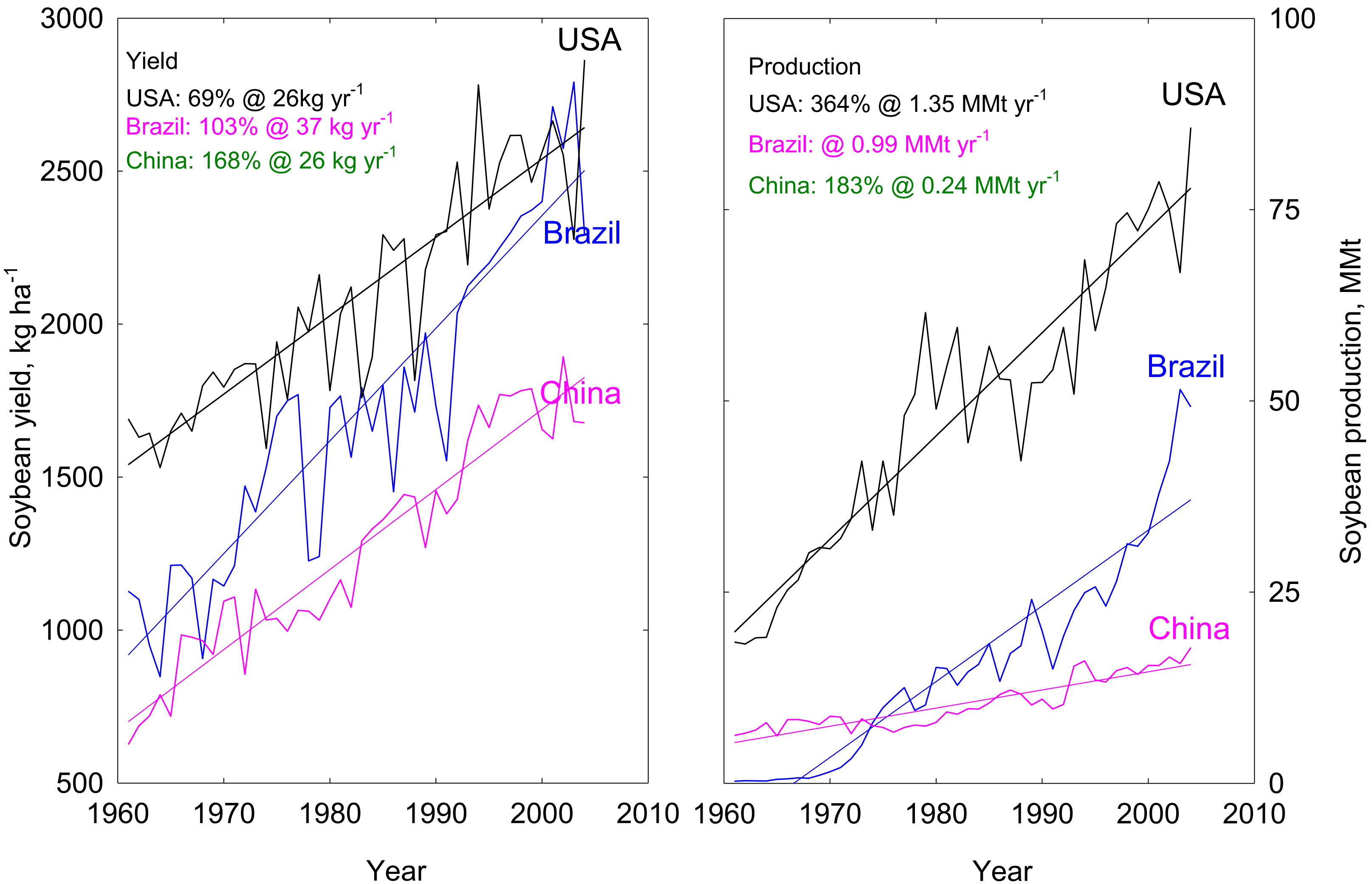
Trends, Signs and Signatures from the Earth

Soybean - Production and Yield – Selected Countries



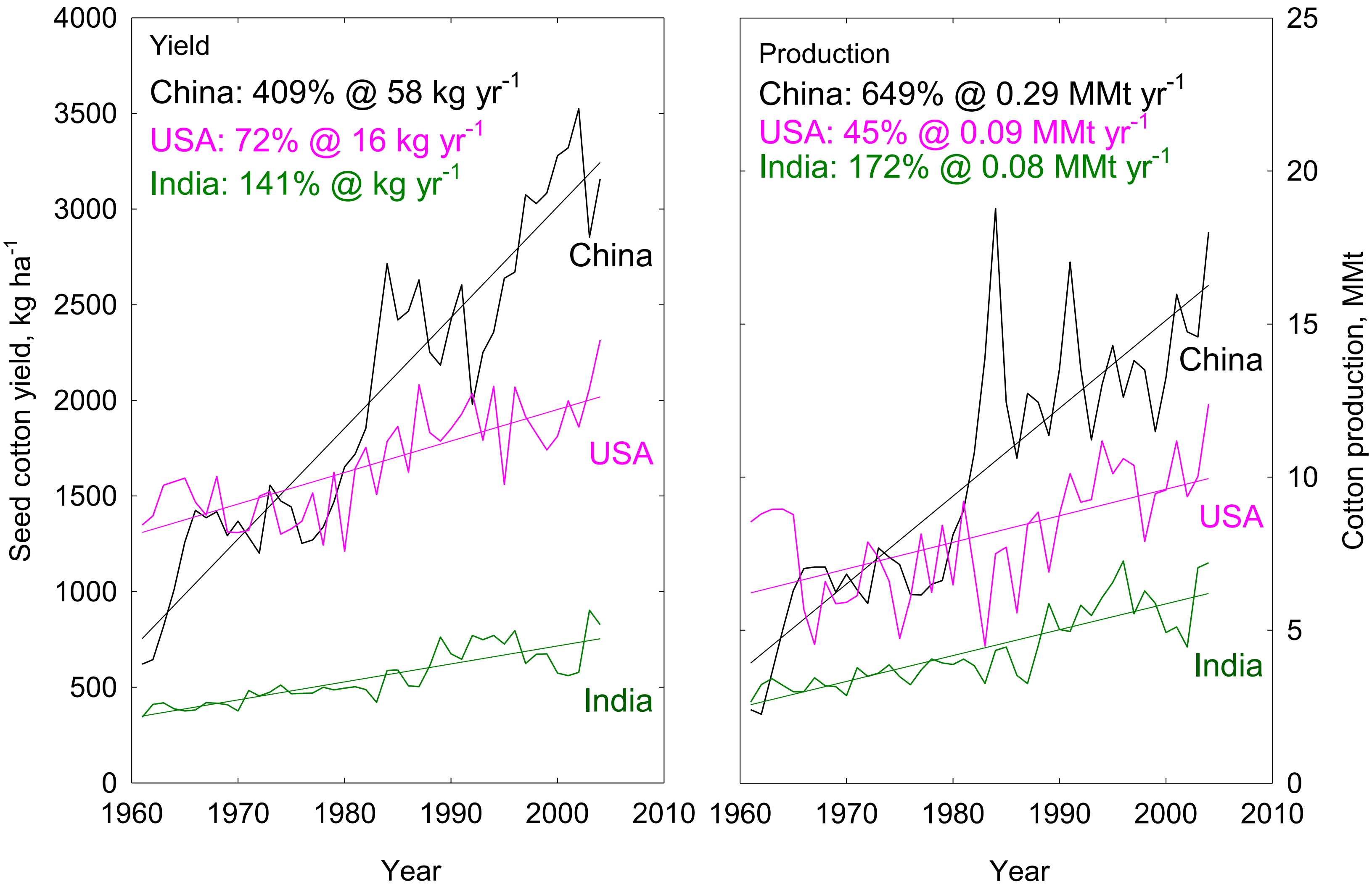
Trends, Signs and Signatures from the Earth

Soybean - Production and Yield – Selected Countries



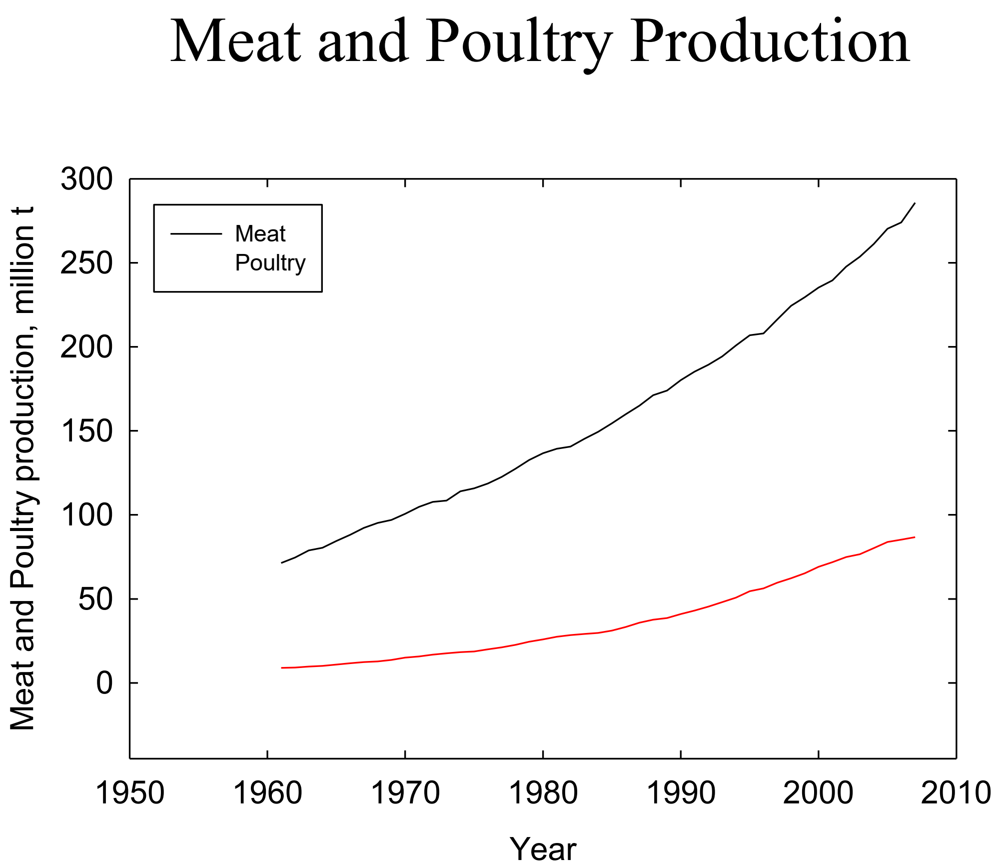
Trends, Signs and Signatures from the Earth

