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I.C.R.A.
International Catholic Rural Association

Food Security and GMOs

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26 June 2012
Rome

UNIVERSITY OF MINNESOTA
ENTOMOLOGY

- Any new or existing technology is neither good nor bad, it is the <u>context</u> and <u>intent</u> in which it is used that determine its value.
- I will explore context and intent with respect to GMOs

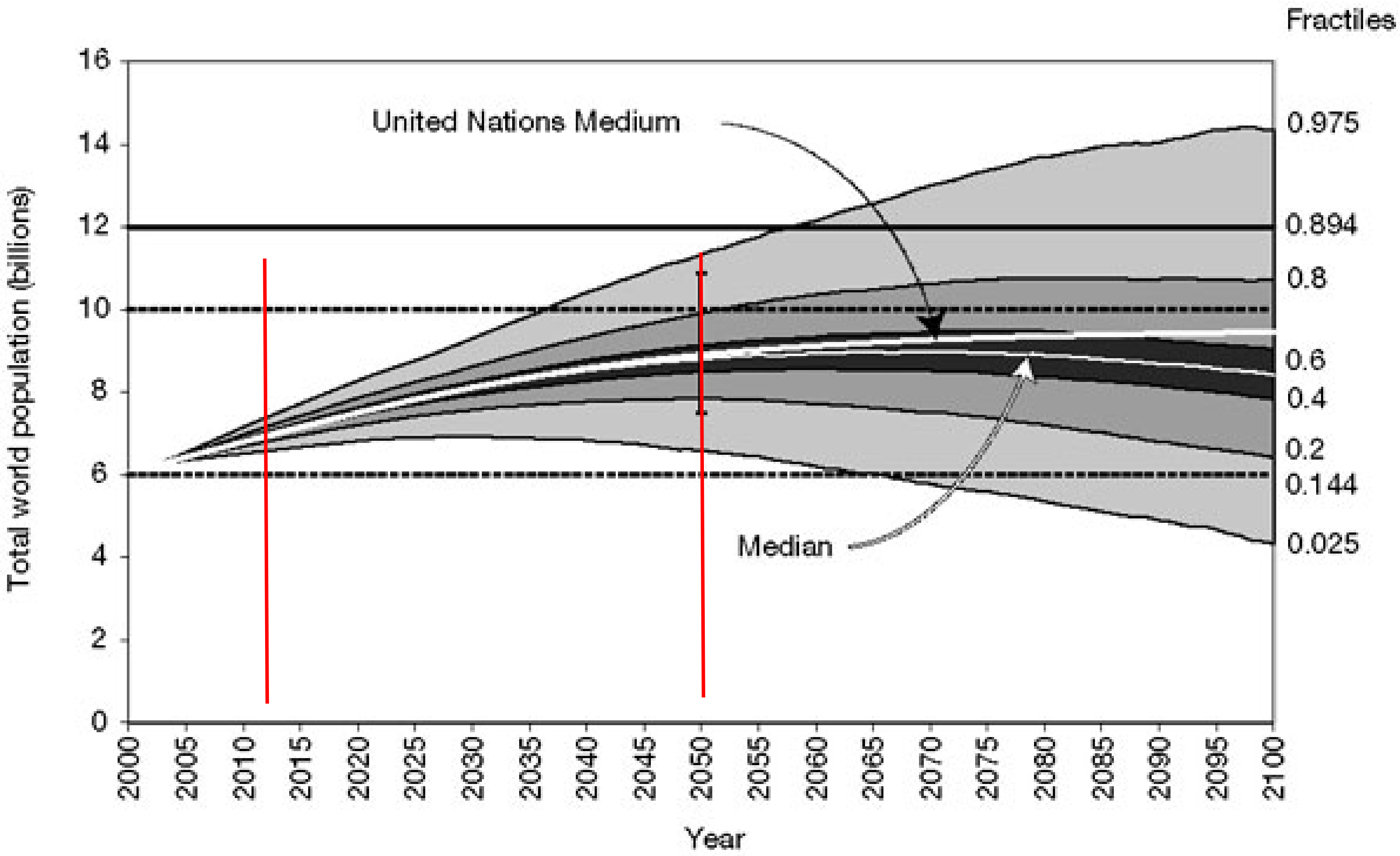
Outline

- Broad Context for Agricultural Technology
- GMO Context
- Case Examples
- Decision-making and GMOs
- Are GMOs the second Green Revolution?
- Can GMOs be used to increase food security?

