Engineering Crops for the Developing World

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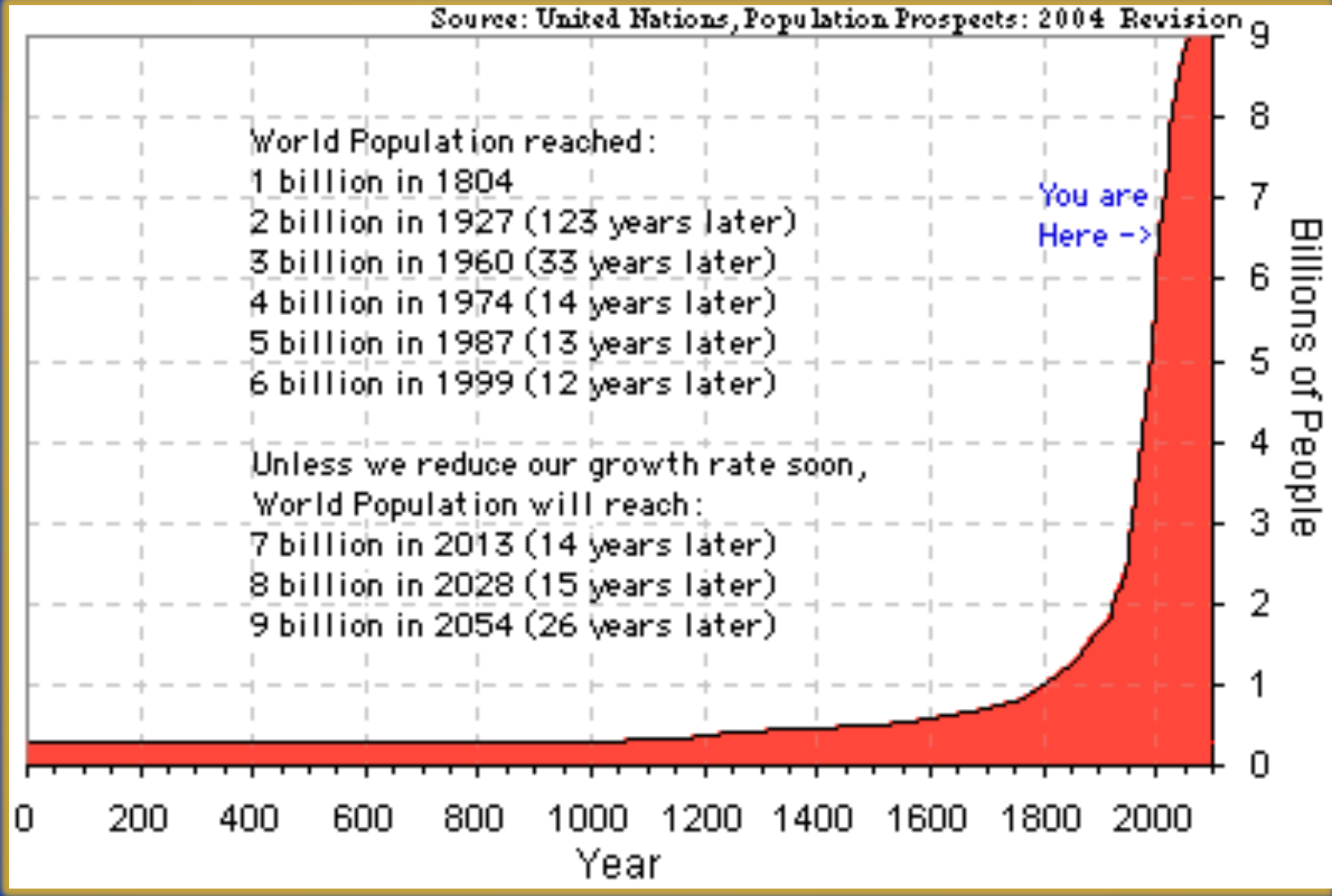
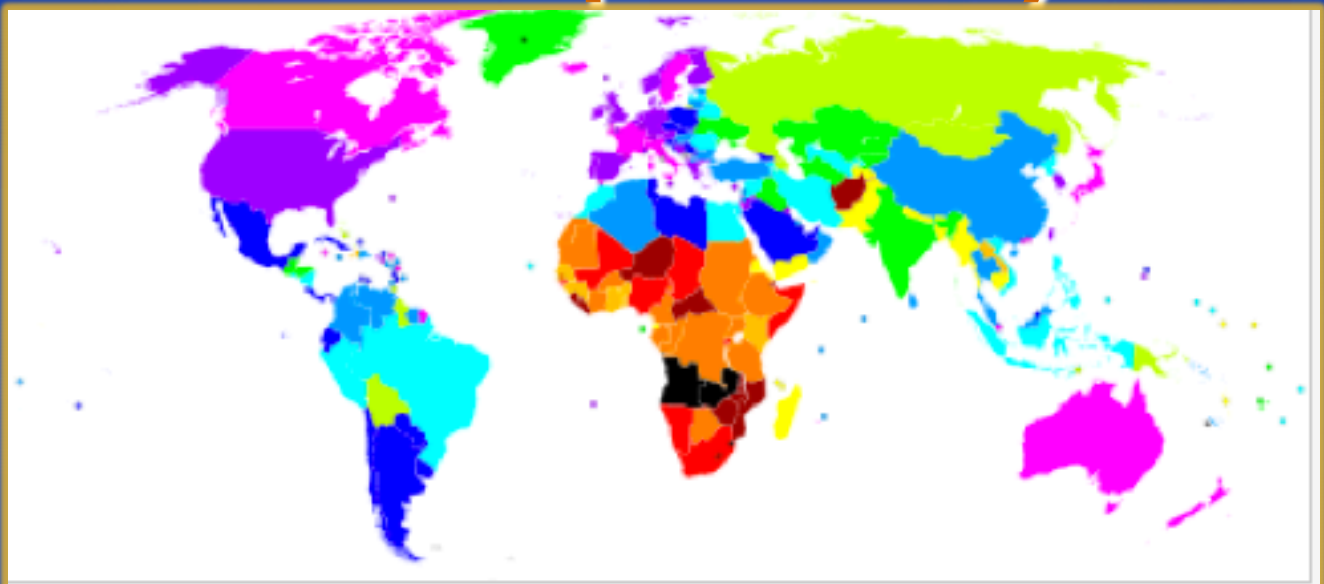
World Population Growth



Life Expectancy

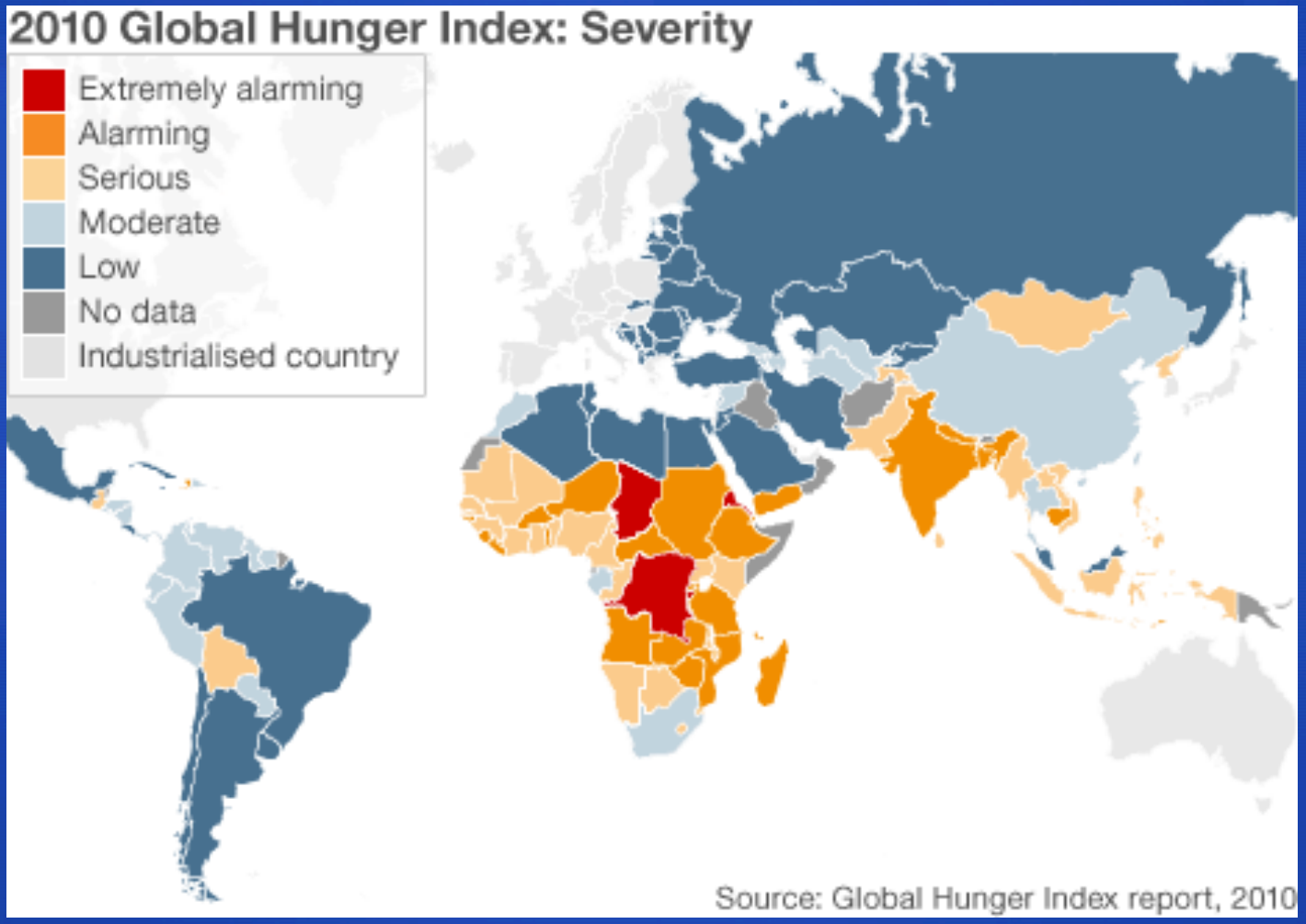


CIA World Factbook 2008 Estimates for Life Expectancy at birth (years).

over 80	60-65
77.5-80	55-60
75-77.5	50-55
72.5-75	45-50
70-72.5	40-45
67.5-70	under 40
65-67.5	not available

Source: Wikipedia

Global Hunger Map



Cost of Food is Going Up

Clicker Question

- How many people die every day due to malnutrition and hunger around the globe?
- a. 300
- b. 300,000,000
- c. 30,000

Stark Realities.....

- Nearly a billion people go to bed hungry every day
- About 30,000 people, half of them children, die *every day* due to hunger and malnutrition
- Nearly 1.2 billion people live on less than a dollar a day
- 650 Million of the Poorest Live in Rural Areas

"In the next 50 years, mankind will consume as much food as we have consumed since the beginning of agriculture 10,000 years ago - Dr. Norman Borlaug"

Hunger - why?

- Poverty
- Poor governance
- Low agricultural productivity
- Poor infrastructure (roads, market access..)
- Little science R &D
- Conflicts
- Infectious Diseases (Malaria, HIV)
- International markets

Low Productivity of Agriculture in the Developing World

- Poor soils
- Unfavorable environment
- Little or no chemical input
- Small Holdings
- Drought
- Market Access
- Disease, Pests, Weeds
- Storage and Transportation

Food and Agriculture Organization (FAO)

To feed a world of 9 billion people in 2050, without allowing for additional imports of food:

Africa has to increase its food production by 300 percent

Latin America by 80 percent; and Asia by 70 percent. Even North America must increase food production by 30 percent

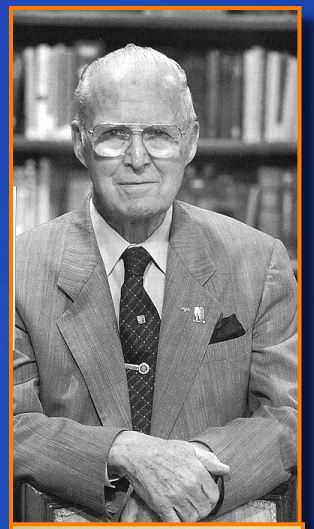
•Without an Increase in Farm Productivity, Additional 1.6 Billion Hectares of Arable Land will be Needed by 2050!

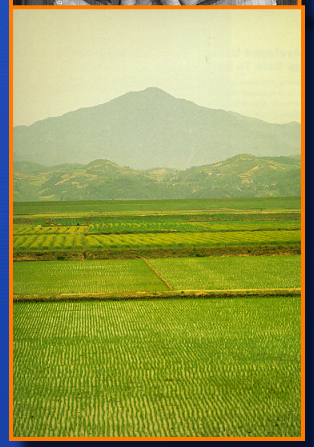
Challenges Ahead….

- **Food Imports Traditionally Do Not Help the Poor**
- **Domestic Food Production Provides for 97% of Consumption in the Low Income Group**
  - ***How to Produce More Food with Less Land, Less Water, Less Chemicals…?***

Innovation in Agriculture

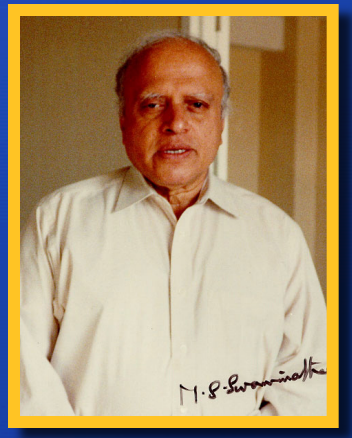
- U.S. Food Production : 252 million tons/year in 1960 to current 700 m. tons/year with 25 million fewer acres
- North American Corn Yields up from 26 bushels/acre (1928) to 180 today
- One North American farmer in 1940 fed 22 people, feeds 150 today.
- 1% of North Americans are Farmers.
- Average 11% of Income on Food





Green Revolution . . .