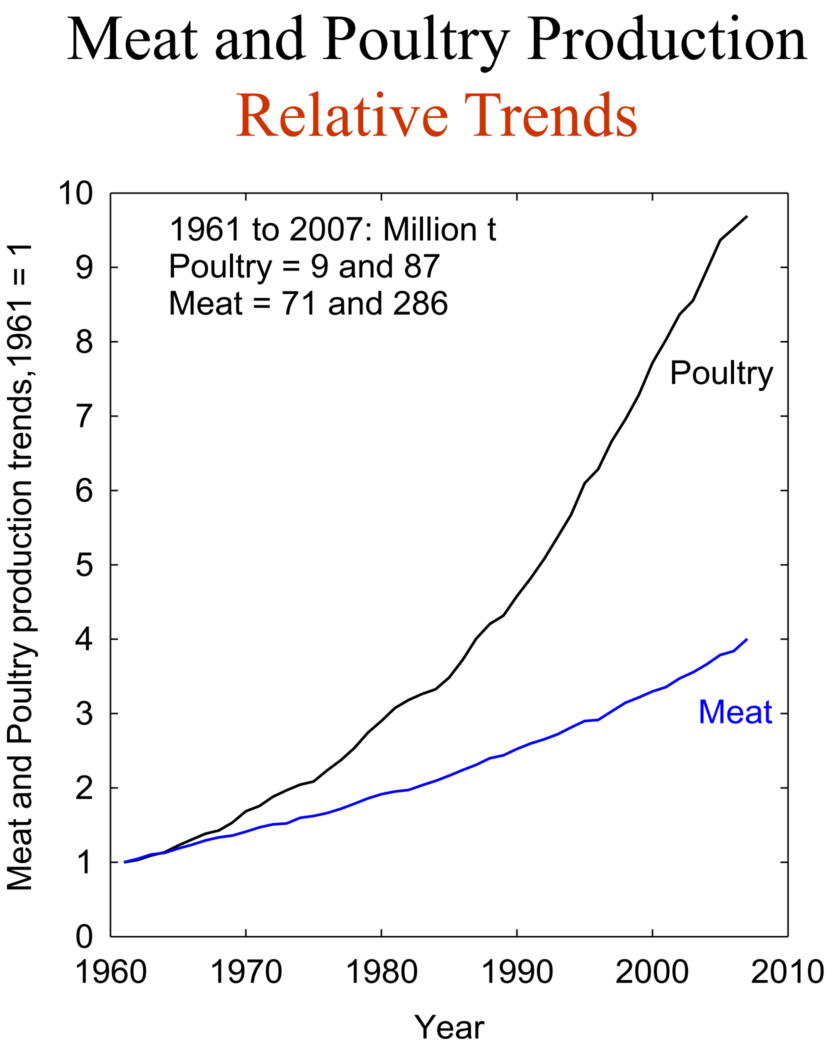
Cotton - Production and Yield – Selected Countries



Trends, Signs and Signatures from the Earth

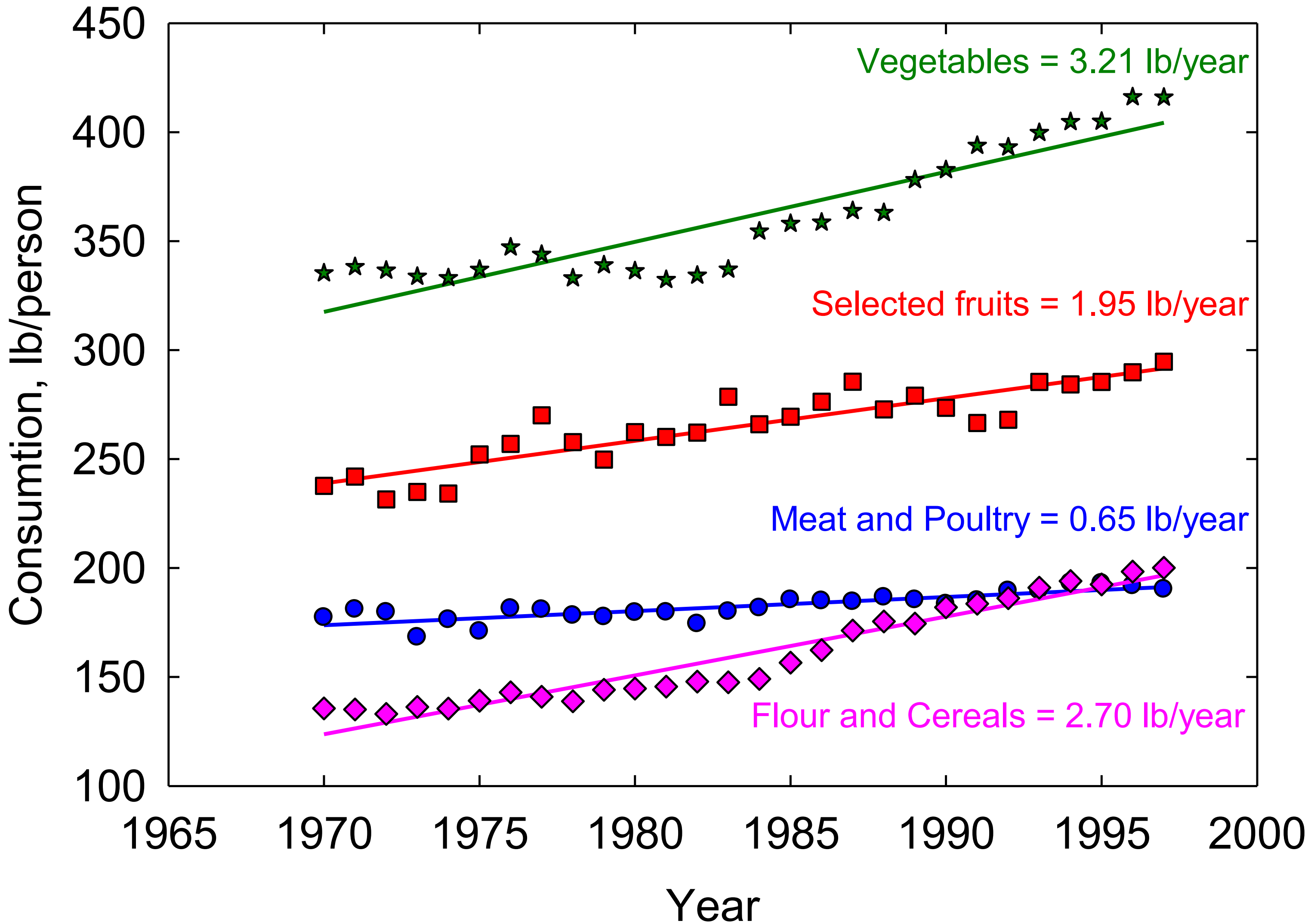
Global Major Foods – Meat and Poultry Production