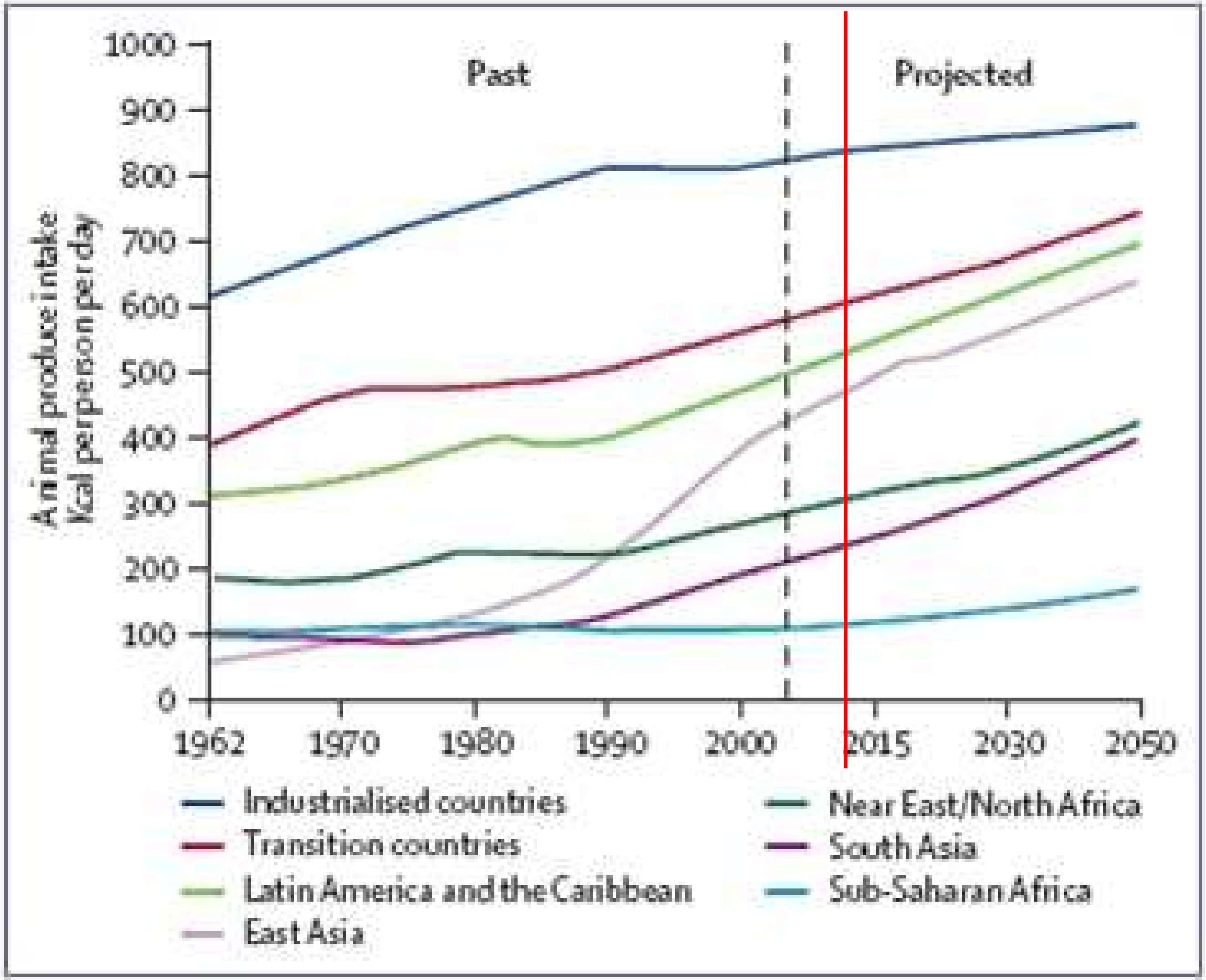
Broad Context – Future of Food

- Food demand
- Land use for food production
- Crop Productivity
- Crop losses
- Food distribution
- Research investments