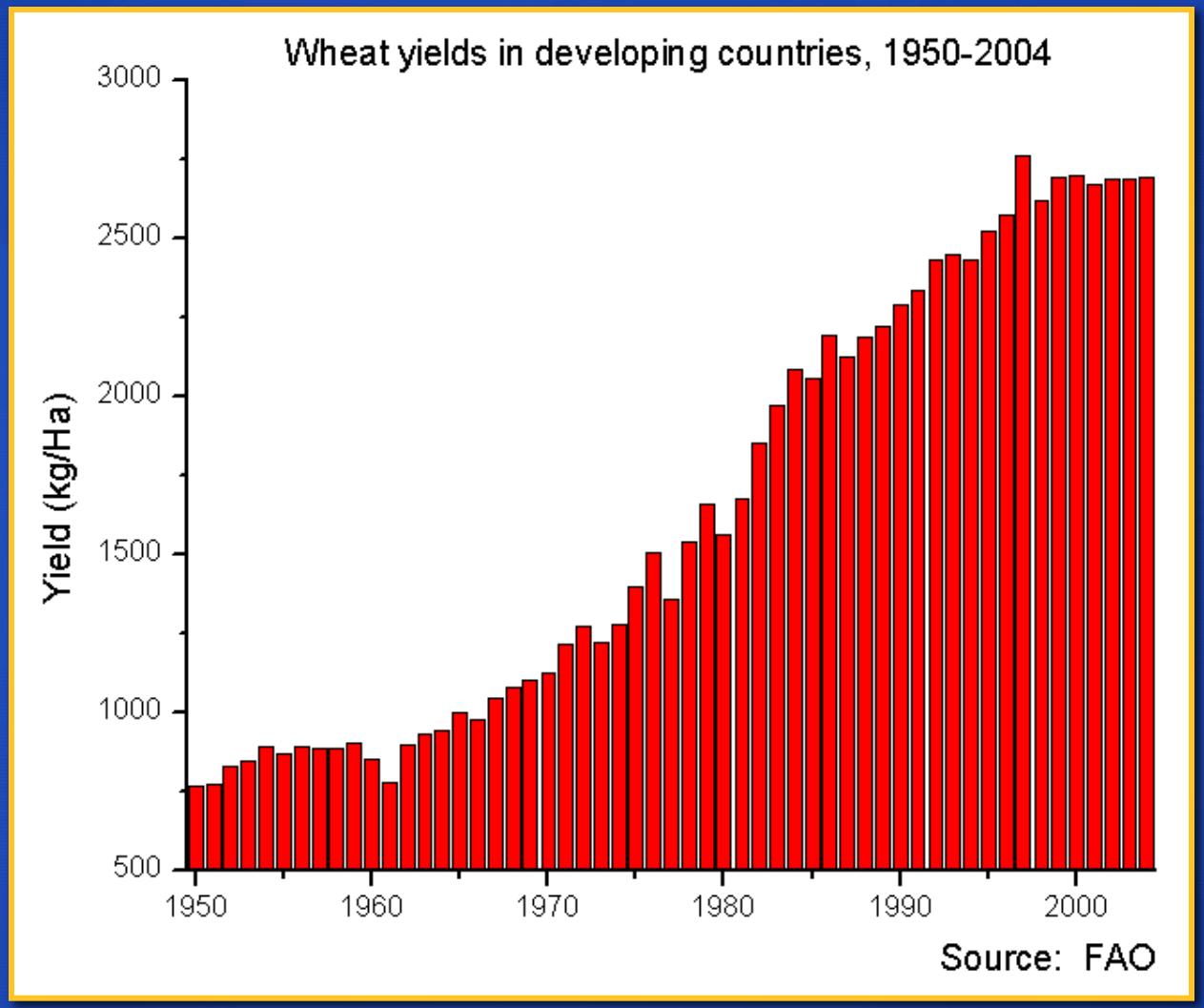
- Lifted Billion Plus Out of Poverty
- Undernourished > from 38% to 19% in past 20 years
- Food Consumption per capita has increased everywhere except in Africa - 18% Globally and 28% in LDCs
- India: Food production from 50 to 225 mil tons in the past 5 decades. Wheat : from 6 to 85 million tons per year!
- Less Starvation and Famine
- Increased Food Self Sufficiency



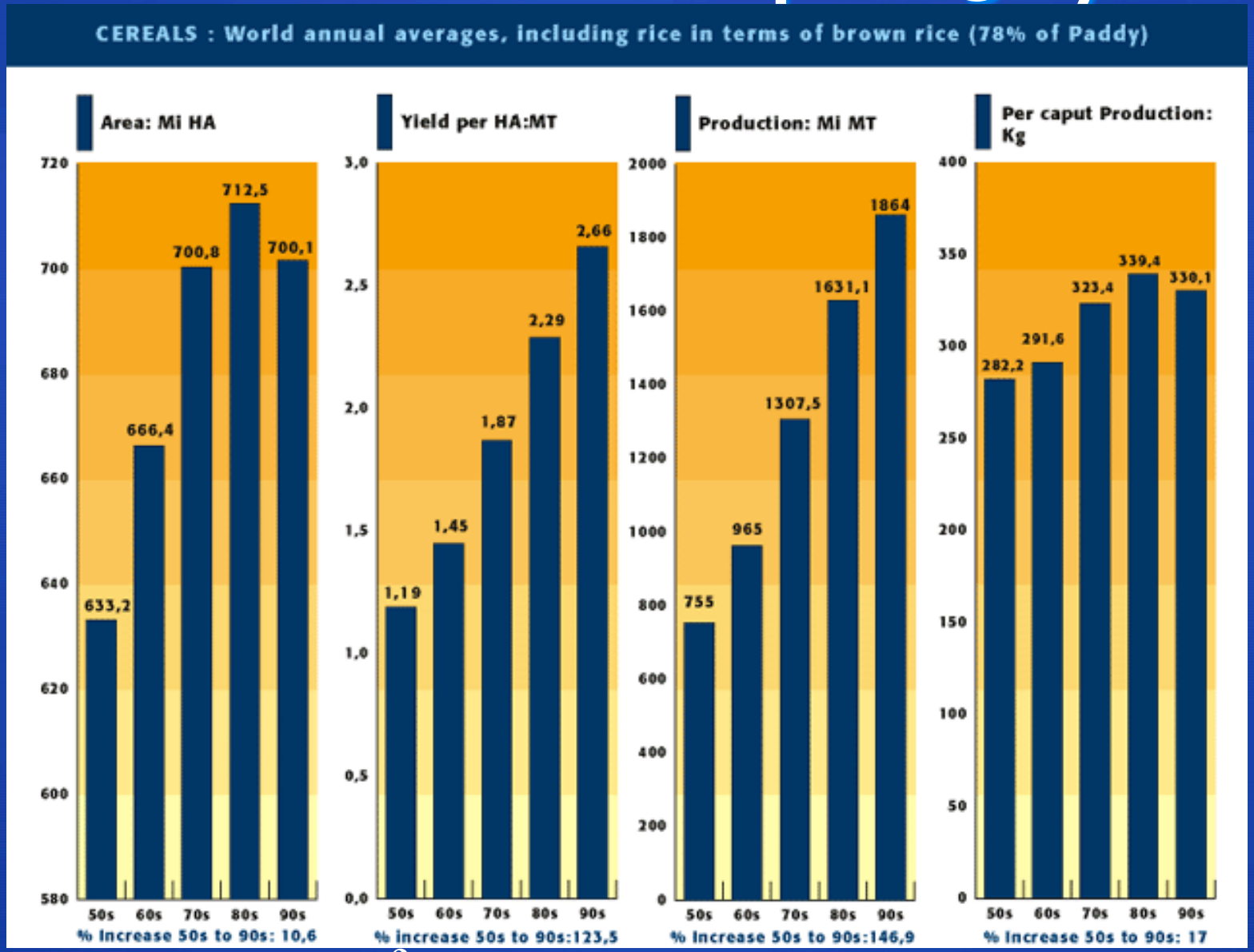
Clicker Question

- Food grain yields in developing countries have increased by how much in the past fifty years?

a. Doubled
b. Four-Fold
c. Ten-Fold


Wheat yields in developing countries, 1950-2004
Yield (kg/Ha)
3000
2500
2000
1500
1000
500
1950
1960
1970
1980
1990
2000
Source: FAO