Trends, Signs and Signatures from the Earth

Global Major Foods – Per Capita Consumption



Trends, Signs and Signatures from the Earth

Management Practices – Cropland area, Irrigation & Salinization

Whatever We do, It will Cost Us

Percentage change from Year 1985 to 2000

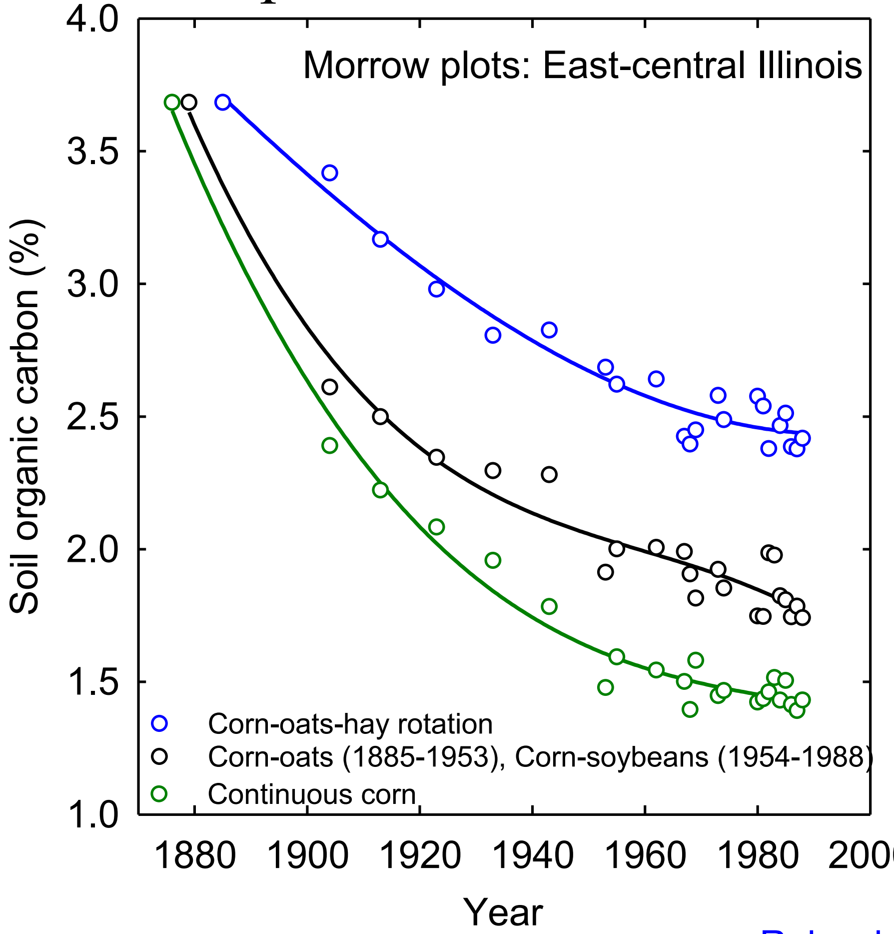
	Cropland area	Irrigated area		Salinized area	
	---------------------------- Mha	-------------------------------			
China	124.0	54.4	(22%)	7-8	(14%)
India	161.8	54.8	(31%)	10-30	(50%)
USA	177.0	22.4	(13%)	4.5 -6	(15%)
USSR	204.1	19.9	(2%)	2.5-4.5	(21%)
World	1364.2	271.7	(21%)	62-82	(37%)

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

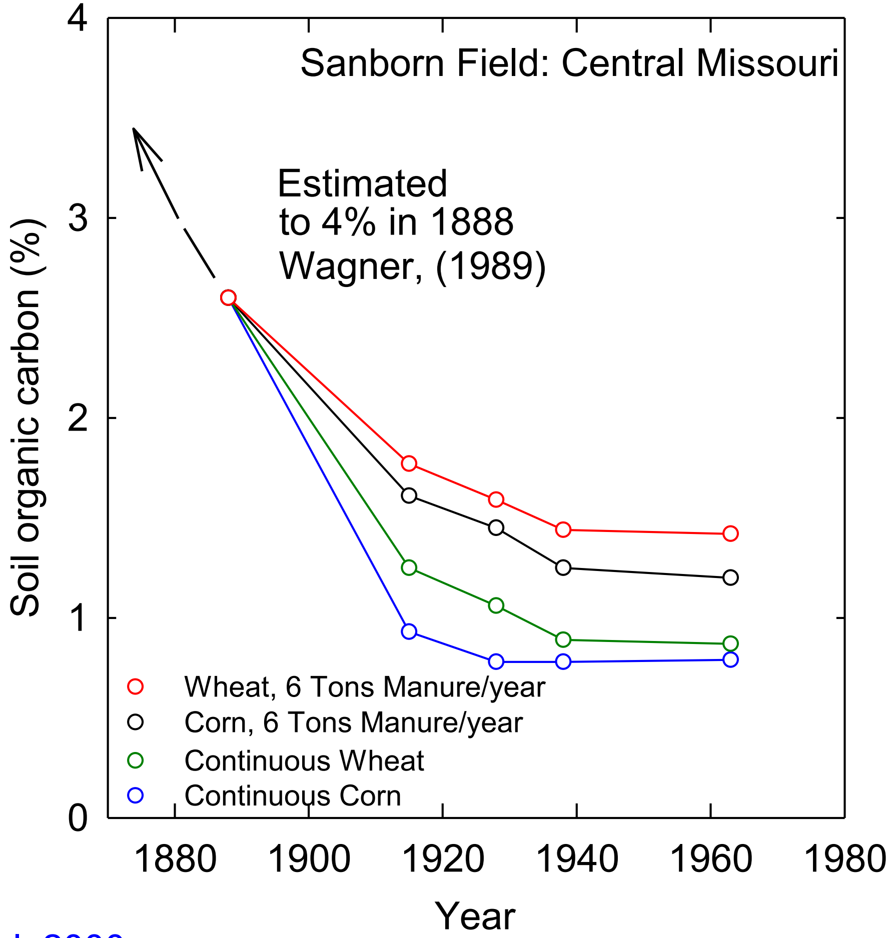
Trends, Signs and Signatures from the Earth