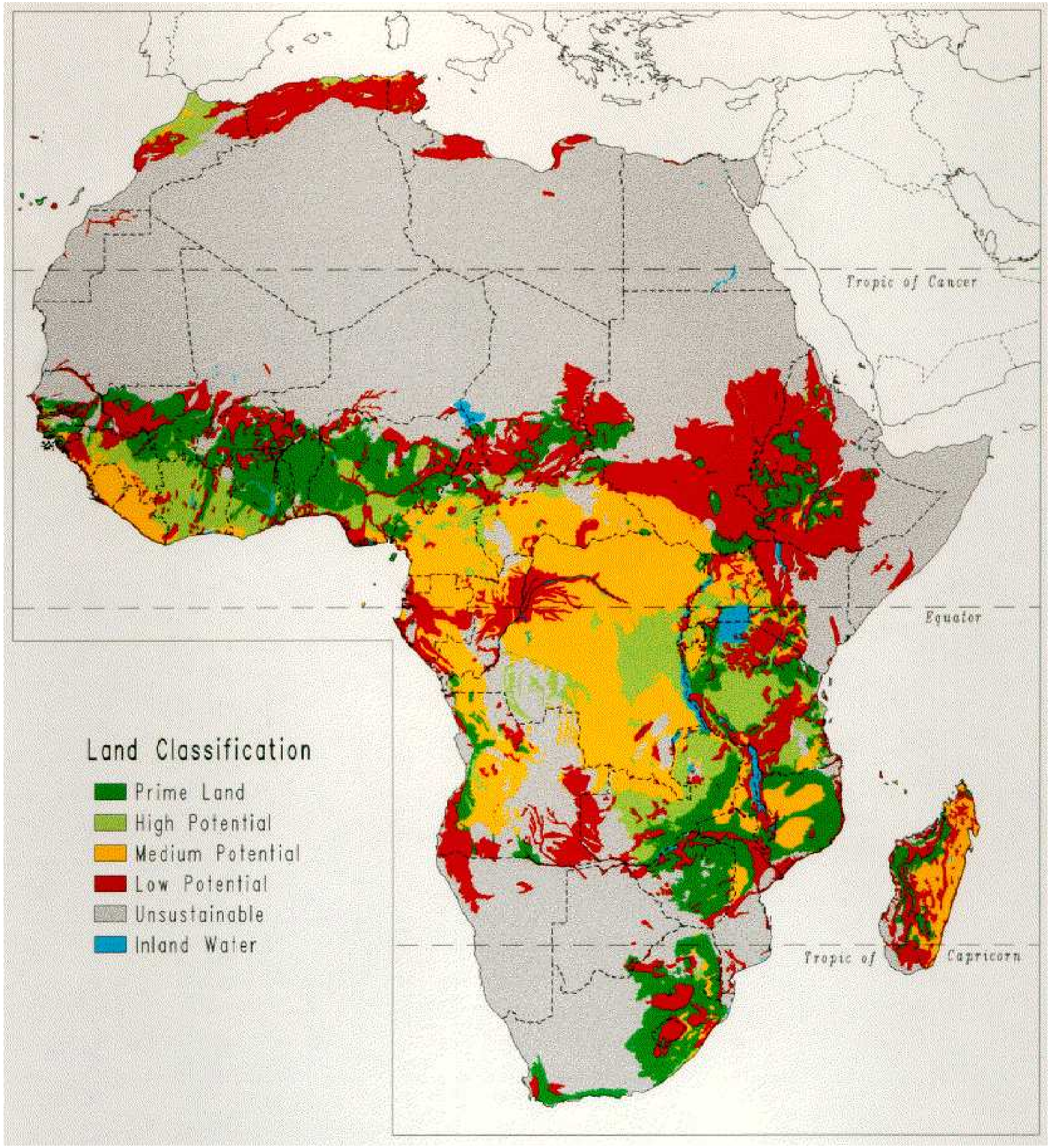
Demand: Projected Population Size



Demand: Projected Meat Consumption



Land Use: Potential Sustainable Use of African Soils



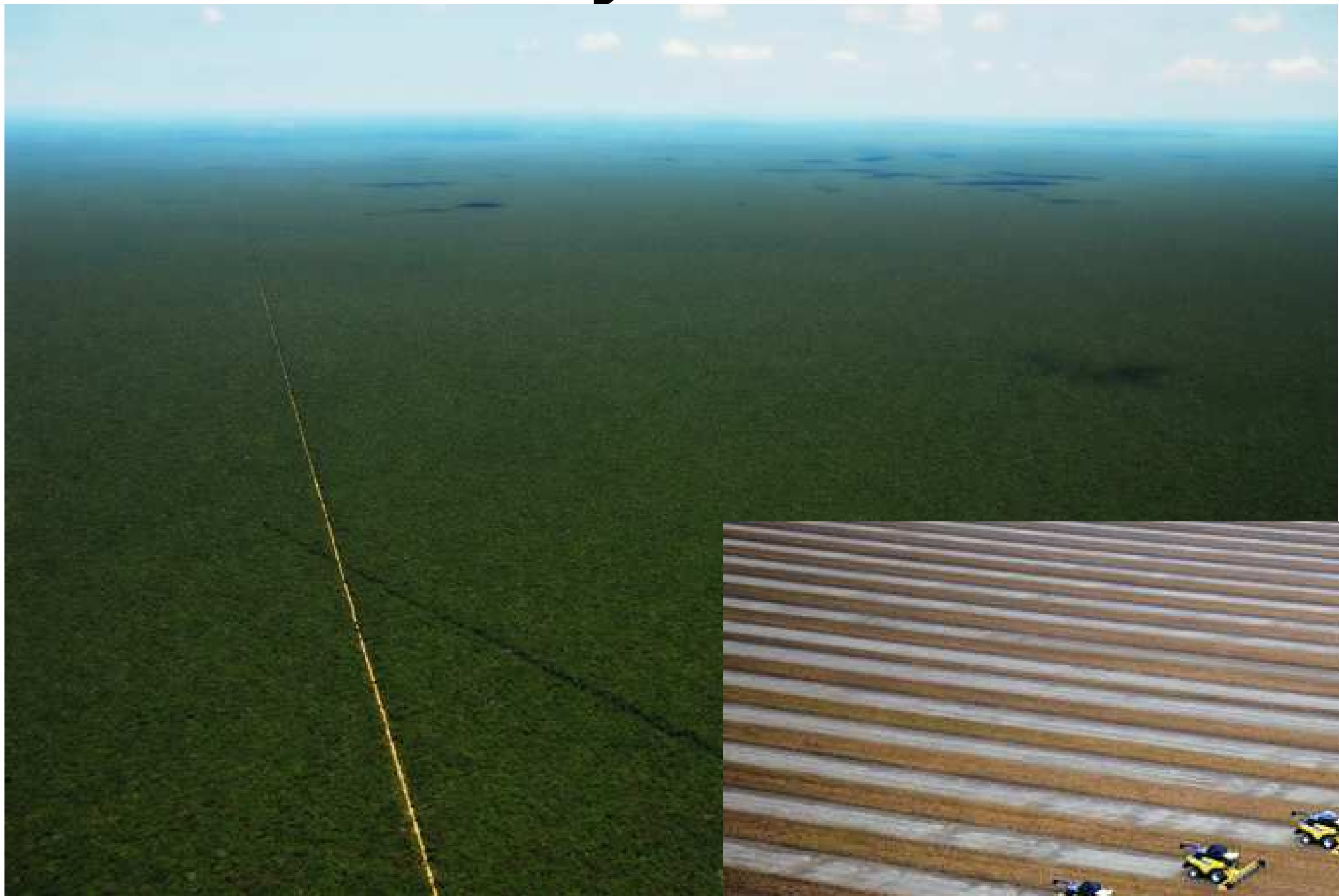
Land Use: Brazilian Cerrado

1990

Transformation of Cerrado

- Appropriate additions of phosphorus and lime mitigated aluminum toxicity
- Development of tropical varieties of soybeans