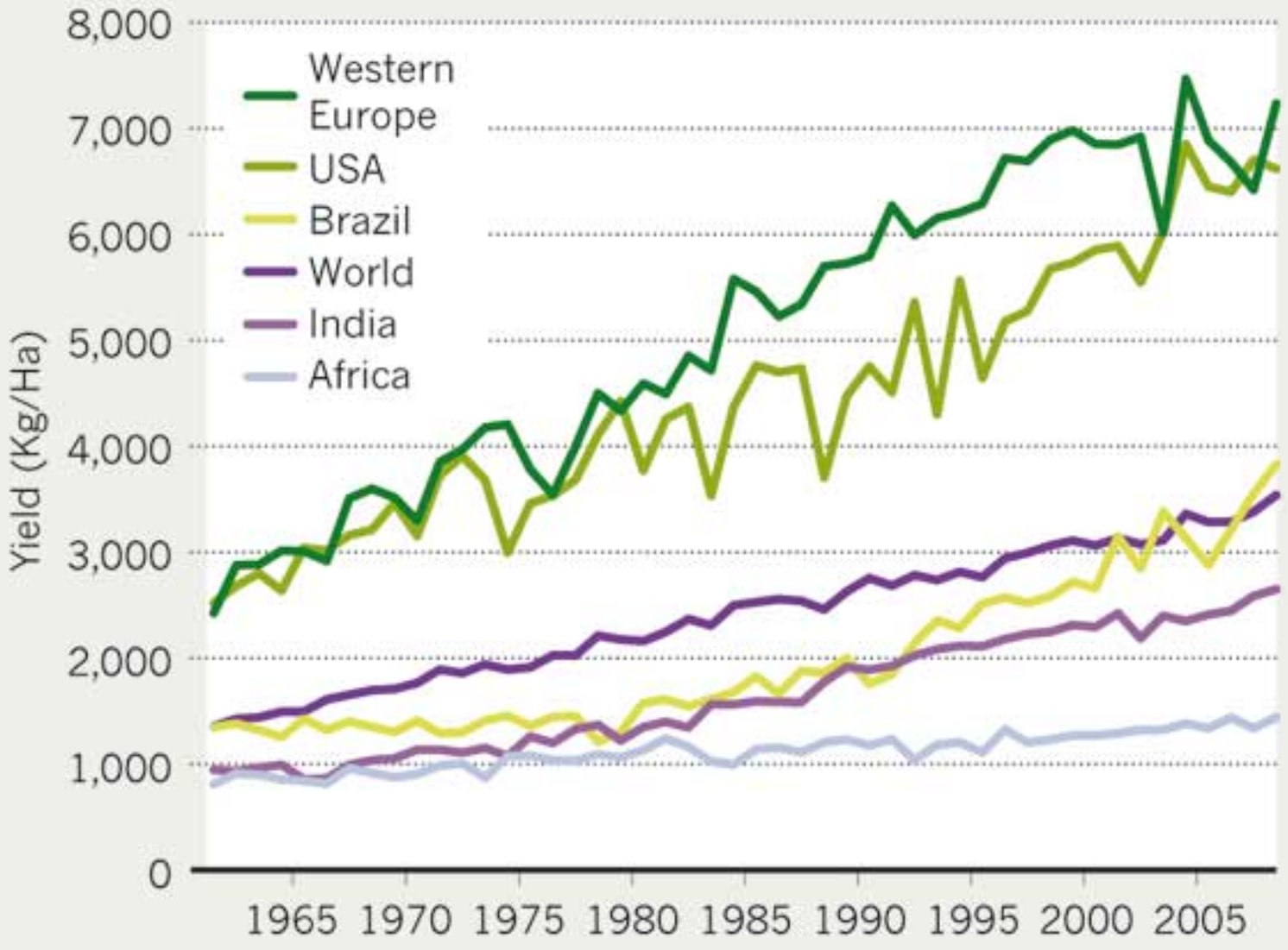
Cereal trends in the past 50 years…

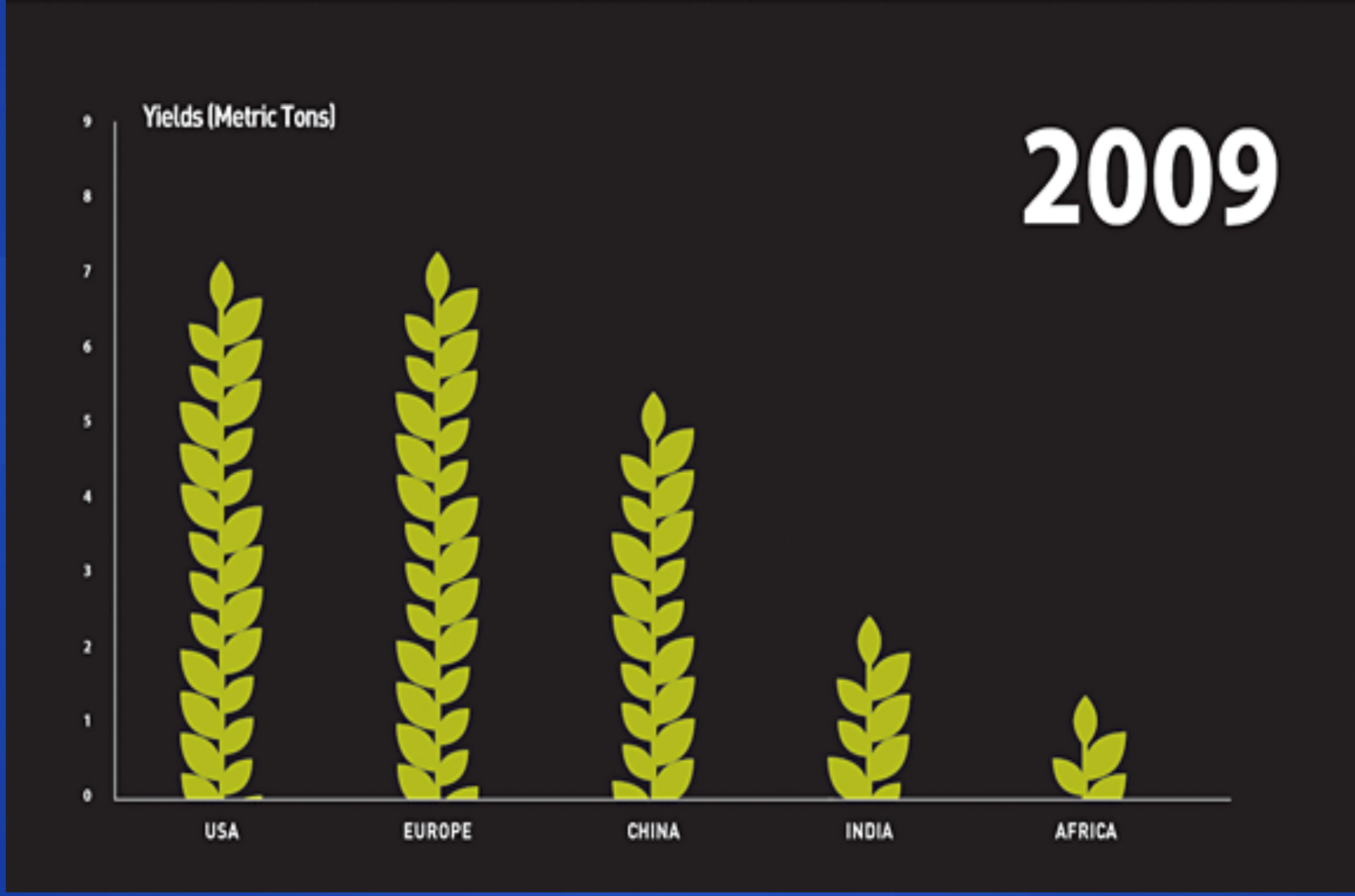


Source: www.fao.org

THE AFRICA LAG

The green revolution largely bypassed Africa, where cereal crop yields have barely improved in 50 years.

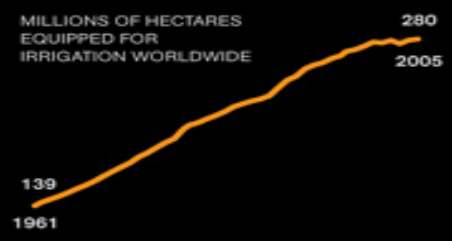


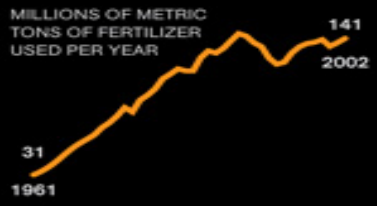

Yields (Metric Tons)
2009
9
8
7
6
5
4
3
2
1
0
USA
EUROPE
CHINA
INDIA
AFRICA

TO MEET RISING FOOD DEMAND, WE NEED ANOTHER GREEN REVOLUTION, AND WE NEED IT IN HALF THE TIME.

HOW WE DID IT BEFORE

Few agricultural achievements have been as profound as the green revolution, the farming system of irrigation, high-yield varieties, pesticides, and fertilizers that more than doubled yields in Asia during the 1960s and '70s, lowering prices of the staple crops that feed most of the world today. But these breakthroughs have come with ecological costs.





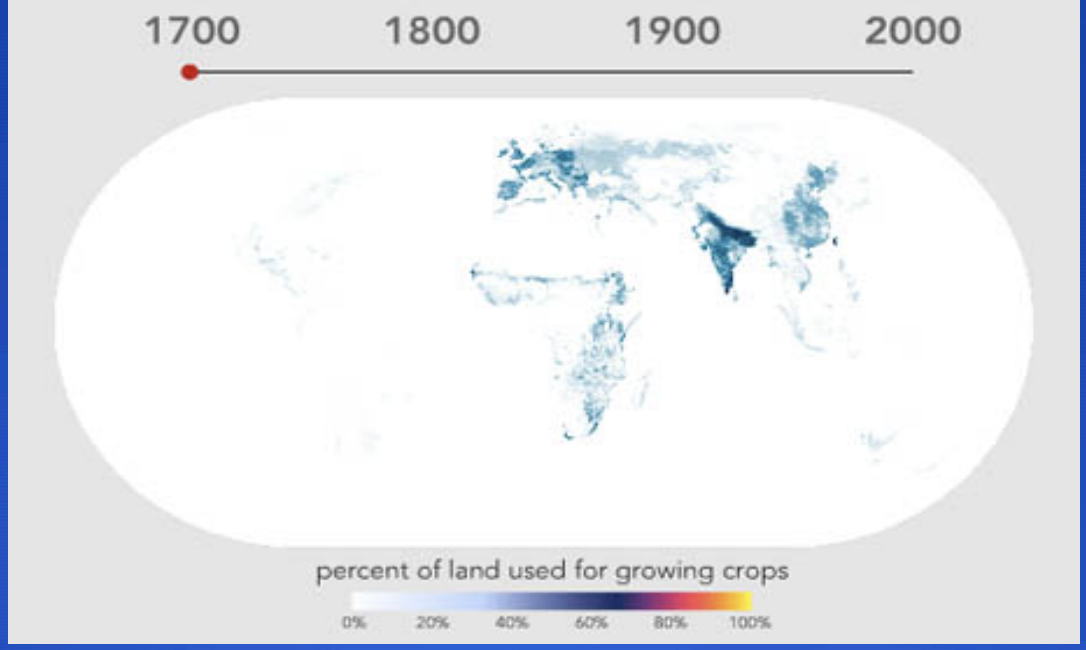
IRRIGATION can double yields compared with those in rain-fed fields. India subsidized more than a million tube wells, resulting in higher production but also aquifer depletion and salinized soils.

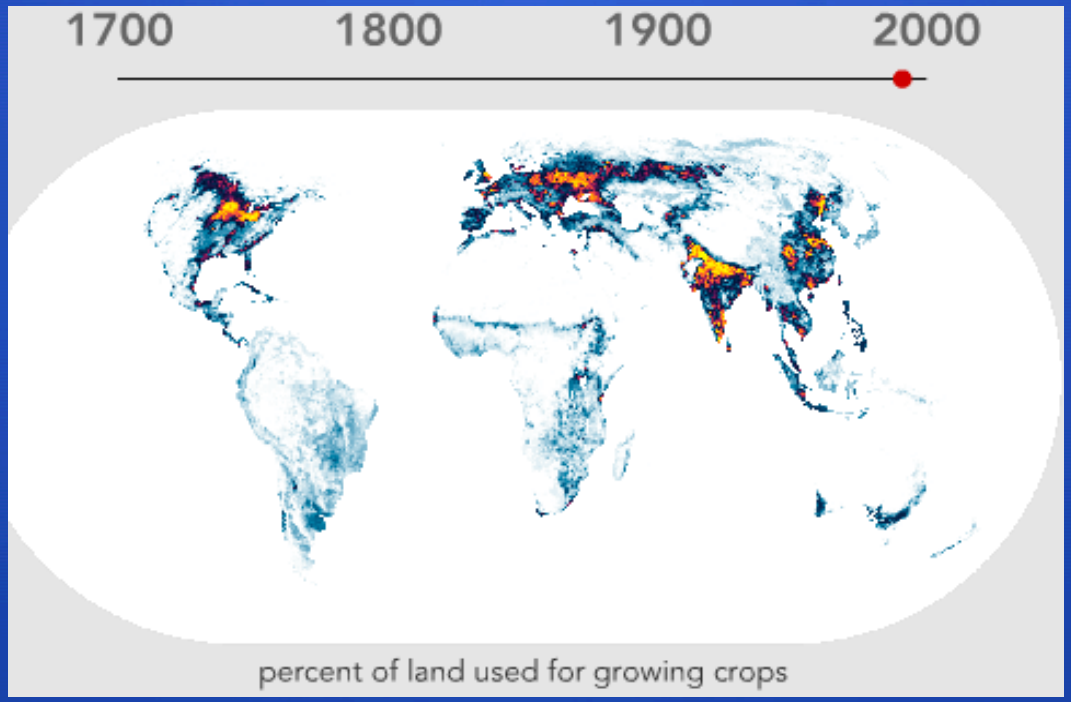
DWARF VARIETIES of wheat and rice allowed farmers to u large amounts of fertilizer an water to produce more grain without the plants getting to heavy and falling over.

CHEMICAL PESTICIDES were needed because dense planted fields were more susceptible to insects and diseases. Overuse may resul in 39 million poisonings a yea

SYNTHETIC FERTILIZERS helped the new varieties hit record yields. But they requir huge amounts of fossil fuels to produce and apply, so the cost skyrockets with the pric of oil. Nitrogen fertilizers also pollute aquifers and streams

(Source: National Geographic)


1700
1800
1900
2000
percent of land used for growing crops
0%
20%
40%
60%
80%
100%


1700
1800
1900
2000
percent of land used for growing crops

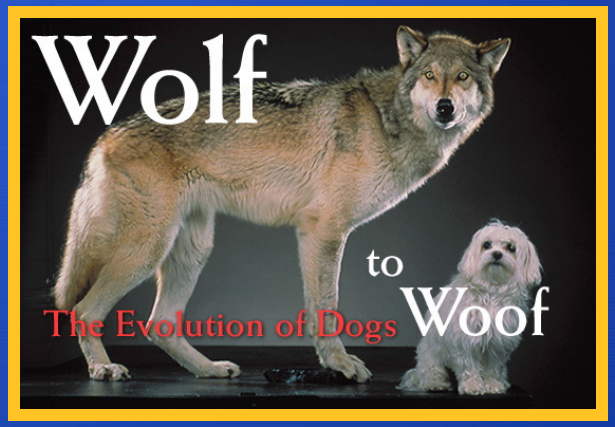
Plant Breeding - Genetic Modification by Farmers and Conventional Breeding

(photos: Dr. Wayne Parrott, Univ of Georgia)

Crop Evolution and Human Civilization

- **Humans have always guided the evolution of crops**
- **A small sample of wild plants were chosen and domesticated**
- **10,000 years of *Selection*.**

- **All crops we grow today were once wild plants. But no crop would survive in the wild any more.**
- **Crops, strains and genes have moved around the globe.**



Many crops never existed in nature

Einkorn x wild wheat

Emmer x goat grass

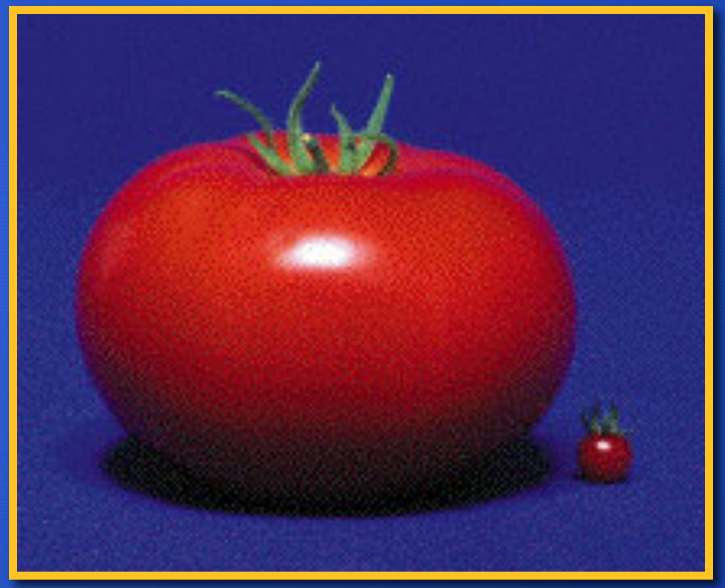
Bread wheat

www.mpiz-koeln.mpg.de/pr/garten/schau/Triticumaestivum/wheat.html


TOTALLY
COOL
PIX.com

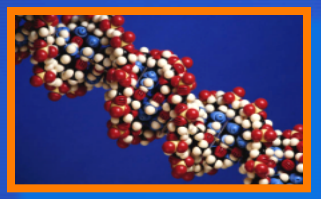
Improving Our Crop Plants

- **Developing Modern Varieties of Crops**
  - **Hybridization**
    - **Crosses with Wild Relatives**
    - **Hybrids**
  - **Mutation**
    - **Irradiation**
    - **Chemicals**
  - **Cell Culture**
    - **Embryo Rescue**
    - **Somaclonal variation**



Modern Genetic Modification

Inserting one or few genes to achieve desired traits.