Management Practices – Whatever We do, It will Cost Us

Crop rotations



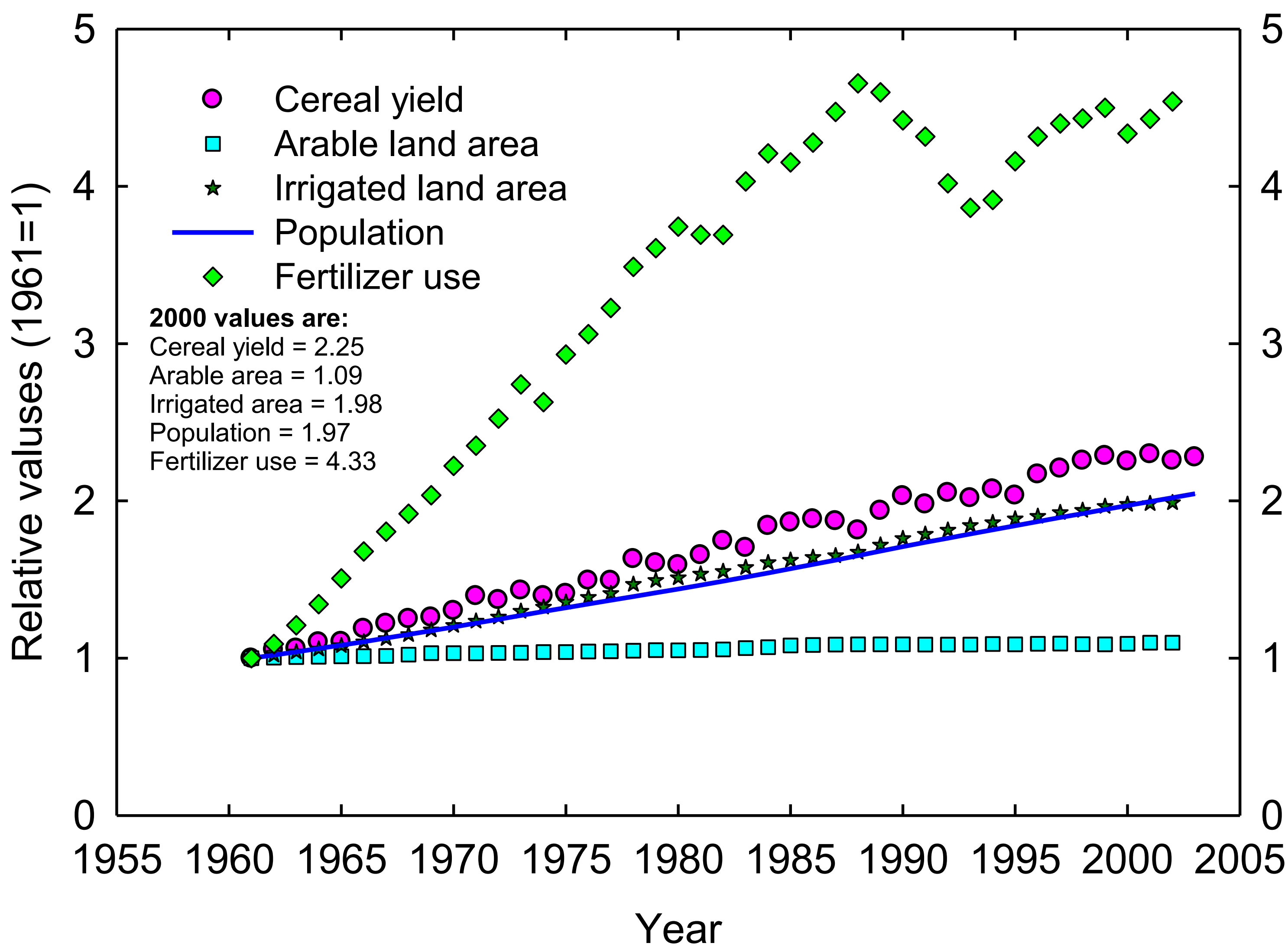
Fertility management



Reicosky et al. 2000

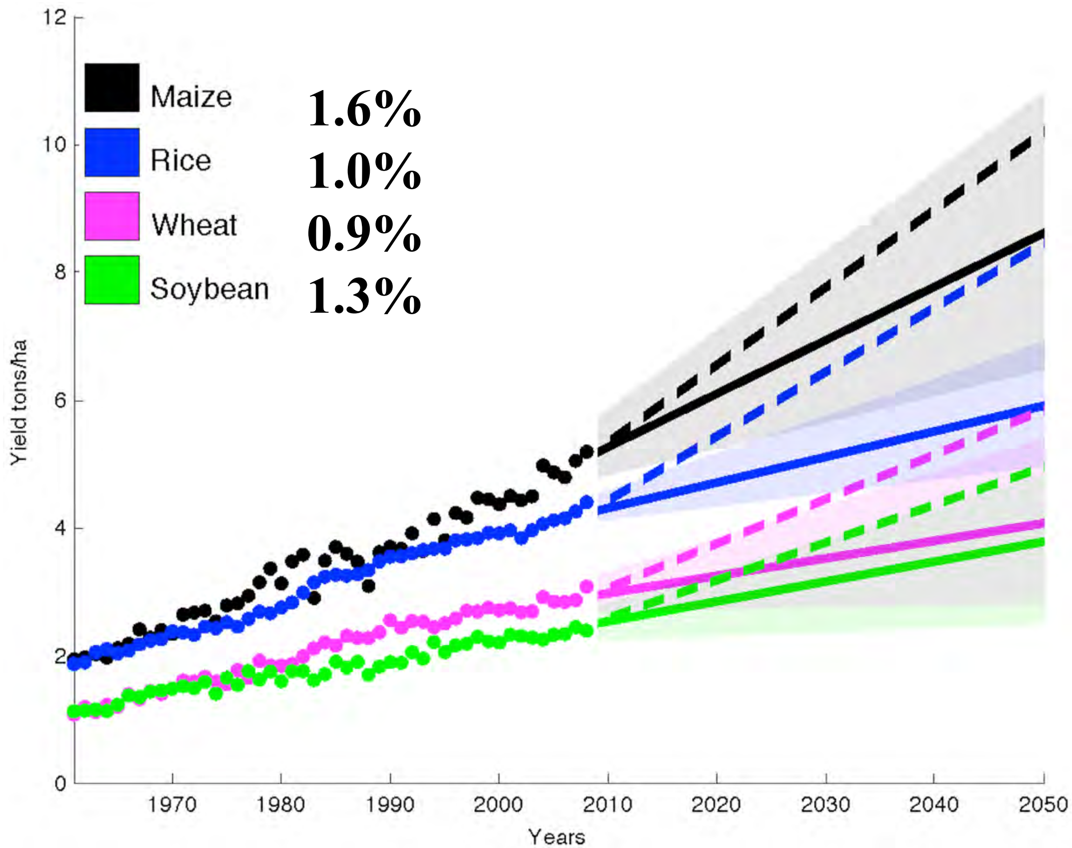
Trends, Signs and Signatures from the Earth

Population, cereal yield, arable and irrigated area, N use



Trends, Signs and Signatures from the Earth

Yield Trends of Major Crops – Past and Future



- Yield has to be doubled by 2050 to meet the demands of rising population with higher earning capacity, diet shifts, and increasing biofuels consumption.
- Based on past trends, projected rate of yield increase was about **1.2%** per year, but we need about **2.4%** per year to double the current yields for major cereal crops including rice.

Ray et al., 2013, PLOSOne

Feeding 10 Billion Mouths

We must develop the capacity to feed 10 billion people within in the next 35 to 85 years.

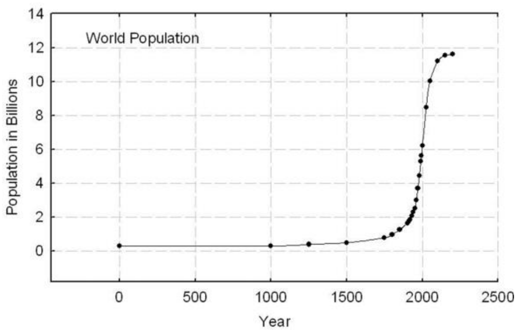
- The average world current cereal yield is about 3.89 tons per ha for about 7.2 billion people (year 2014).
- We need about 5.24 tons per ha for 9.7 billion (2050; 35 % more than the current), and 5.94 tons per ha for 11 billion (2100; 53% more than the current).

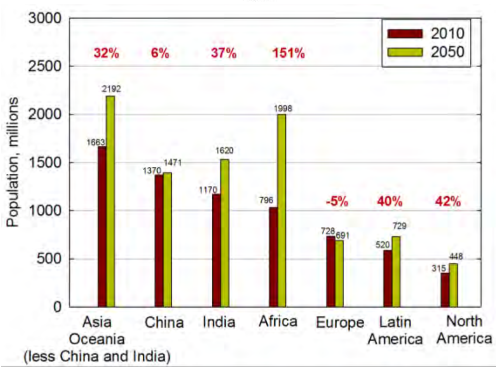
Routes to Greater Food Production

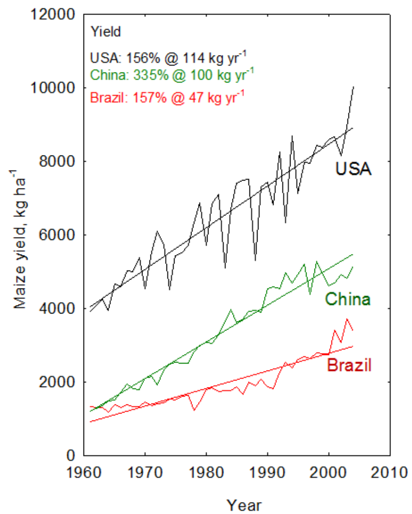
- Increase in the area of land under cultivation.
- Increase in the number of crops per hectare per year (mostly practiced in tropics, requires access to irrigation, high input use, short season cultivars, and others such as labor, pest and disease control may be a problem).
- Displacement of lower yielding 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.

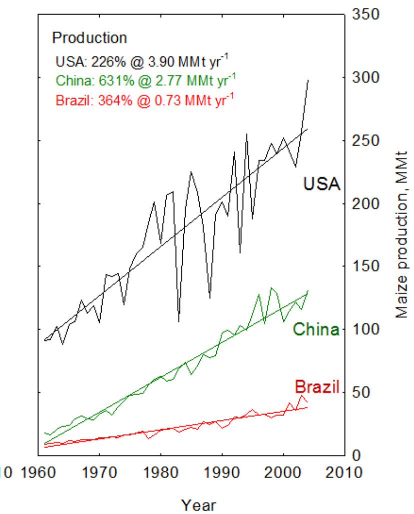
Trends, Constraints, Environmental Stresses and Food Production

Global Present and Past Trends

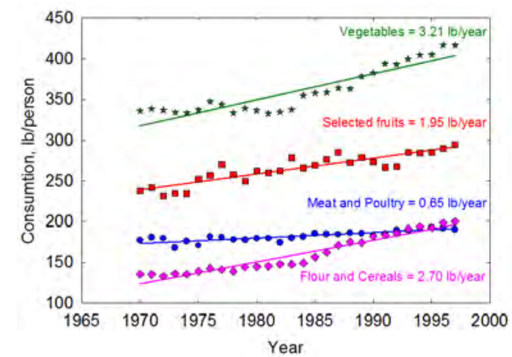




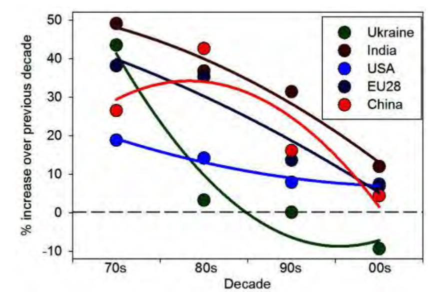




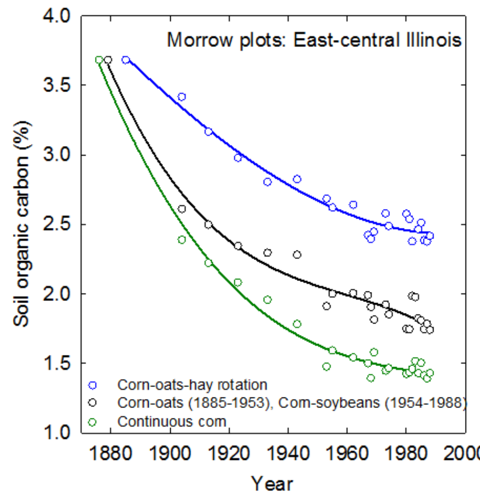
Per Capita Consumption



Percent increase in crop yield over decades



Cropping systems and soil health



Irrigation Practices

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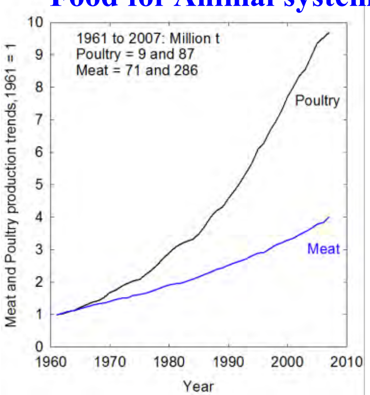
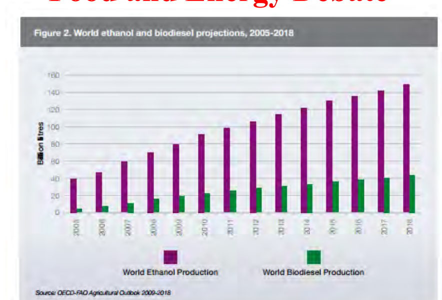
Food for Animal systems