Soybean in cerrado

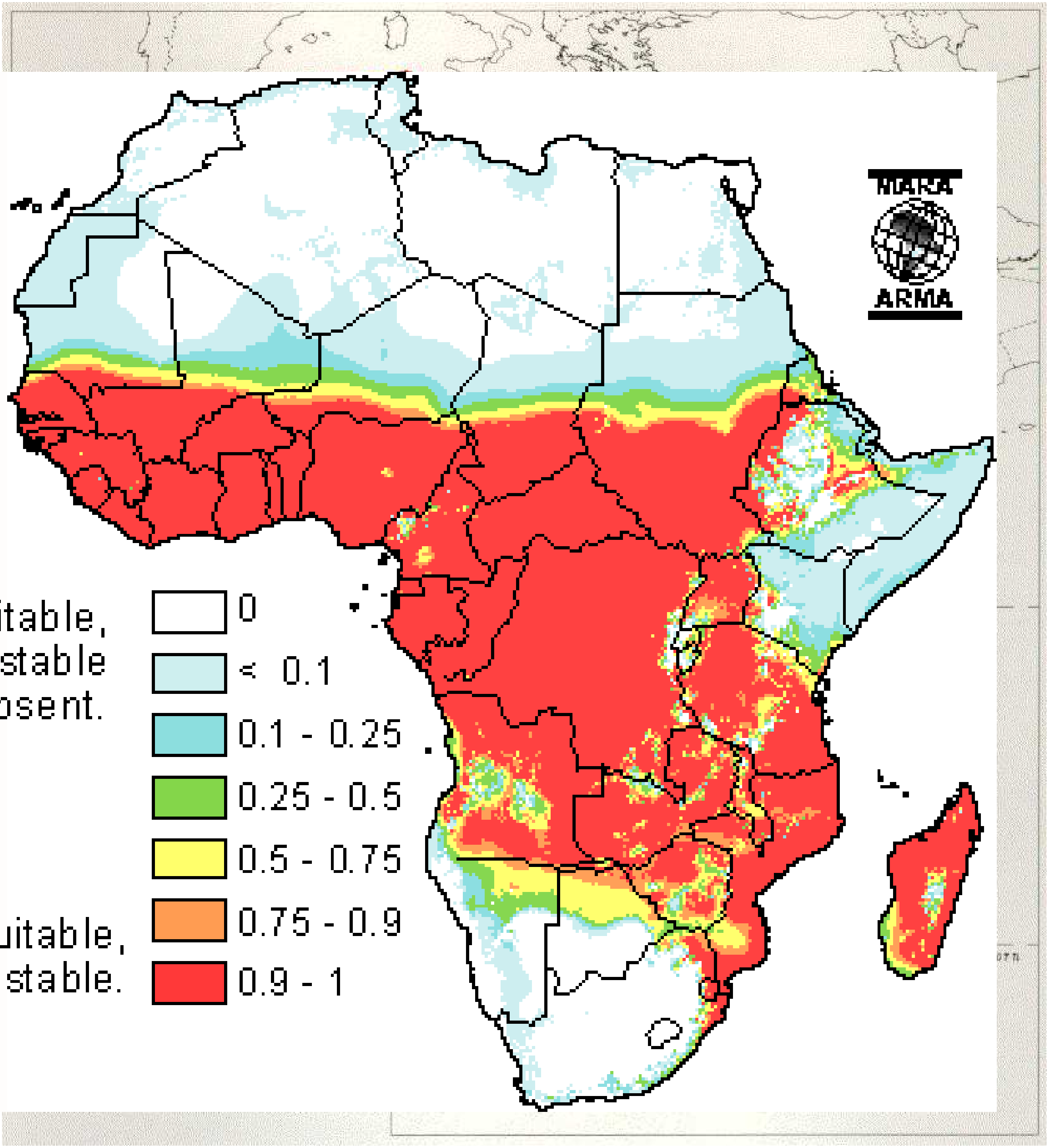


Not without problems

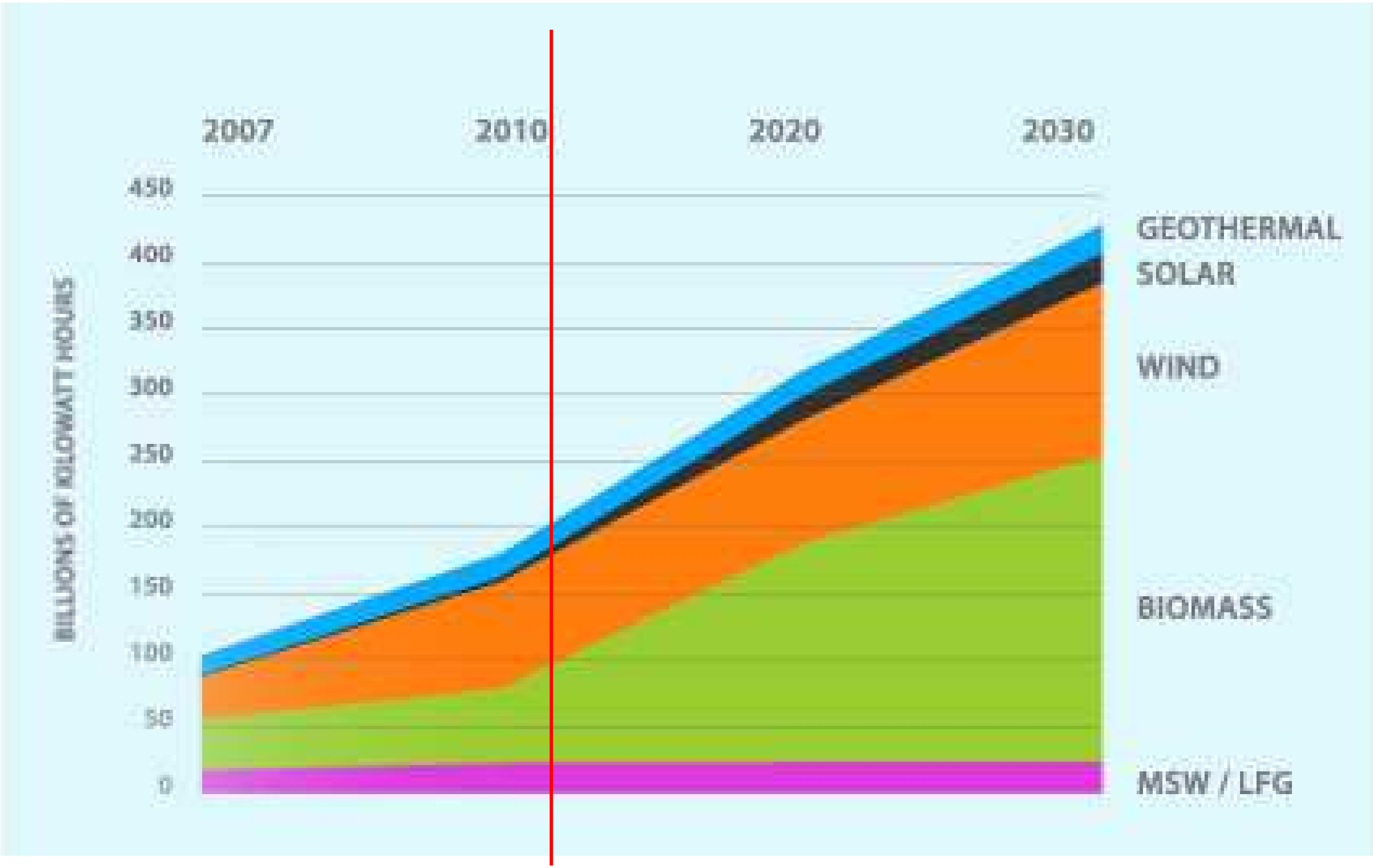
- Cerrado has greater biological diversity per hectare than the amazonian region
- Intensive agricultural chemical use
- Major use of GM cotton and GM soybean