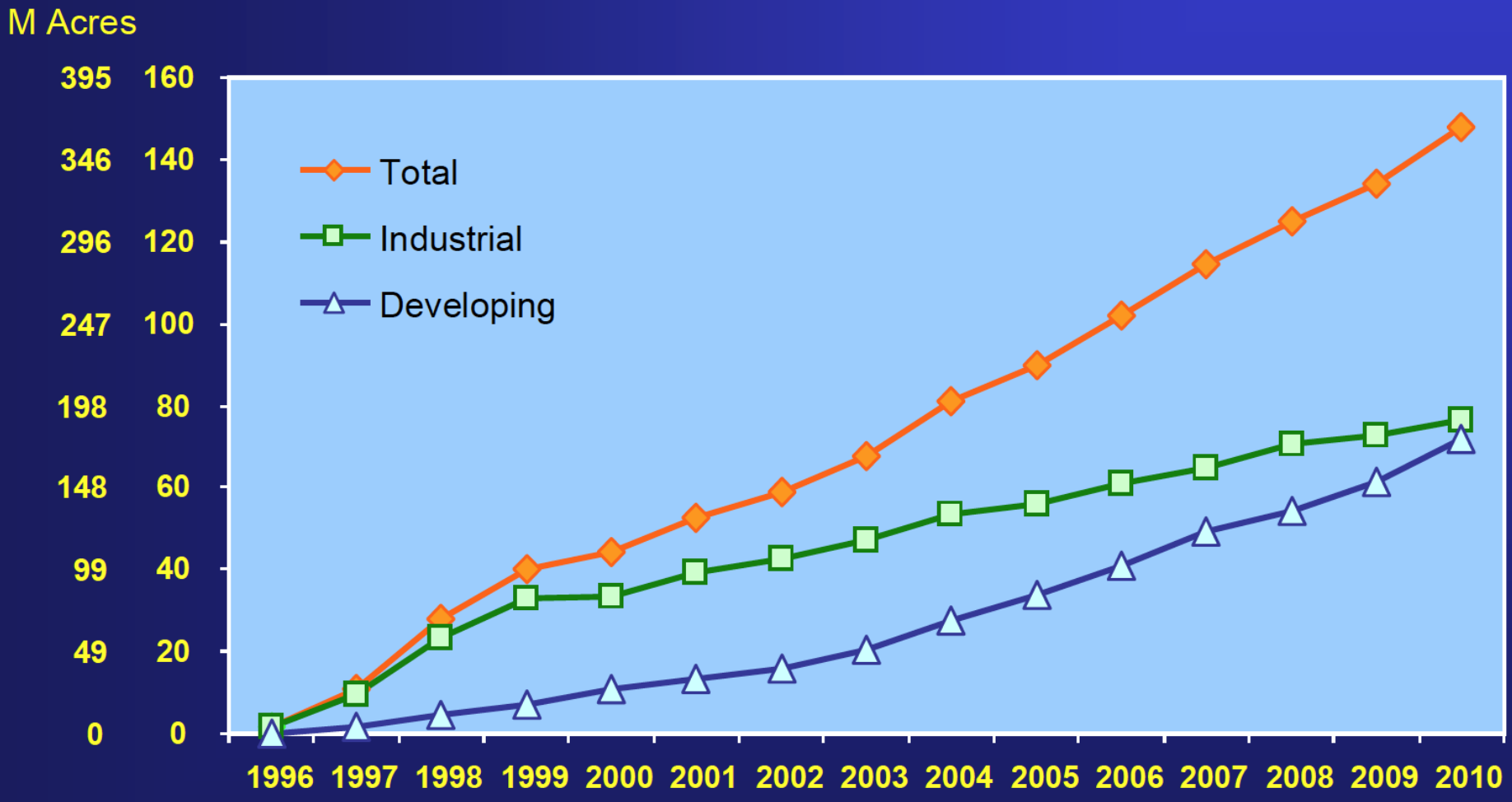


Transfer of Genes into Crop Plants

- Relatively Precise and Predictable
- Changes are Subtle
- Allows Flexibility
- Expeditious

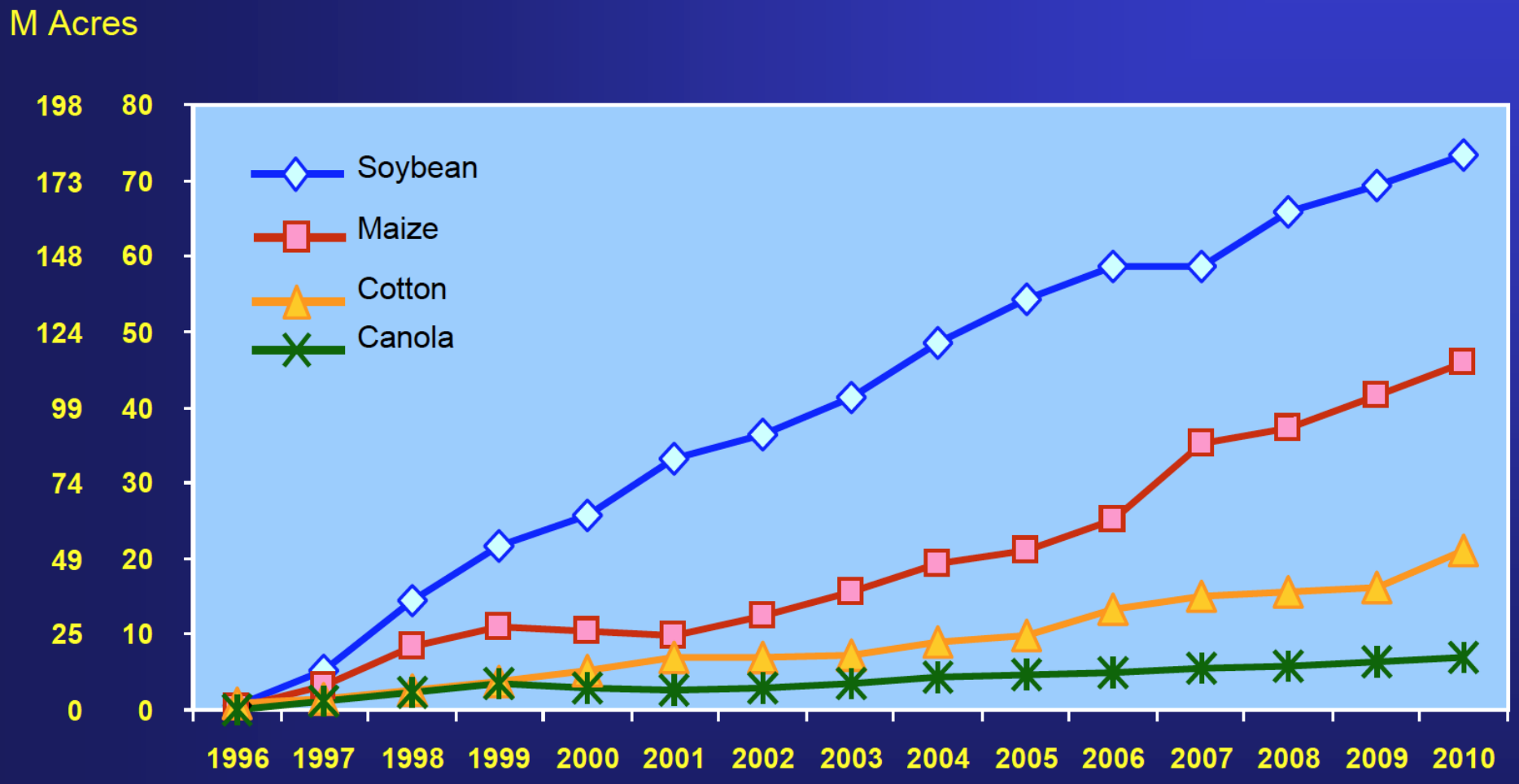
Global Area of Biotech Crops, 1996 to 2010: Industrial and Developing Countries (M Has, M Acres)

ISAAA



Source: Clive James, 2010

Global Area of Biotech Crops, 1996 to 2010: By Crop (Million Hectares, Million Acres)



Source: Clive James, 2010

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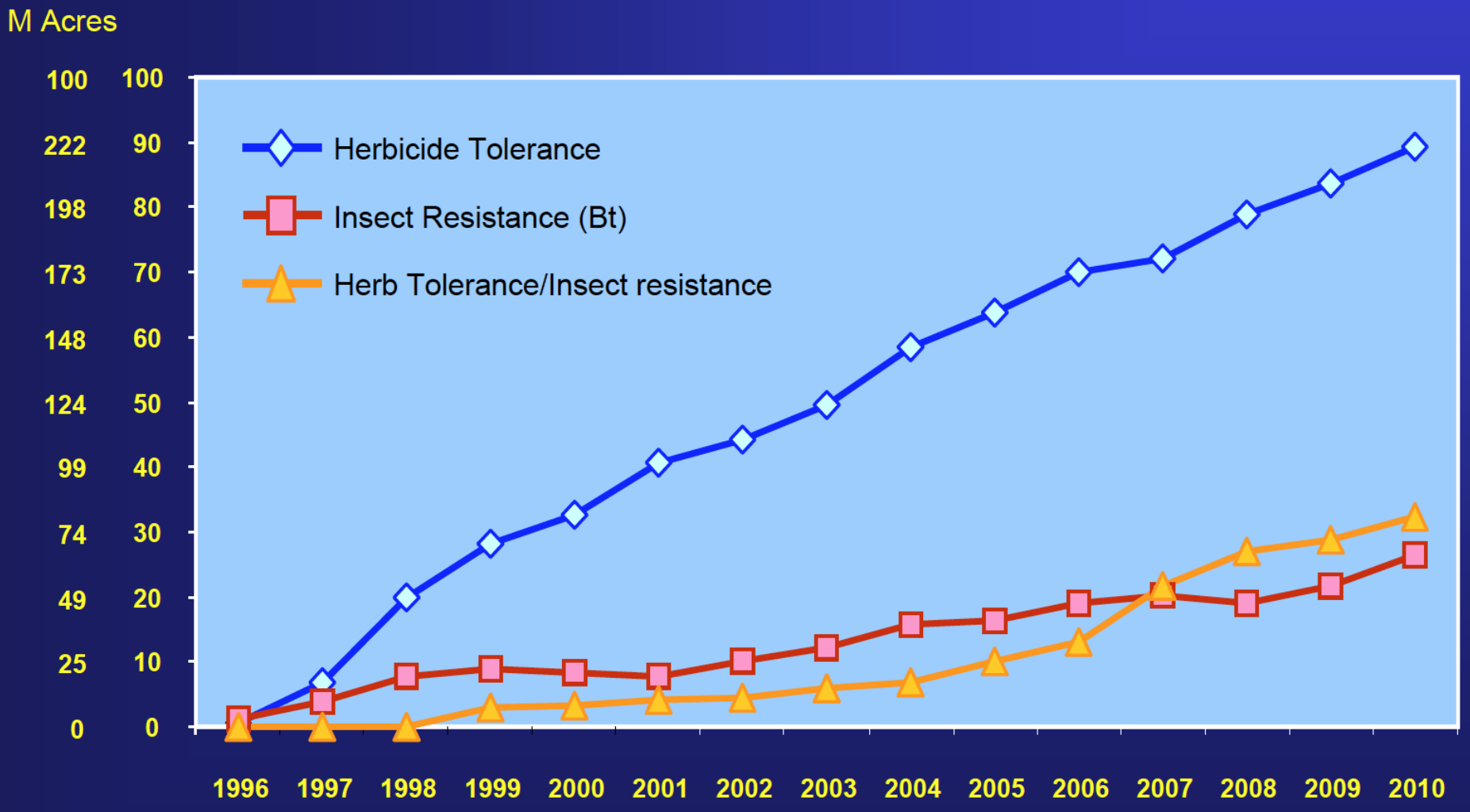
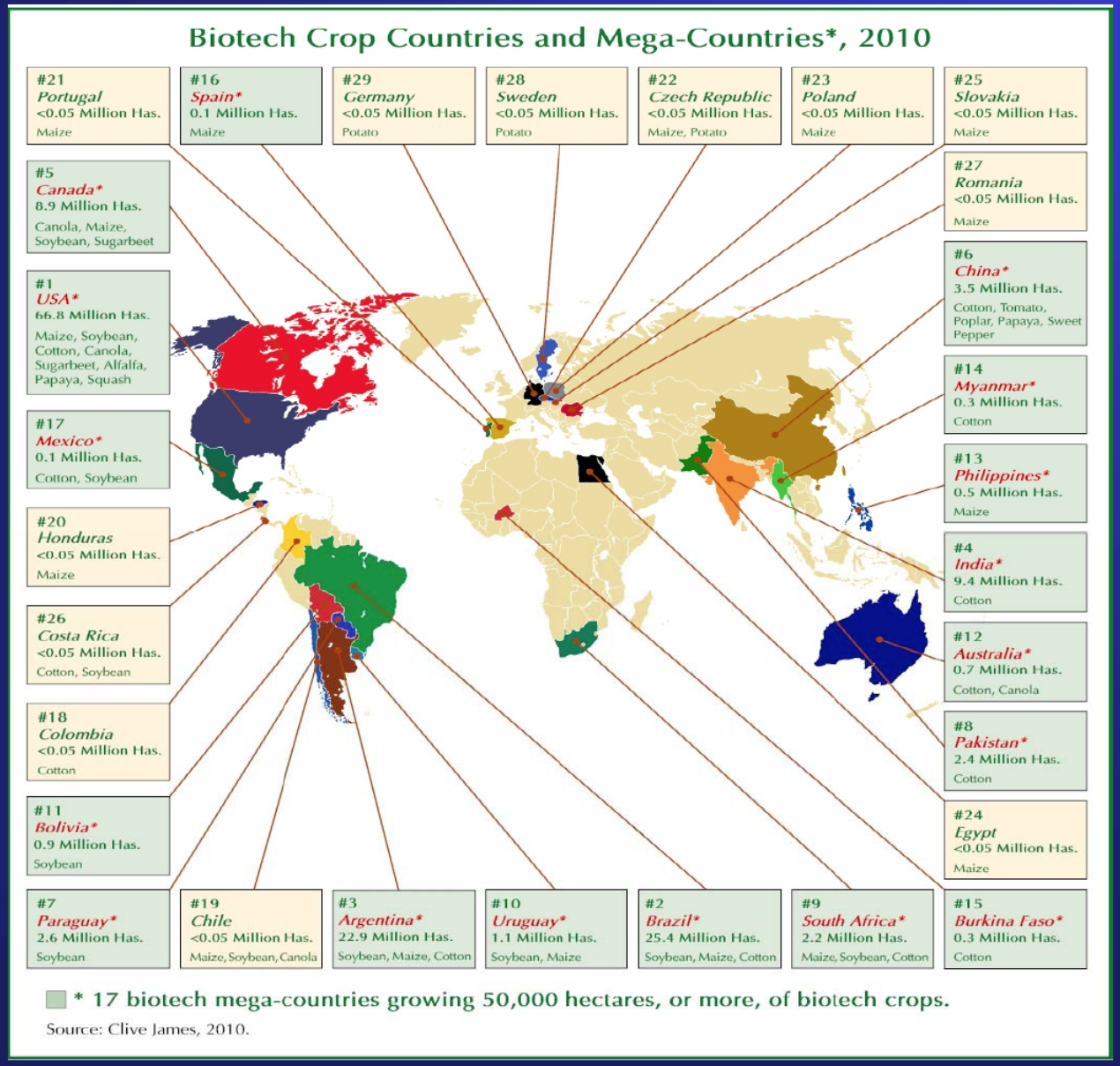