Food and Energy Debate



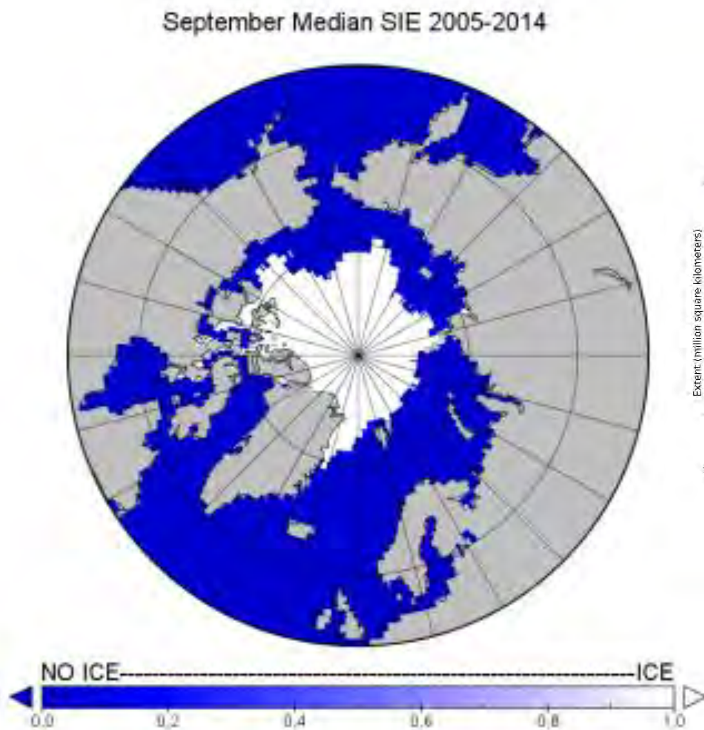

Here comes the greatest
challenge of our time,
The Global Climate Change

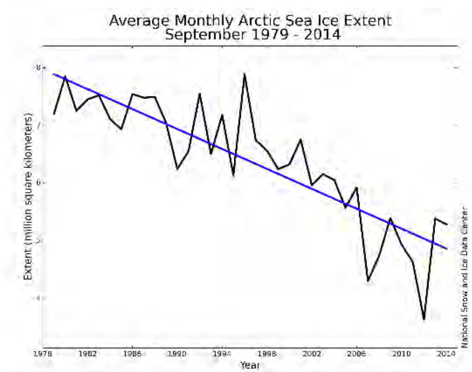
Trends, Signs and Signatures from the Earth

What is Expected in the Future Climate?

- Greenhouse gases (CO_2, CH_4, N_2O etc.) ↑
- Temperatures ↑
- Glaciers ↓
- Oceans and sea-levels ↑
- Precipitation patterns ↓↑ and drought intensities ↑
- Stratospheric ozone ↓ and ground-level UV-B radiations ↑
- Frequency of extreme events ↑

Climate Change Footprint

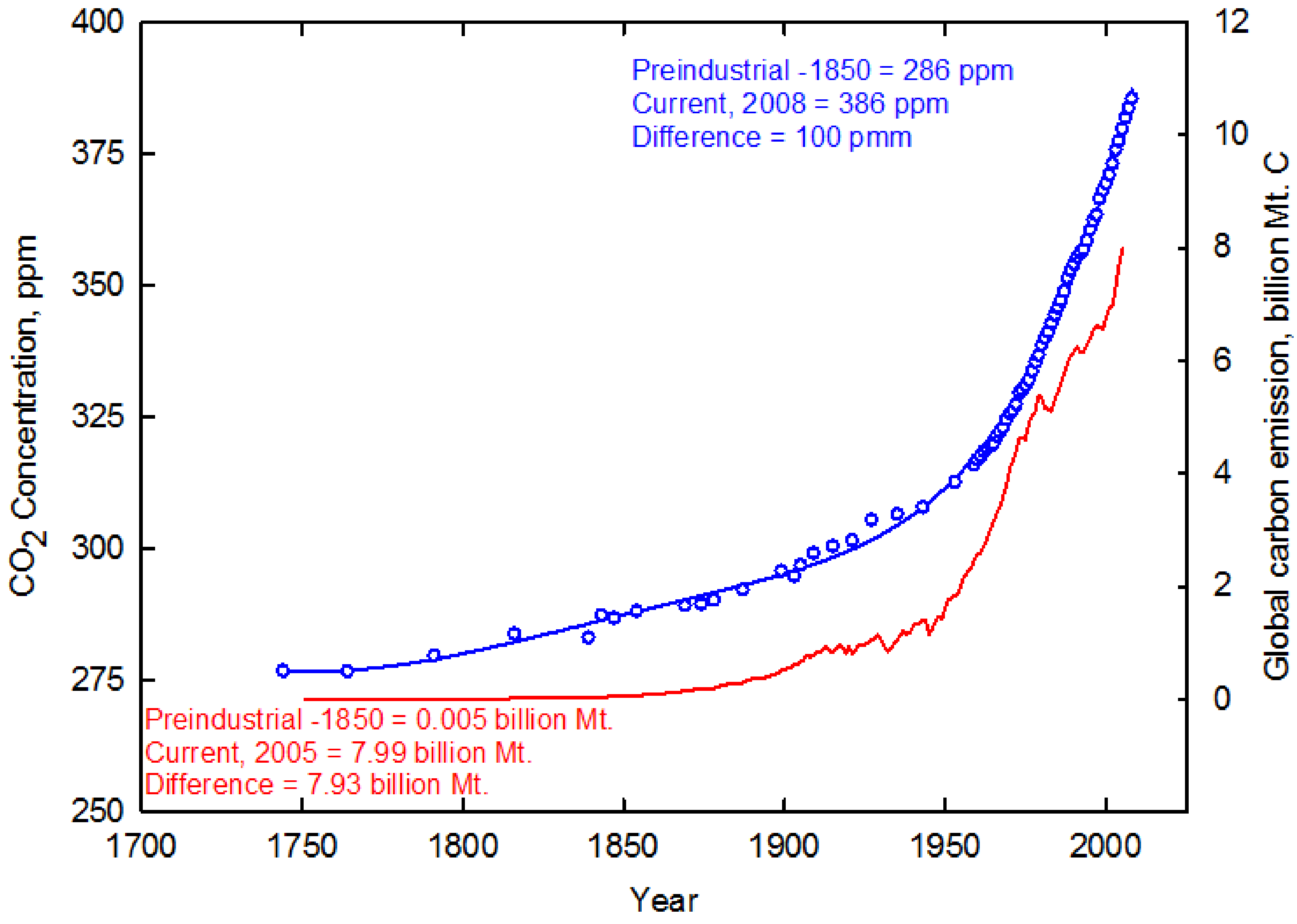


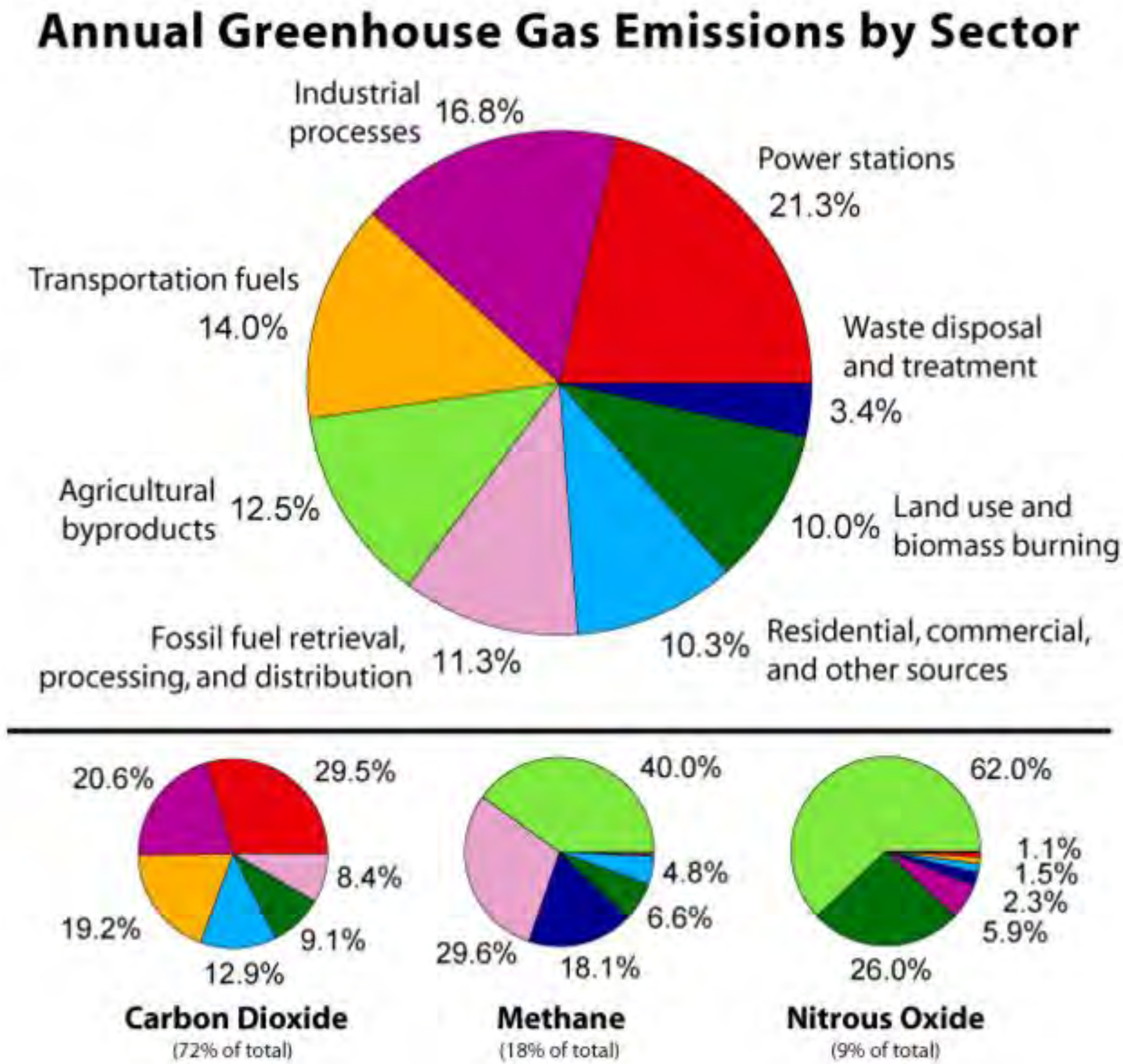


Arctic sea ice reaches its annual minimum in September. The satellite images above show September Arctic sea ice in 1935-44 and 2005-2014.