Land Use: Potential Sustainable Use of African Soils

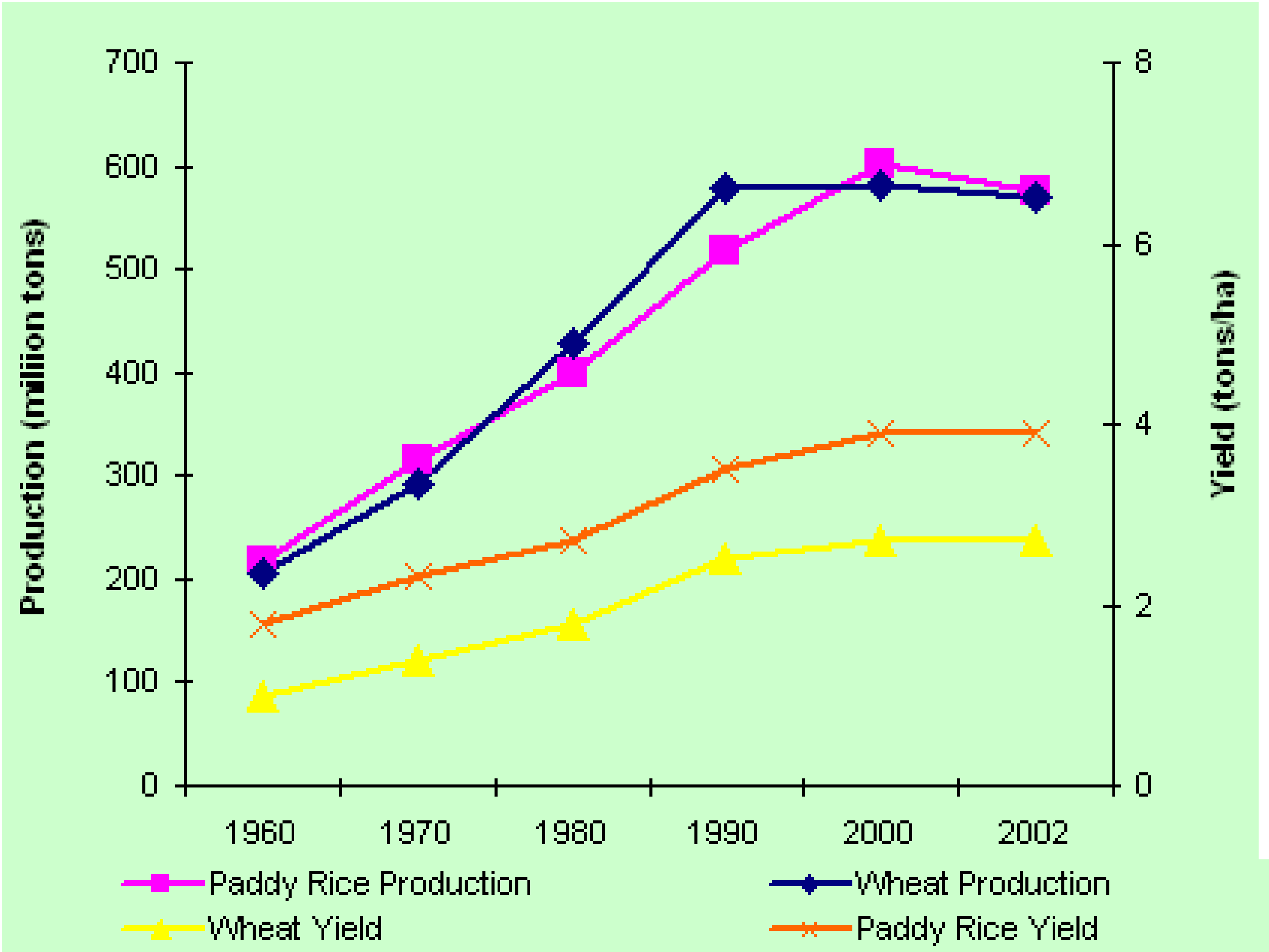
Malaria



Competition for Land
Biomass Energy Production



Productivity Projections



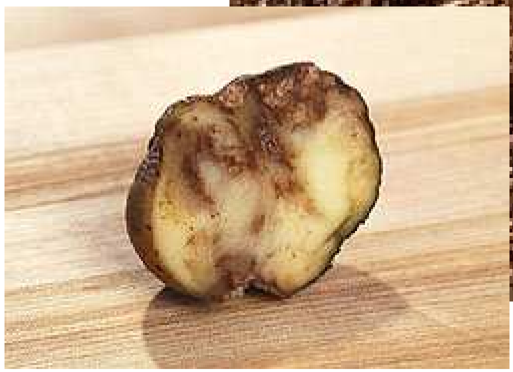
Crop Losses: Pre-Harvest
Weeds (maize)

Striga, a parasitic weed, common in Africa

Crop Losses: Pre-Harvest
Insect pests (rice)

Brown planthopper – hopper burn in rice

Crop Losses: Pre-Harvest
Plant Disease (potato)



Late blight in potato

Crop Losses: Pre-Harvest
Drought and Flooding

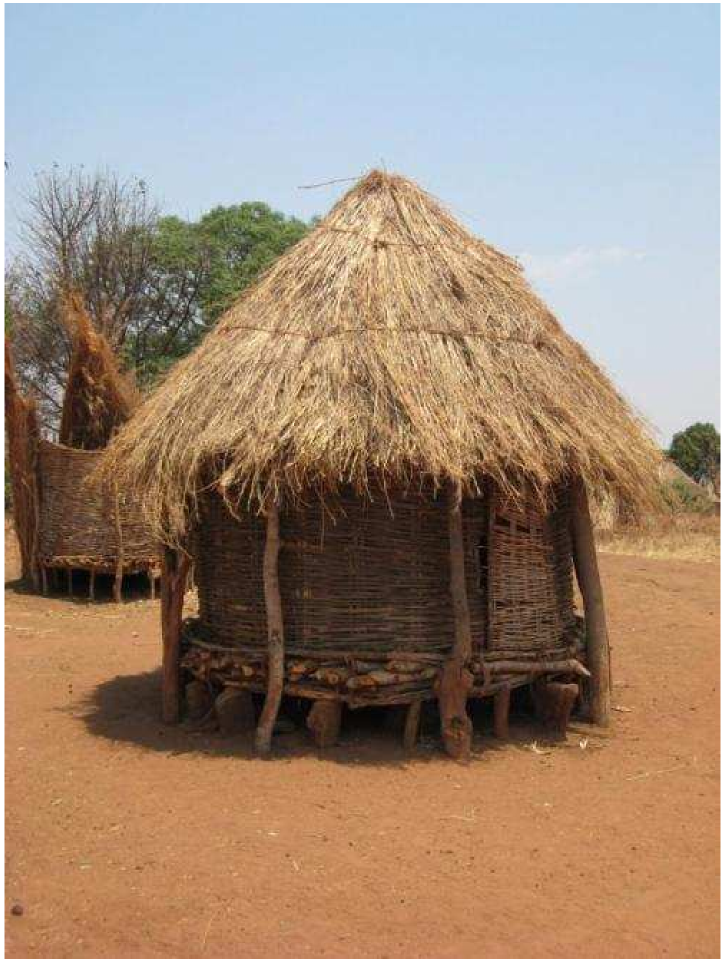
Drought-stressed maize

Flooding in maize

Often Unpredictable

Pre-harvest pest losses in US (30%) constant

Crop Losses: Post-harvest



15% loss in developing countries (>50%)

Food Distribution

- When capital flows are unregulated, nutrients and calories flow from the poor to the rich
- This is exacerbated during times of regional food shortage
- Distribution and production are not alternatives – distribution follows from the production system so designed

Agricultural Research Investments (2000)

Region/country	Expenditures (million 2000 international dollars) Total	Share (percent) Public	Share (percent) Private
Asia–Pacific	8,186	91.9	8.1
Latin America and the Caribbean	2,578	95.2	4.8
Sub-Saharan Africa	1,486	98.3	1.7
Middle East and North Africa	1,432	96.5	3.5
Developing-country subtotal	13,682	93.7	6.3
High-income country subtotal	22,277	45.7	54.3
Total	35,958	64.0	36.0

China	3,150
India	1,858
Others	3,178 (40%)

Broad Context

- Food demand: Increasing
- Land use for food production: Limited
- Crop Productivity: Lagging
- Crop losses: 50%
- Food distribution: Structural problem
- Research investments: Public, Limited

Broad Context -- Conclusions

- Each of these issues can be addressed in several ways.
- None of these issues require or favor any particular agricultural technology. There is no *a priori* reason to believe that GMOs are better suited to address these problems than another technology.
- New technologies must be viewed in terms of tradeoffs. Investments in GMOs means less funding for other technologies.