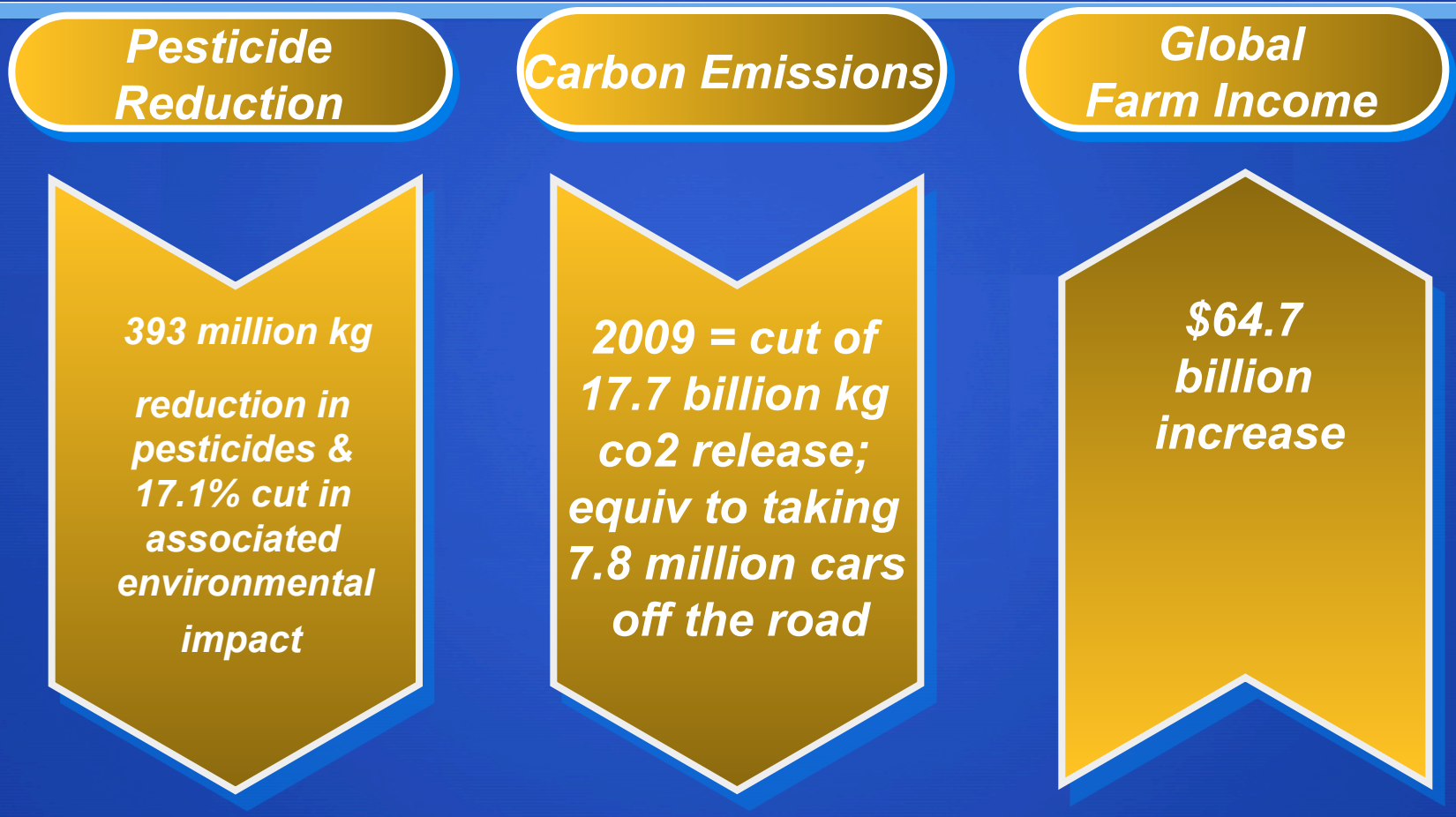
Source: Clive James, 2010

Biotech Crop Countries and Mega-Countries, 2010

ISAAA



Environmental and Economic Impact



After 14 years of commercialization, biotech crops have yielded a net increase in farm income while significantly

How Can Biotechnology Add Value to Global Agriculture?

- Environmental Impact - Decreased use of pesticides
- Reduce losses from pests and diseases
- Improve nutrient efficiency
- Improve productivity

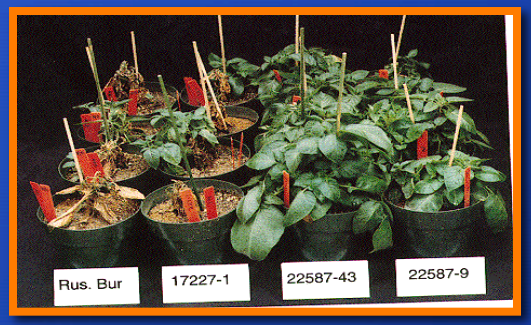
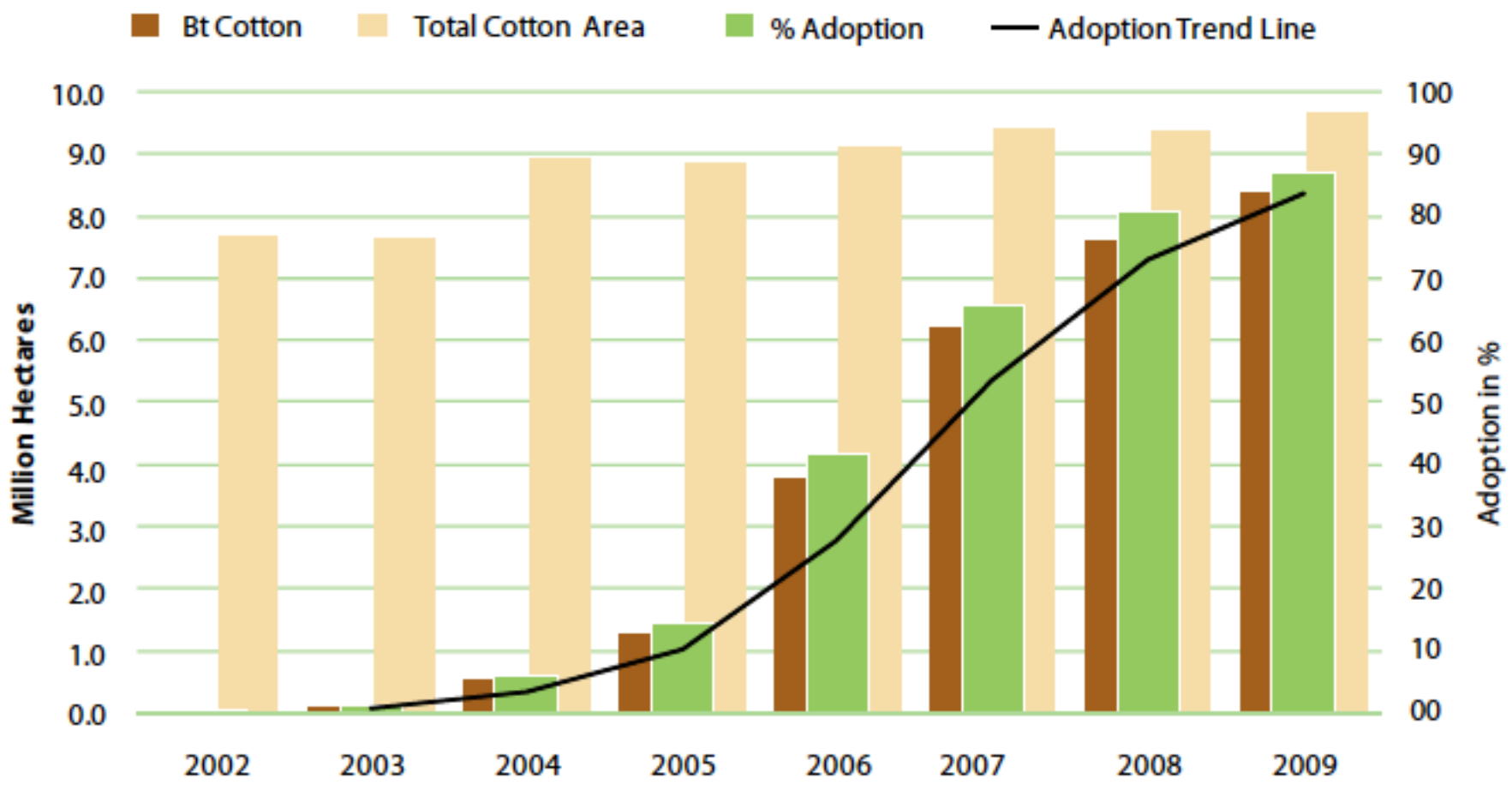
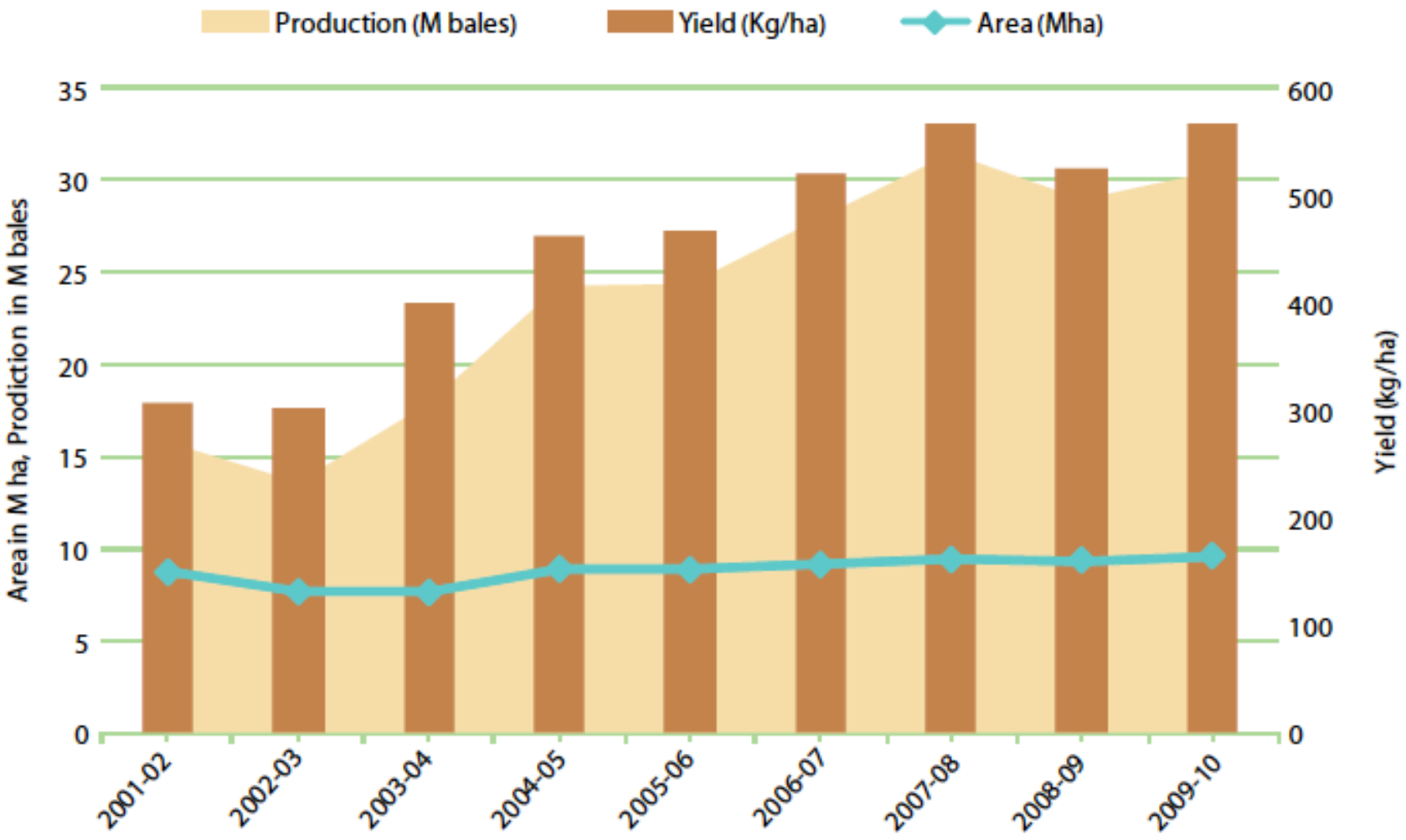


Figure 1. Adoption of Bt cotton in India for the eight year period, 2002 to 2009



Source: Compiled by ISAAA, 2009.