Trends, Signs and Signatures from the Earth

Atmospheric Carbon Dioxide Concentration

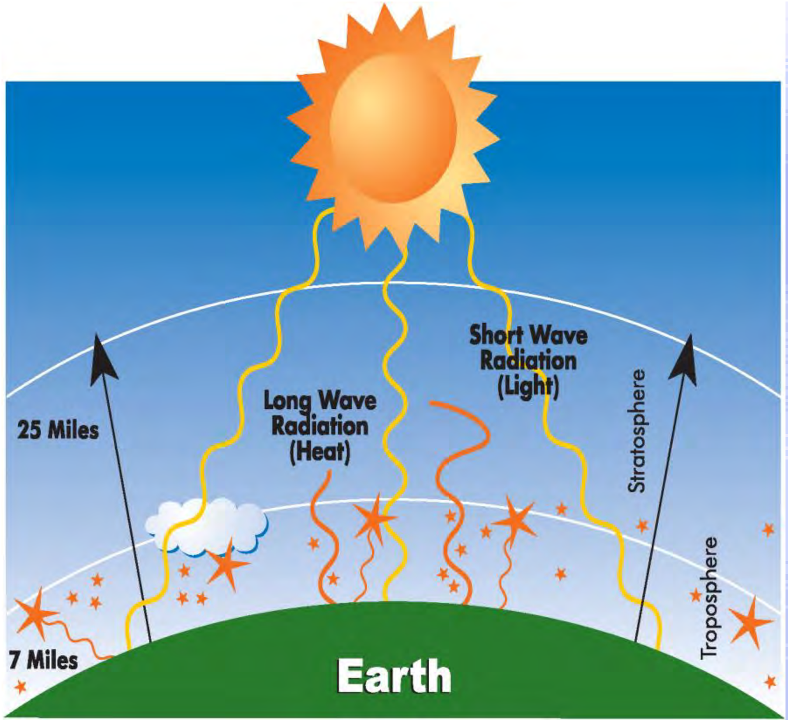




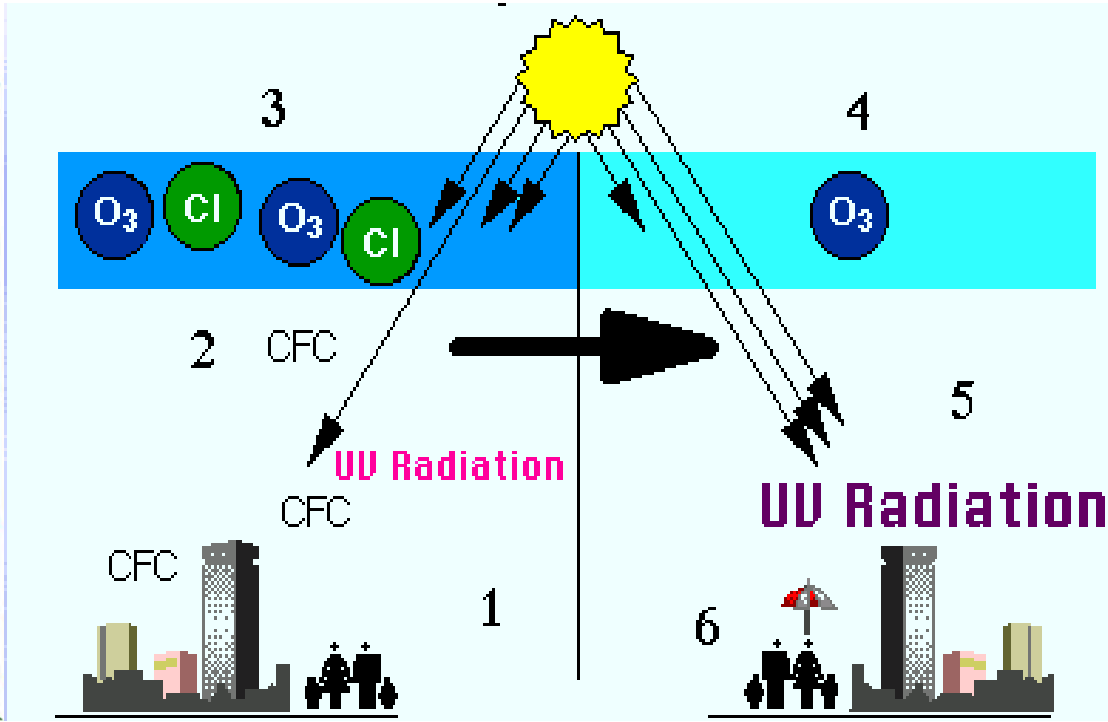
www.climatelab.org

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

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

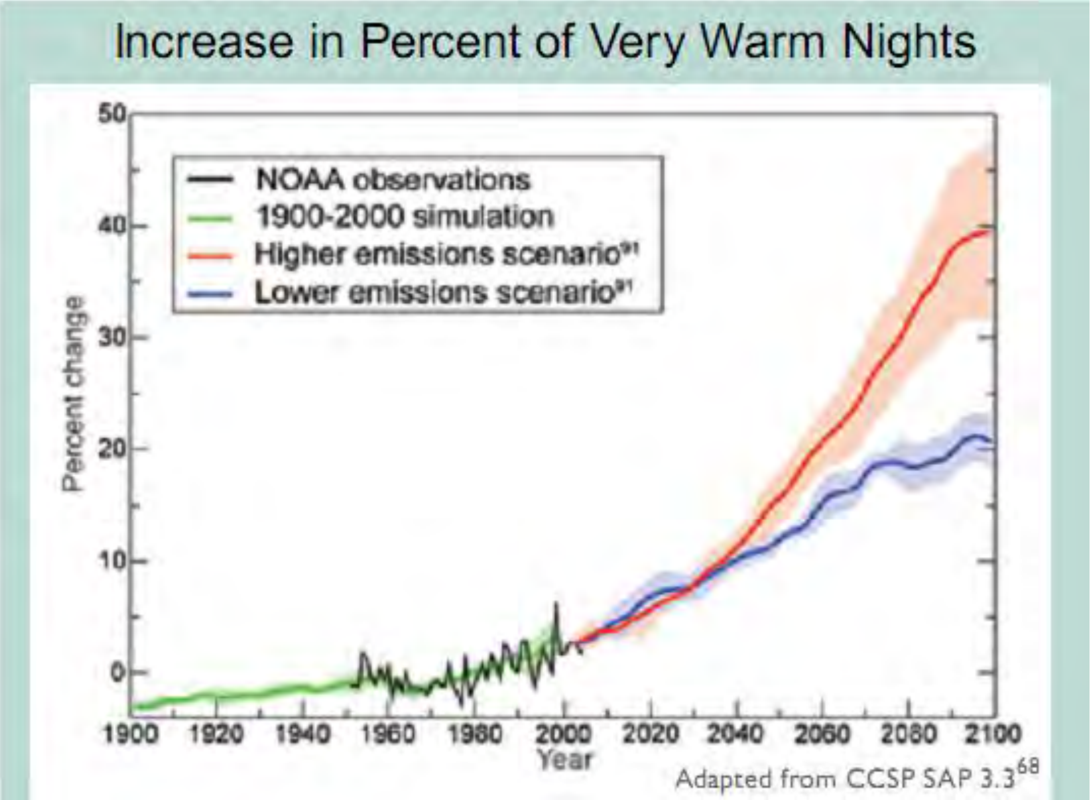
Trends, Signs and Signatures from the Earth

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 °C	0.8-2.6 °C	2.4-6.4 °C
Global mean sea-level rise from the year 1990	3-14 cm	5-32 cm	26-59 cm