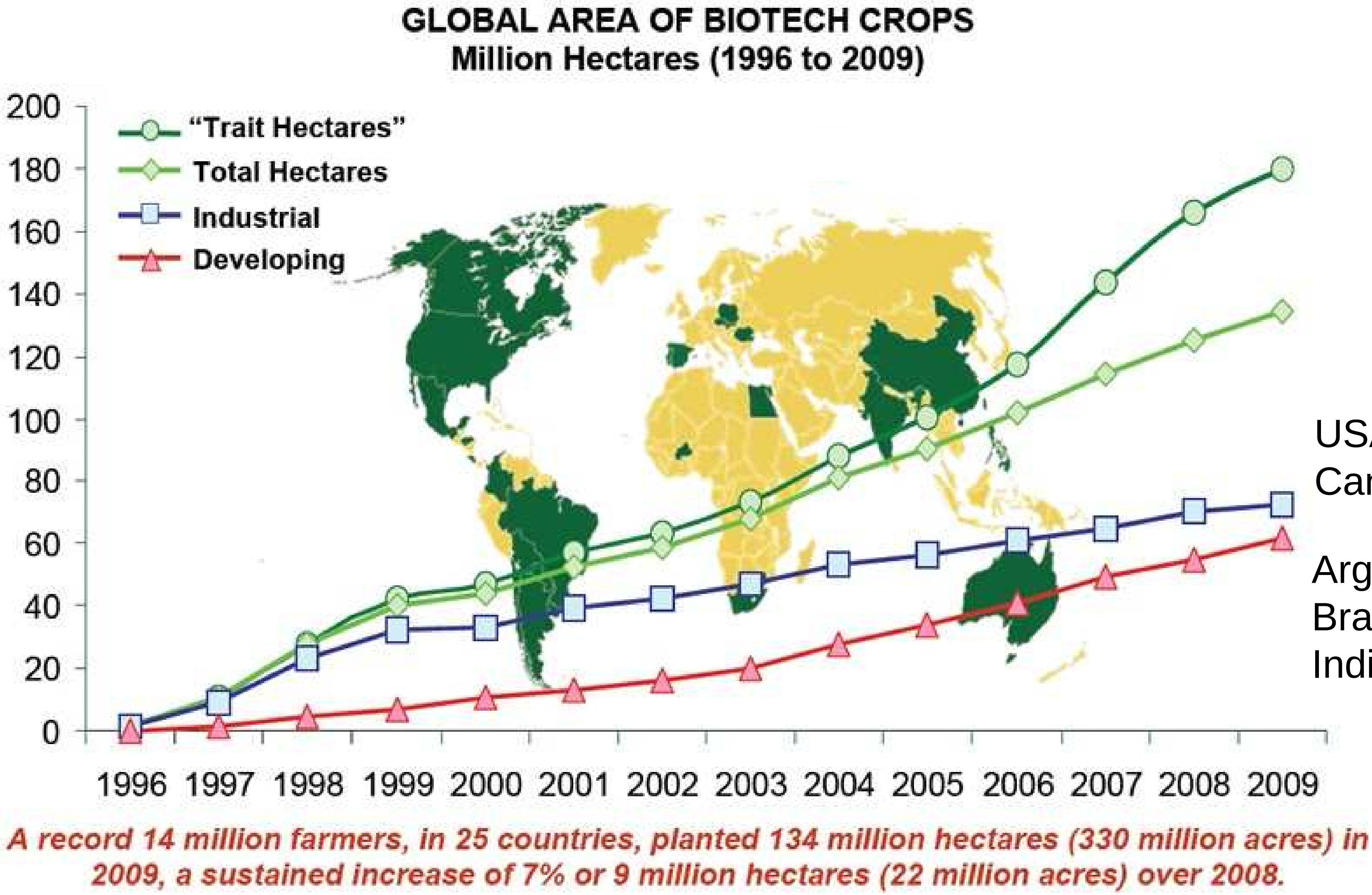
GMO Context in Agriculture

- Biotechnology
- Worldwide use
- Traits
- Crops
- Ownership

Biotechnology vs. GMOs

- Biotechnology - broad tools like
  - tissue culture
  - maker assisted selection (MAS)
  - molecular diagnostics
  - genetic engineering or genetic modification
- Increase speed and efficiency of normal plant and animal breeding
- Novel traits from other species can be introduced in plant and animal breeding (GMOs only)