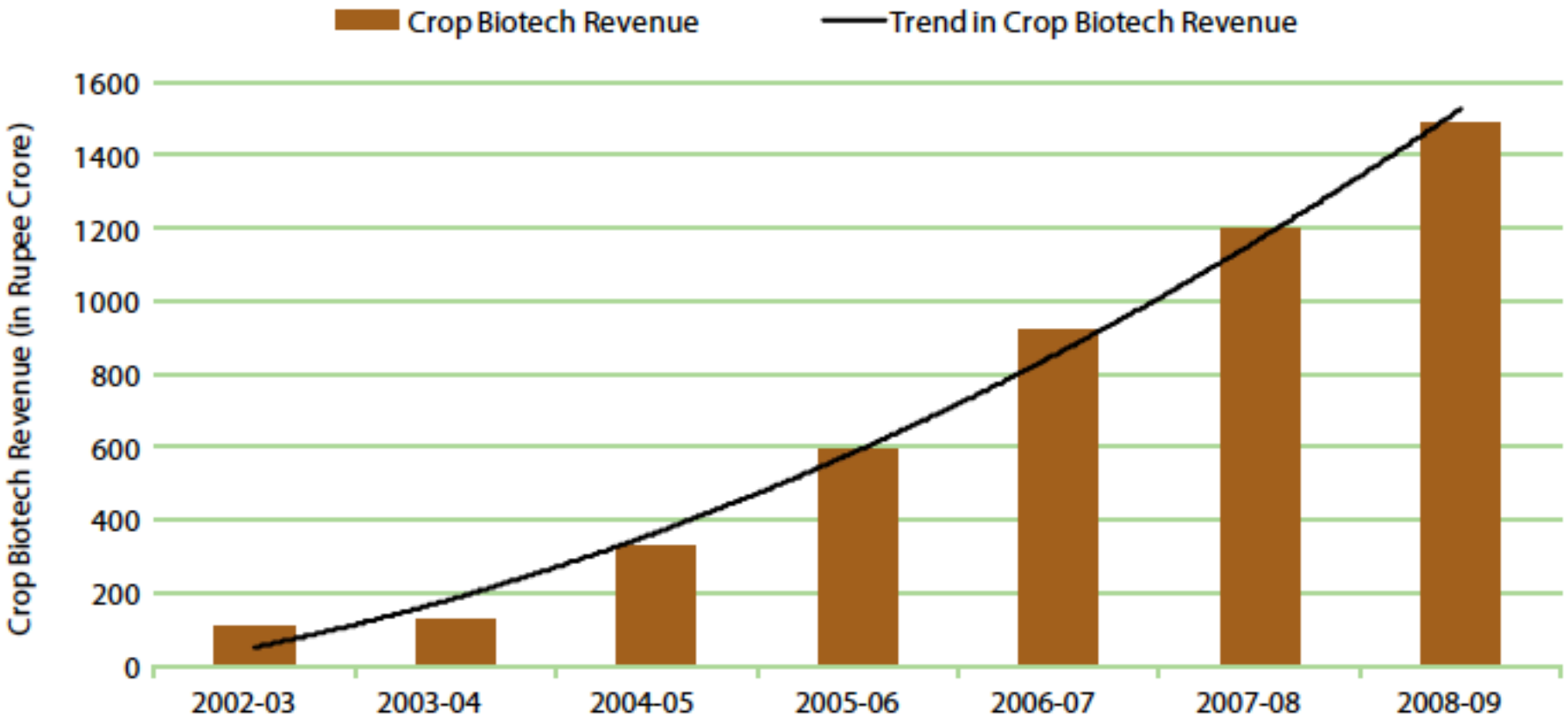
Figure 5. Cotton hectarage, production and yield in India, 2001 to 2009



1 bale = 170 kg

Source: Cotton Advisory Board, 2009.

Figure 7. Bt cotton hybrids market in India (in rupee crore), 2002 to 2008

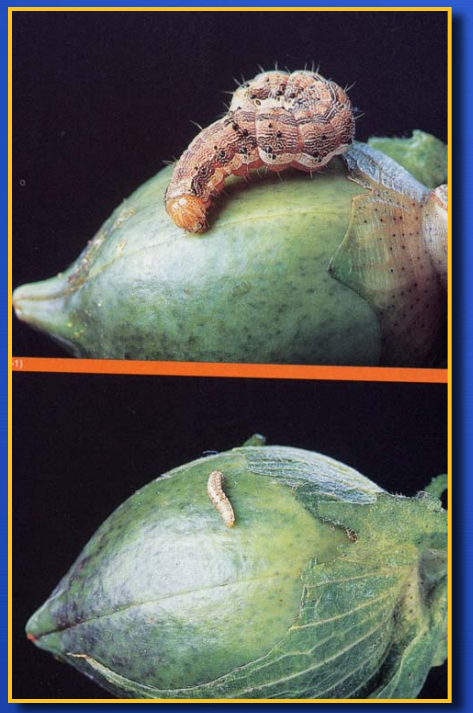


(1 Crore = 10 Million Rupees)

Source: BioSpectrum India, 2009.

Cotton - China, South Africa, India, Mexico, Burkina Faso

- Losses due to Bollworm $1.5 billion in India and China
- Cotton - 50% of the total pesticides



India

- Bt Cotton - yield increases up to 40%.
- ~90% of Indian cotton farmers grow Bt
- Savings up to $182 per hectare
- More than 600 varieties
- Spraying reduced from 12 to 1
- Both private and public sector

‘GM’ Eggplant in India – Not Approved!

Bt Corn

(Low Mycotoxin)

Corn Earworm

Photos: Zamorano, Honduras by María Mercedes Roca; NPR

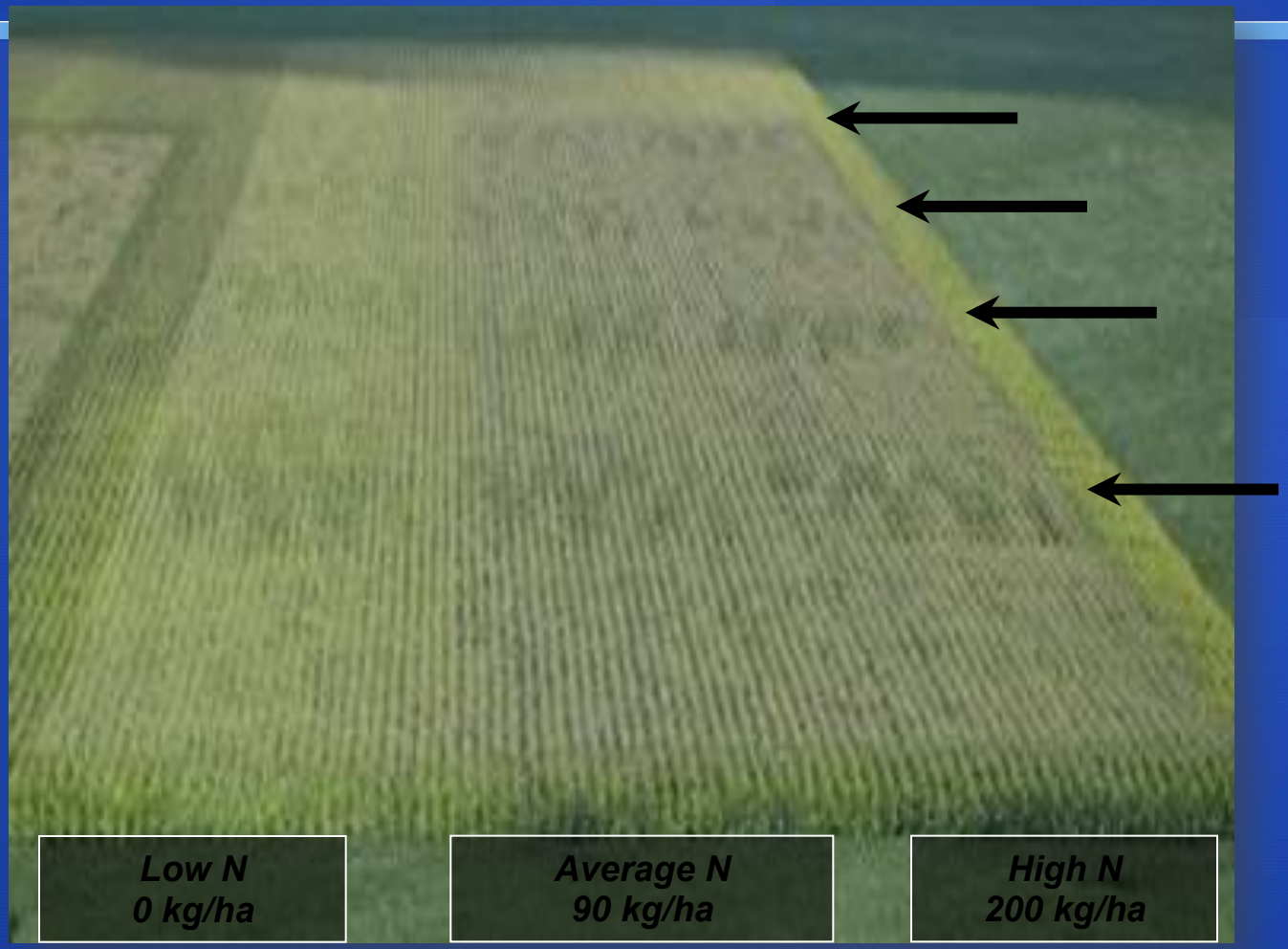
Virus-resistant papaya

Saved the Hawaiian industry in the mid-1990s
90% of crop today

Virus-resistant trees

Provided by Denis Gonsalves, formerly of Cornell University

Better fertilizer use

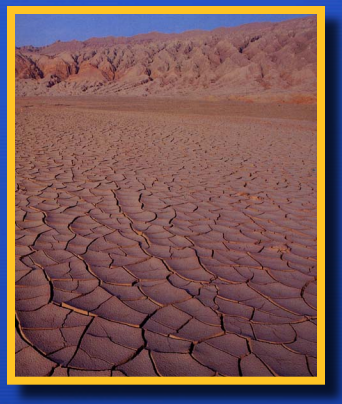


Herbicide Tolerance

Simplifies non directed applications

Benefits of Biotechnology…..

- Post Harvest Quality - prolong shelf life of fruits, vegetables and flowers
- Extend crop area and season
- Stress tolerance - drought, acidity, salinity, heat, flooding



Freeze Tolerant Biotech *Eucalyptus*

Results from first winter in South Carolina

Results from second winter in Alabama

Field results indicate freezing tolerance to ~16°F (- 8° to - 9°C)

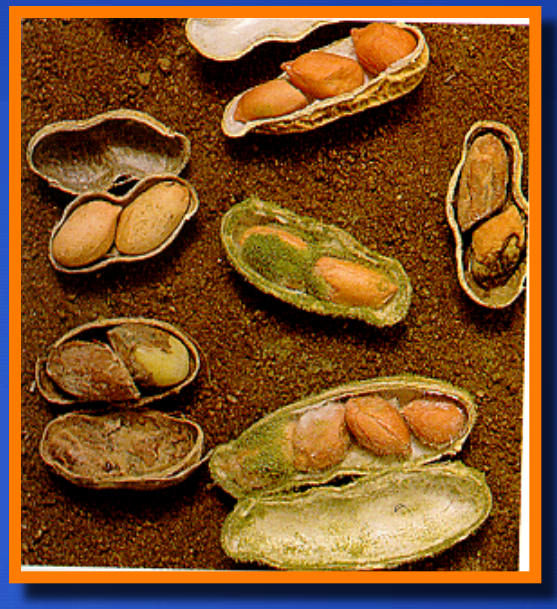
Source: www.arborgen.us

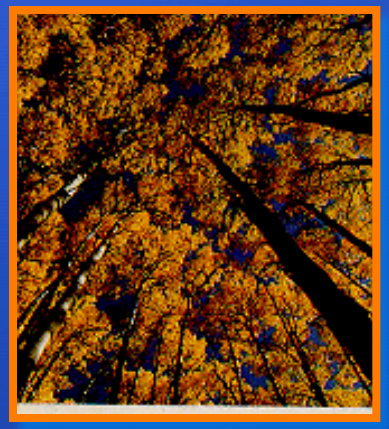
Golden Rice

- Milled rice has no beta-carotene
- Vitamin A deficiency - 200 million children and woman
- About 500,000 children go blind (60 every hour!)
- 2 million children die each year
- Golden Rice may provide one of the many solutions