Climate change footprint

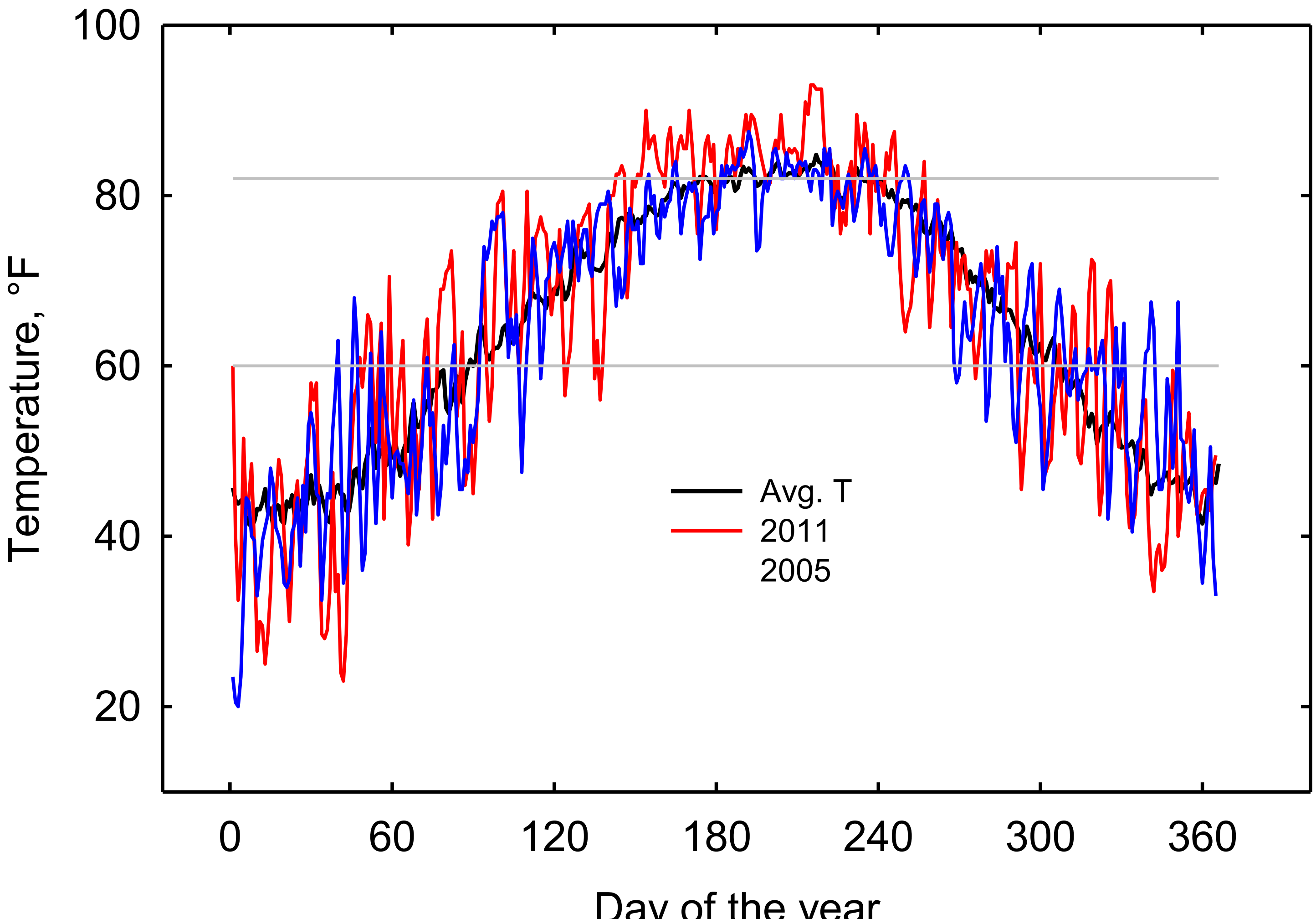
Changes in night time temperature



The graph shows the observed and projected change in percentage of very warm nights from the 1950-1990 average in the United States. Under the lower emissions scenarios, the percentage of very warm nights is projected to increase about 20% by 2100. Under the higher emissions scenario it is projected to increase by about 40%. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. The projections appear smooth because they show the calculated average of many models.

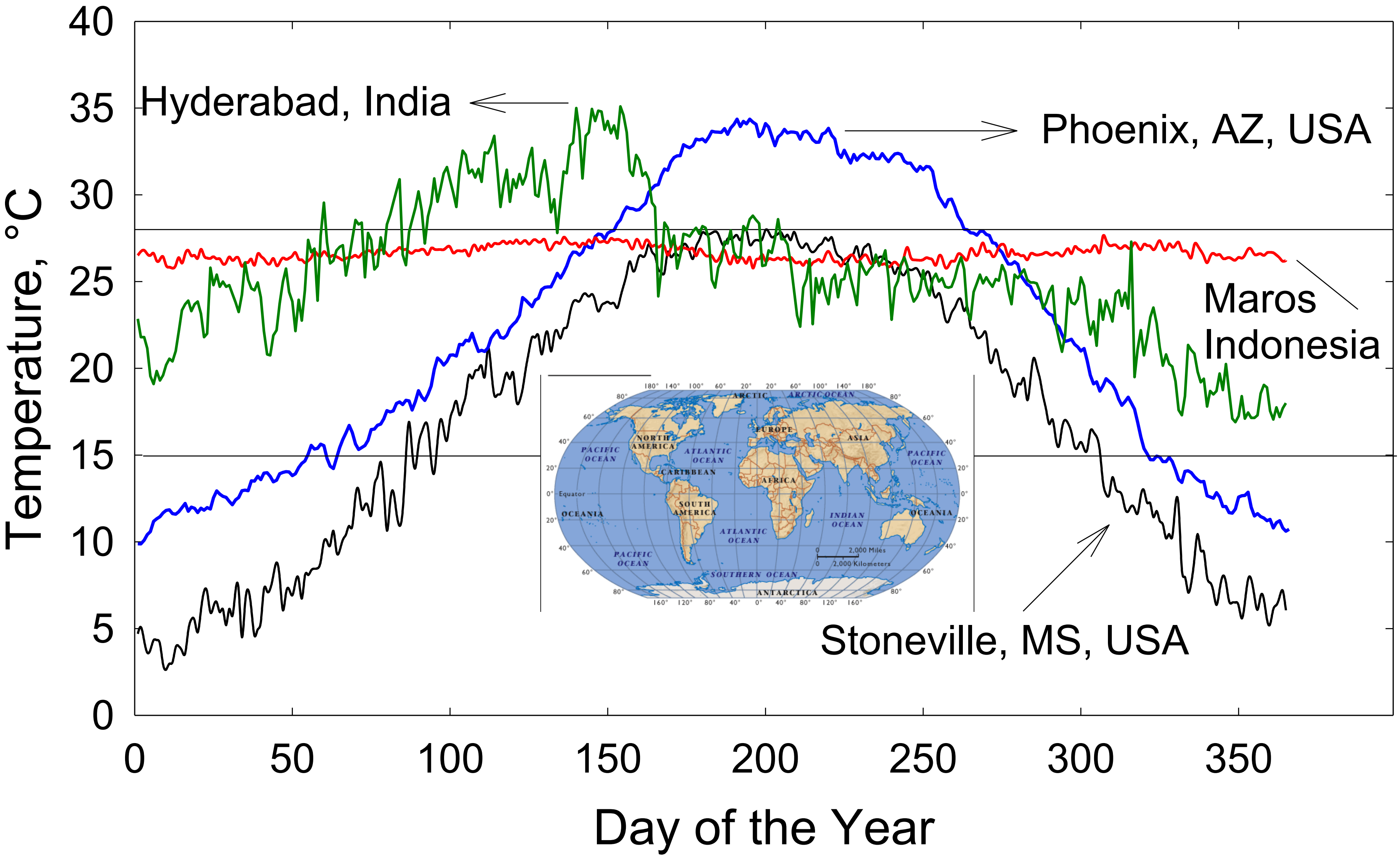
Trends, Signs and Signatures from the Earth

In a production environment, no two seasons are equal



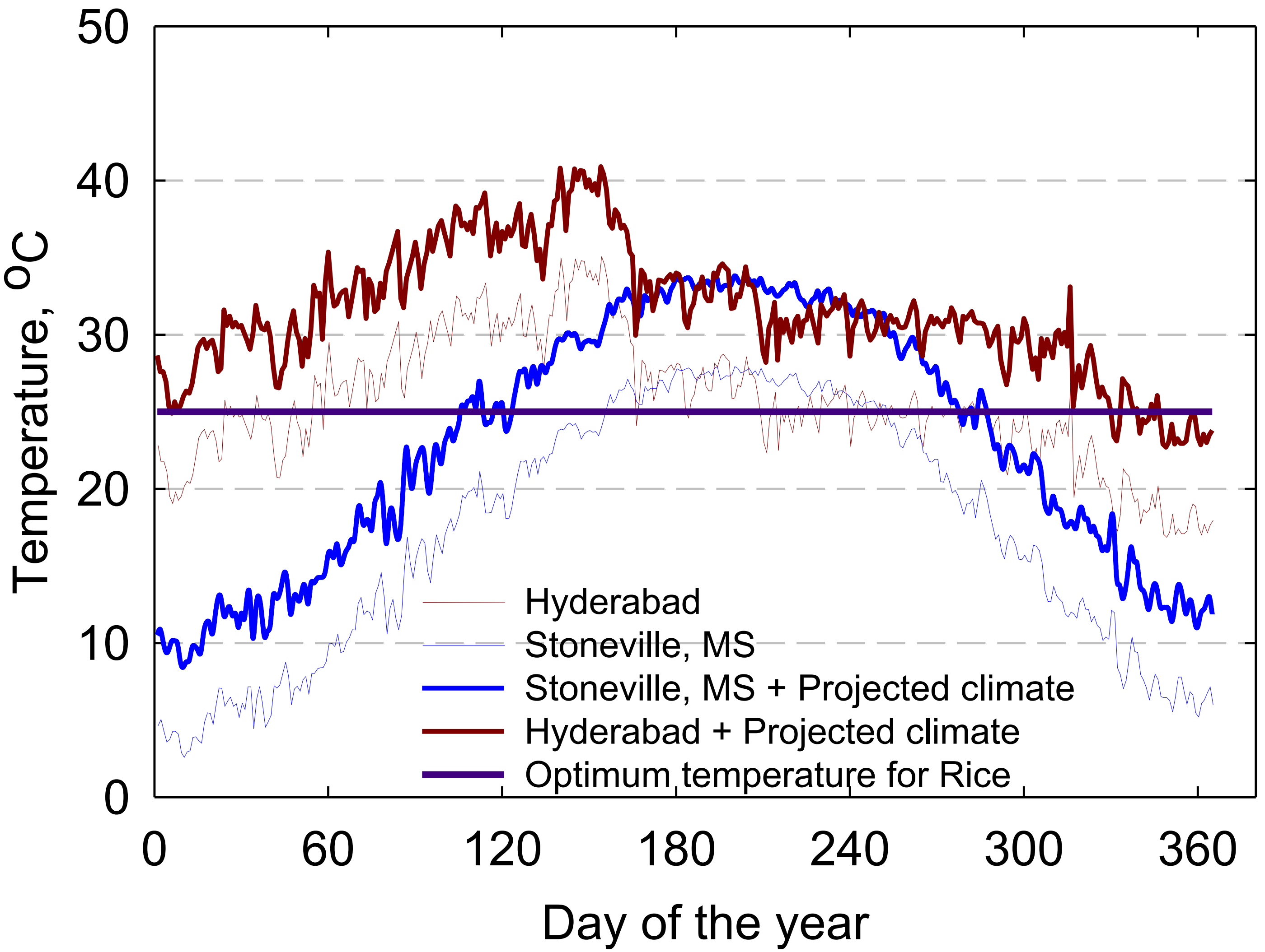
Trends, Signs and Signatures from the Earth

Spatial and temporal trends in climate



Trends, Signs and Signatures from the Earth

Present and Projected Temperature Changes



Climate Change and Crop Productivity
Some Considerations

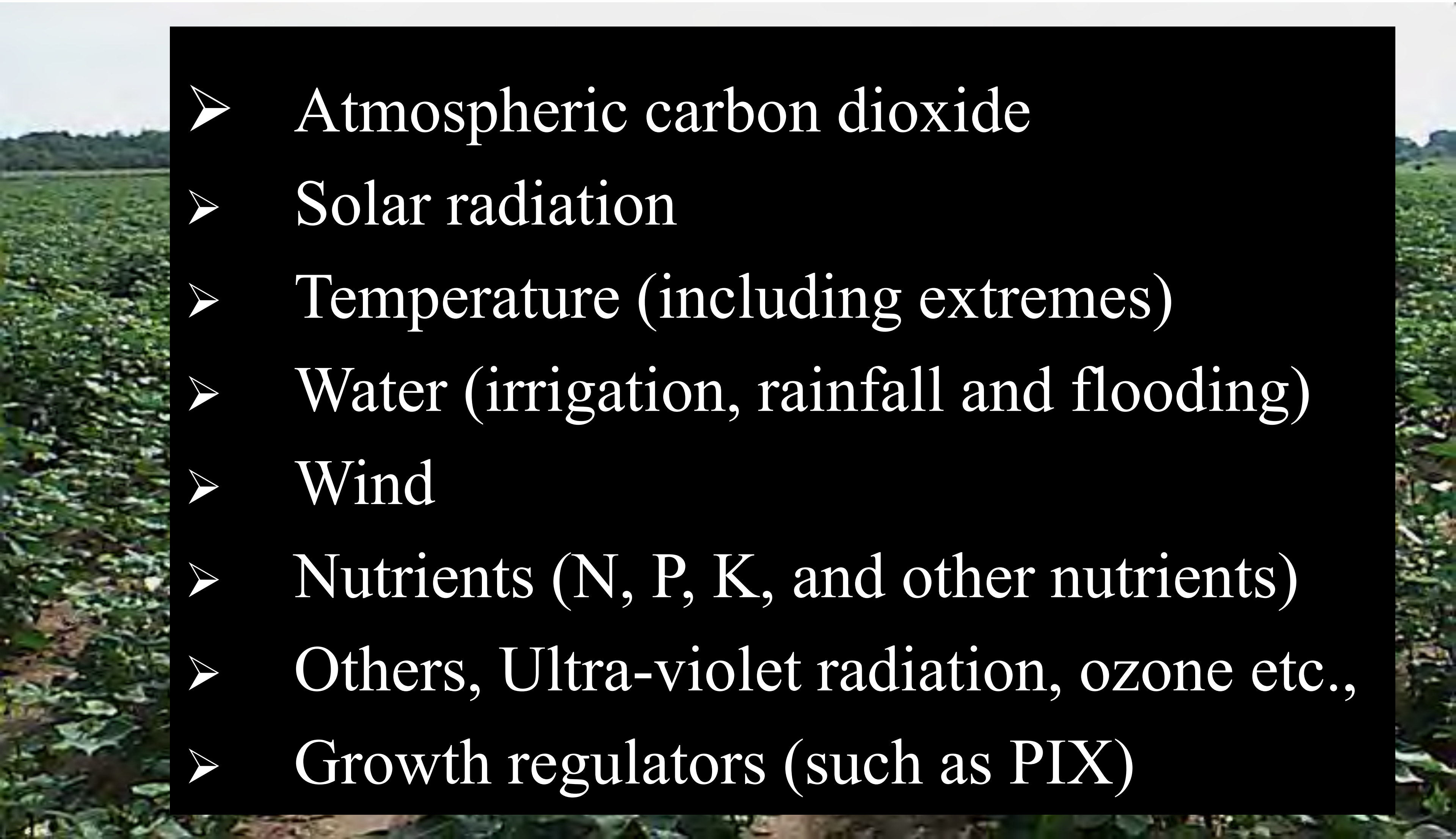
- As human population expands and demand upon natural resources increases, the need to manage the environments in which people live becomes more important, but also more difficult.
- Climate change has no boundaries, and can't be viewed in isolation.
- We should consider other stresses on food production systems such as population dynamics, habitat destruction and fragmentation, land-use changes, biodiversity, land and water management and invasive species dominance.

Climate Change and Crop Productivity
Some Considerations

- Land and water management is especially critical as the use of upstream watersheds can drastically affect large numbers of people living in downstream watersheds.
- The current and projected changes in climate are unprecedented, and the ecosystems including managed ecosystems such as agriculture may not cope with the changes projected in climate.
- An integrated approach that stresses both the importance of participatory planning and the institutional and technical constraints and opportunities is therefore necessary.

Environmental Stresses and Plant Growing Conditions

Environmental and Cultural Factors Limiting Potential Yields



- Atmospheric carbon dioxide
- Solar radiation
- Temperature (including extremes)
- Water (irrigation, rainfall and flooding)
- Wind
- Nutrients (N, P, K, and other nutrients)
- Others, Ultra-violet radiation, ozone etc.,
- Growth regulators (such as PIX)

Area of Total World Land Surface Subject to Environmental Limitations of Various Types

Limitation	Area of world soil subject to limitation (%)
Drought	27.9
Shallow soil	24.2
Mineral excess or deficiency	22.5
Flooding	12.2
Miscellaneous	3.1
None	10.1
Total	100
Temperature	14.8 (over laps with other stresses)

Environmental Stresses and Crop Productivity

Factors Affecting Yields of Major US Crops

Major US Crops – Record yield, average yield and losses due to various factors

	Yield, kg ha^{-1}						Physiochemical
Crop	**Record**	**Average**	**Diseases**	**Insects**	**Weeds**	**Physiochemical**	**%**
Maize	19,300	4,600	836	836	697	12,300	**64**
Wheat	14,500	1,880	387	166	332	11,700	**81**
Soybean	7,390	1,610	342	73	415	4,950	**67**
Sorghum	20,100	2,830	369	369	533	16,000	**80**
Oat	10,600	1,720	623	119	504	7,630	**72**
Barley	11,400	2,050	416	149	356	8,430	**74**
Potato	94,100	28,200	8,370	6,170	1,322	50,000	**53**
Sugar beet	121,000	42,600	10,650	7,990	5,330	54,400	**45**
Mean	**100**	**21.5**	**5.1**	**3.0**	**3.5**	**66.9**	**67**

Physiochemical = Record yield – (average yield + disease loss + insect loss + weed loss)

Environmental Plant Physiology
Objectives

- The objectives of this course are to learn plant responses to abiotic stresses, particularly plant growth and development, and to learn modeling methodologies on how to integrate those plant processes under multiple stress conditions.
- At the end, the students are expected to:
  - ✓ understand individual as well as interactive abiotic stress effects on photosynthesis, respiration, growth, development and finally yield.
  - ✓ understand on how to develop methodologies to integrate multiple stress factor effects on various plant/canopy processes.

Environmental Plant Physiology

Chapter 1:

- Atmospheric carbon dioxide
- Solar radiation
- Temperature (Including extremes)
- Water (rainfall, flooding, and irrigation)
- Wind
- Nutrients
- Other factors such as ozone
- Plant growth regulators
- The facilities and tools

Environmental Plant Physiology

Chapter 2:

Photosynthesis and the environment

- The Environmental productivity index (EPI) concept.
- The photosynthesis - Species variability.
- Photosynthesis and aging process.
- Respiration.

Chapter 3:

Crop growth and development

- Phenology
- Growth of various organs and whole plants.
- The concept of environmental productivity index in quantifying crop growth and development in response to the environment.

Environmental Plant Physiology

Chapter 4:

Scaling of processes from leaves to whole plant, canopies or ecosystems.

Chapter 5:

Special topics include:

- Plant growth regulators – PIX.
- Remote sensing and environmental plant physiology.

Environmental Plant Physiology
Introduction

Suggested reading:

- Environmental Plant Physiology. 2016. N. Willey, New York, NY. 390p.
- Feeding the Ten Billion-Plants and Population Growth- 1998, L. T. Evans, Chapter 12, pages 195-225.
- Crop Science Progress and Prospects- 2000, edited by J. Nosberger, H. H. Geiger and P. C. Struik, Chapter 3, Crop Science research to assure food security by K.G. Cassman, pages, 33-51.
- Crop Responses to Environment –2001, A. E. Hall. Chapter 1, Introduction, pages 1-7.
- Meeting cereal demand while protecting natural resources and improving environmental quality, KG Cassman, A. Dobermann, DT Walters and H. Yang, Annual Review of Environmental Resources, 2003, 28:315-358.