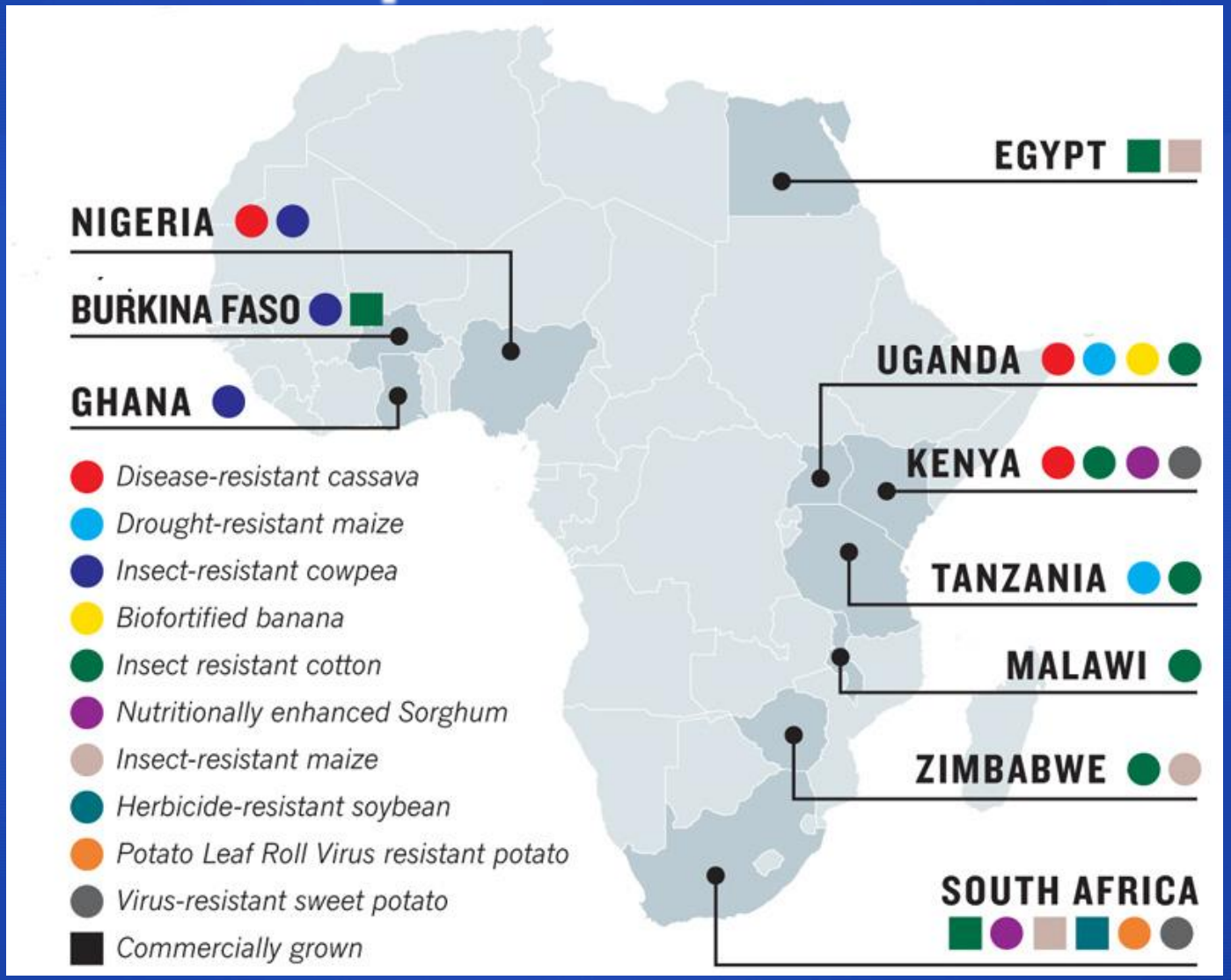
Enhancing Food and Agriculture

- More Nutritious Food
- Healthy Produce. Low Toxins
- Pharmaceutical Proteins
- Clean Up Environment
- Biofuel - Ethanol, biodiesel
- Industrial Products
- Value-Added Products





GM Crops in Africa



(From Nature, Oct. 1 2010

Sweetpotato

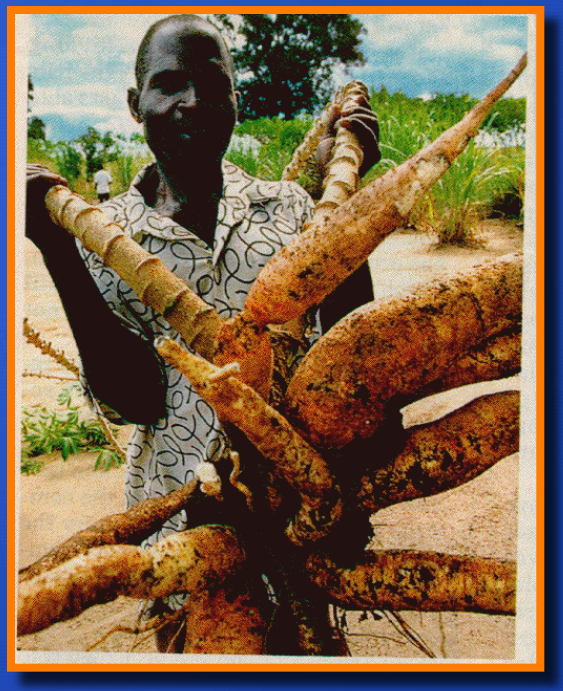
- Fourth largest crop in the developing world
- Excellent source of calories, vitamins and minerals
- Grown by resource-poor farmers
- Very hardy

Resistance to Virus and Weevil
Enhancement of Nutritional Protein

Cowpea

Cassava

- Eaten by 500 million Africans
- Very productive, drought-tolerant
- Rich in Calories. Cyanogenic glucosides.
- African Cassava Mosaic Virus devastating the crop
- ILTAB - Danforth Ctr (Beachy, Fauquet)



Healthy Cassava

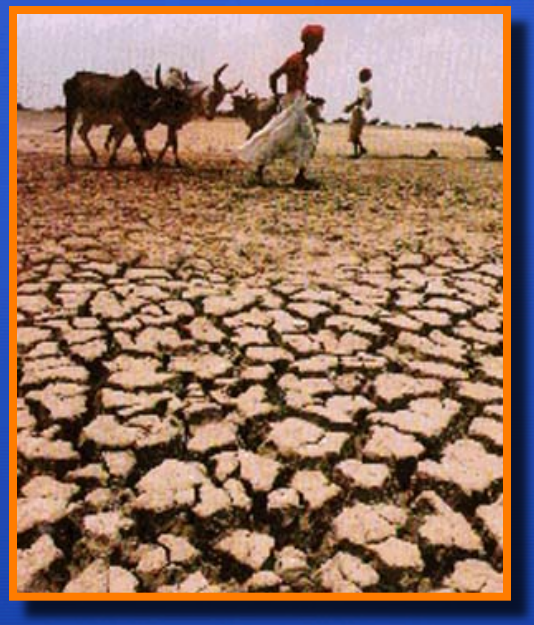
Virus-infected Cassava

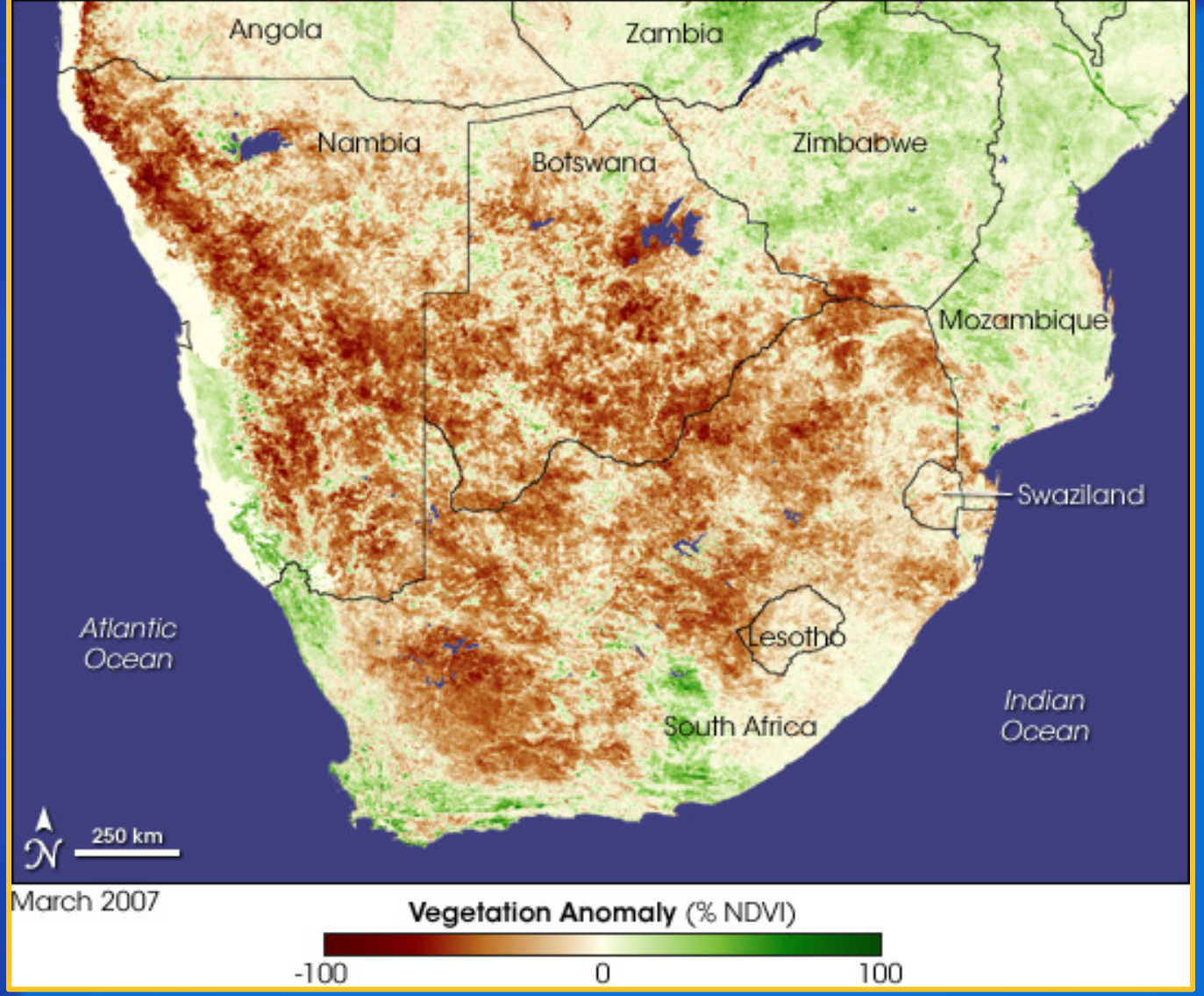
Black Sigatoka Disease of Banana

Banana

Drought

- Extended period of deficiency in water supply
- Major constraint to farming
- Spurred Green Revolution in India?





Drought in Southern Africa - Impact on vegetation (Source: NASA)

Drought Tolerant Corn

Photo: Monsanto Co.


Striga = witch weed

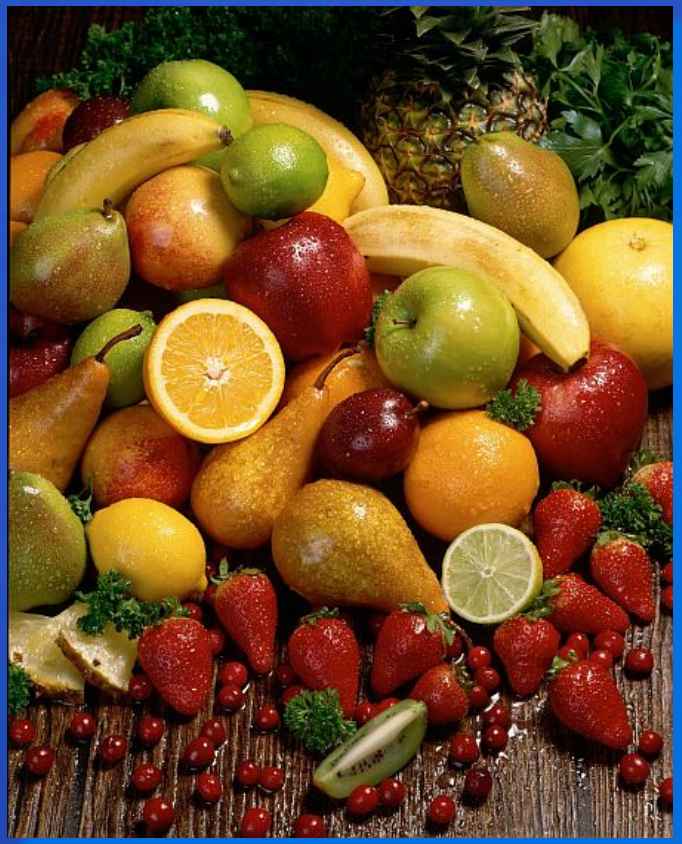

LOCAL CHECK
H513
IR MAIZE
SINGLE CROSS 1

Wheat

Rice

Vegetables

Fruits



Blue Rose!


I WON'T EAT ANYTHING THAT'S GENETICALLY MODIFIED...
IT COULD BE UNHEALTHY...
CHIPS
NICK ANDERSON 6-6-00
Rex Babin is on vacation
Anderson / Courier Journa

Assessment of Food Safety

- Standard - “Reasonable certainty that no harm will result from intended uses under the anticipated conditions of consumption”
- **Food is not inherently safe**
- Considered to be safe based on experience
- **Not absolute but relative safety**

Regulatory Systems in the U.S.

USDA

Field testing
permits
notifications

Determination of
nonregulated
status

FDA*

Food safety

Feed safety

* Voluntary Consultation process for substantially equivalent products.

EPA

Pesticidal plants
tolerance
exemption
registrations

Herbicide
registration

Standards & Agencies

ILSI

efsa
European Food Safety Authority

USDA
APHIS

Health Canada | Santé Canada

FDA

OECD

食の安全、を科学する。
食品安全委員会
Food Safety Commission

FOOD STANDARDS
Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

KFDA KOREA FOOD & DRUG ADMINISTRATION

Safety Testing of GM Crops

Phase I

Safety of gene, protein, crop

- Choice of genes / proteins
  - mechanism of action
- Source of genes
  - history of safe use
  - ethics
- Environmental / ecological considerations

Phase II

Biological / agronomic equivalence

- Stringent agronomic performance and efficacy criteria
- Greater than 99% of all events are eliminated
- Key step in product evaluation for conventional varieties

Phase III

Detailed product safety

- Food
- Feed
- Environmental

Substantial Equivalence - Evaluation

PHENOTYPE

- Morphology
- Agronomic
  - disease resistance
  - drought resistance
  - yields
- Organoleptic

COMPOSITION

- Macronutrients
- AA composition
- FA composition
- Anti-nutrients
- Toxic substances
- Allergens
- Specific constituents

SAFETY ASSESSMENT

- Toxicity
- Allergenic potential
- Nutritional

FEED EQUIVALENCE

- Performance

Compositional Equivalence

- Evaluate Key
- - Nutrients
- - Vitamins
- - Minerals
- - Anti-nutrients
- - toxicants
- - Allergens
- - Others

List depends on crop

Grain	Forage
- Protein	- Protein
- Fat	- Fat
- Fiber	- Fiber
- Starch	
- Amino acid composition	
- Fatty acid composition	
- Ash	
- Sugars	
- Calcium	
- Phosphorous	

OECD Consensus Documents

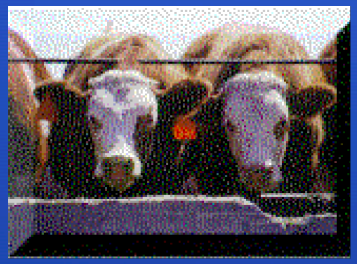
Feed Performance

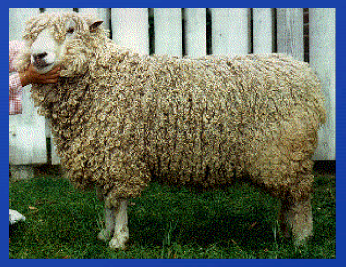
Animals fed biotech corn products perform in a comparable manner to animals fed conventional corn products

No Significant Differences in:

Feed Intake	Feed Conversion	Nutrient Composition
Body Weight	Milk Yield	
Carcass Yield	Milk Composition	
Feed Efficiency	Digestibility	

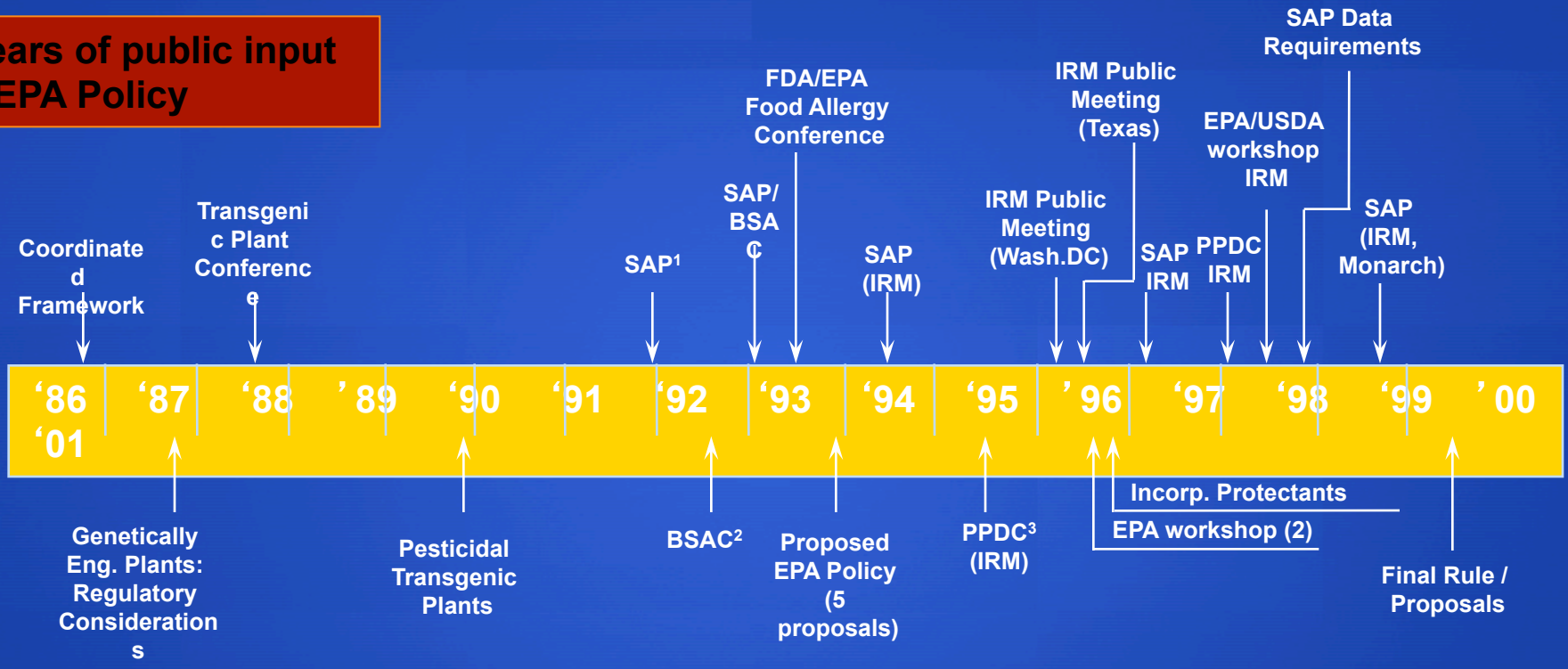






Regulatory Path for Bt Corn

15 years of public input into EPA Policy

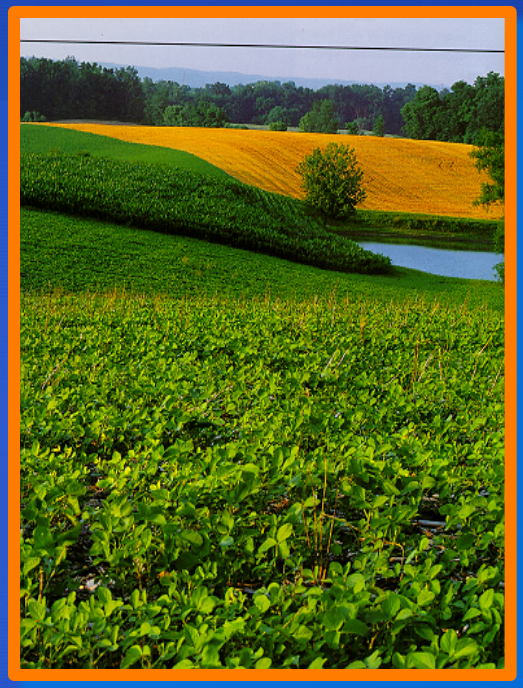


[1] Science Advisory Panel
[2] Biotech Science Advisory Committee
[3] Pesticide Program Dialogue Committee


NO
GREENPEACE
NO GMO
NEWS STAR
EUROPEAN STUDIES SAY GMOS SAFE!
THAT'S OKAY, THIS CAMPAIGN WAS NEVER BASED ON SCIENCE, ANYWAY.

Environmental Issues

- What are the Ecological Effects of New Crops?
- Would Superweeds Emerge?
- Does Biotech Affect the Biodiversity?
- Genetic Pollution?
- Horizontal Transfer…..Will Bacteria or *I* get those genes?
- ….What about Monarch Butterflies?



Addressing Environmental Concerns

- Extensive Risk Assessment for the Past 15 years with 5,000 Field Studies; Careful Monitoring
- Evaluate Risk on a Case-by-Case Basis.
- Most Introduced Traits Not Unique to Biotechnology;
- Plant Breeding History - Introducing Novel Genes All the Time

What Can Scientists Do?

- Write Commentaries, Op-Eds
- Social Media – Facebook, Twitter
- Regulatory and Legislative process
- Public Forums
- Regional Networks
- Community Outreach
- Respond to Misinformation
- Letters to The Editor

Famine in Southern Africa

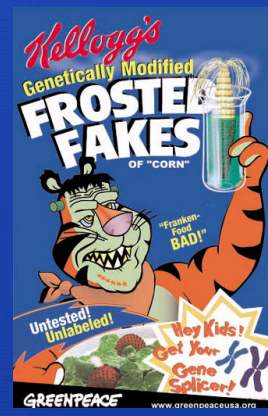
- Nearly 13 Million people in 19 African countries faced severe hunger and starvation during 2003-2004
- About 300,000 faced death
- World Food Program
- US Donated 500,000 tons of corn

Zambian President, Levy Patrick Mwanawasa
"We would rather starve than get something toxic."

African rejection of GM crops

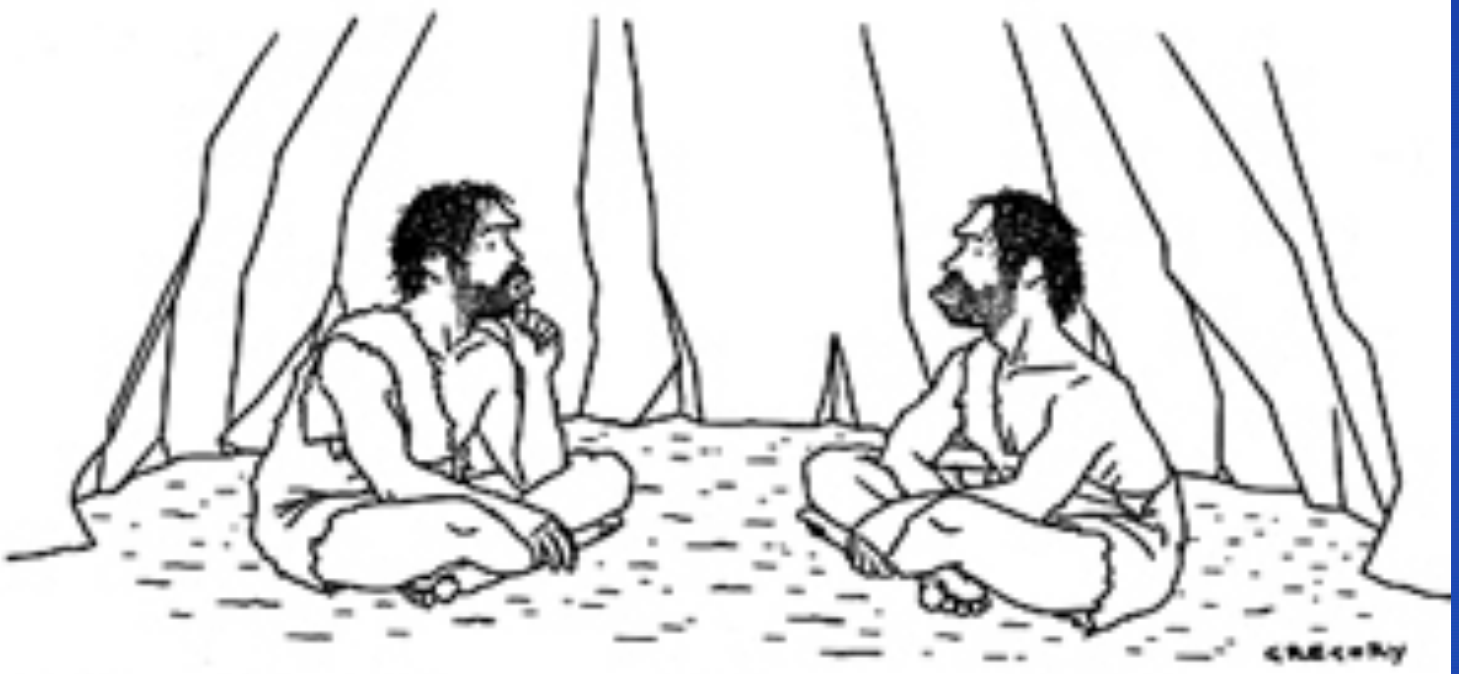
- Only 3 countries (S. Africa, Egypt and Burkina Faso) out of 53 countries growing biotech-enhanced crops
- Lack of government support
- Absence of regulation or law
- NGO Campaign
- UN Convention on Biological Diversity

  - Biosafety Protocol



Downgrading and withdrawing support for Agricultural science in the West

- Very low R&D spending in agriculture
- Not a top priority for politicians
- Poor donor support
- Hostility from NGOs
- Advocates of organic farming in Africa
- Uncertain support from philanthropic foundations
- “Caring about Africa, but not agriculture” (R. Paarlberg, 2008)



"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."

How Can Biotech Help Third World Agriculture?

- Improve Food and Nutritional Security
- Increase Crop Productivity
- Enhance Production Efficiency
- Reduce Crop Damage& Food Loss
- Promote Sustainable Agriculture
- Reduce Environmental Impact
- Empower the Rural Sector through Income Generation
- Reduce Economic Inequity