GM Crops: Worldwide Use

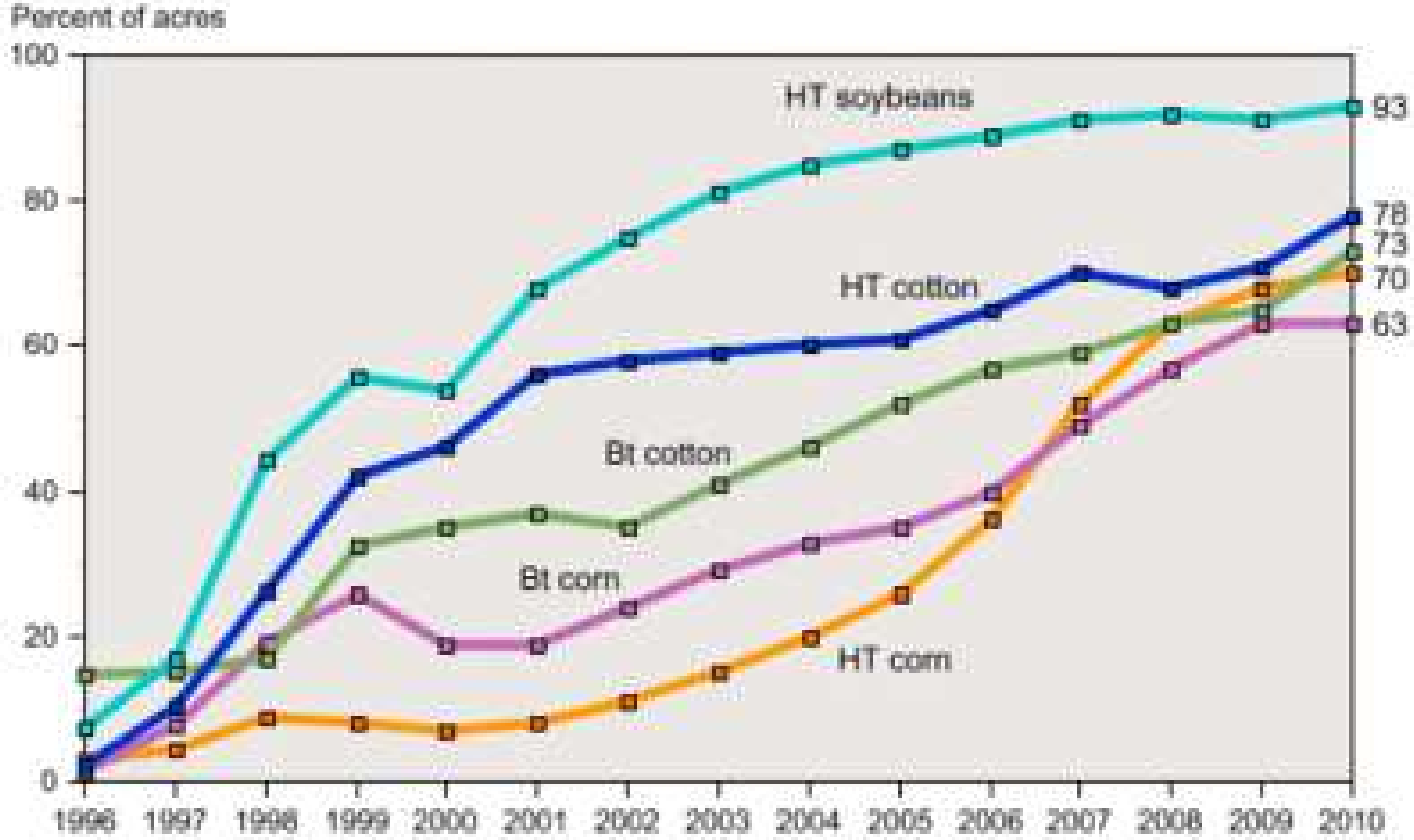


USA
Canada

Argentina
Brazil
India

GM Crops: Traits and Crops

Rapid growth in adoption of genetically engineered crops continues in the U.S.



Data for each crop category include varieties with both HT and Bt (stacked) traits.
Sources: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-10 are available in the ERS data product, Adoption of Genetically Engineered Crops in the U.S., tables 1-3.

GM Crops: Traits

- HT – herbicide tolerant
  - Soybean, cotton, maize, canola
  - glyphosate, glufosinate
- Bt – *Bacillus thuringiensis* Cry toxins
  - Maize, cotton
  - Cry1Ab, Cry1Ac, Cry1F, Cry2Ab, Cry3Bb, Cry34A/Cry35A

- Virus resistant papaya and squash
- Modified oils
- Industrial and pharmaceutical plants
- All major crops under development
- Some new traits (drought tolerance in maize)

GM Crops: Ownership

- Monsanto
- Dow
- DuPont
- Bayer
- Syngenta

GM Crops: Ownership of Traits

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- Virus resistant papaya
- Virus resistant squash
- Modified oils
- Industrial and pharmaceutical plants

Patent Issues

- Golden rice
  - 70 patents in developed countries
  - 12 patents relevant for all developing countries

GM Crop Context – Conclusions

- All commercial GM crops were developed for use in industrialized countries
- Typically, GM crops were developed to address a particular agricultural problem in those industrialized countries
- This is the problem today: Nearly all GM crops are industrialized hammers looking for a poor rural nail.
- The development of a useful GM crop is not as simple as funding public research to do so

"Biotechnology is not a stand-alone technology. An enabling environment for agriculture must be created before biotechnology can show results."

- Agro-input supply
- Farmer credit
- Market infrastructure
- Extension support

Alhassan 2002

Case Examples

- GM sweet potato in Kenya
- Golden rice
- Bio-cassava Plus
- Bt cotton and the Makhathini Flats

- Terminator technology
- Bt rice
- Failures of Bt cotton in India, Bt corn in South Africa and Puerto Rico, HT soybean in Argentina, Brazil and USA, HT cotton in USA

GM sweet potato in Kenya

- Virus resistant sweet potato
- Florence Wambugu
- $6 million (US), 10 years
- Monsanto, USAID, ISAAA, World Bank
- No virus resistance, lower yield
  http://www.lobbywatch.org/archive2.asp?arcid=2481
- Likely that transgene was lost during breeding
- Funding is insufficient for developing useful GMOs for poor farmers. Infrastructure and institutional capacity for identifying needs and conducting reliable breeding is not present.

Golden Rice

4-23 micrograms carotenoid/ gram rice

Golden rice (Efficacy)

- Bioavailability of beta-carotene is ~10%
- Digestion, absorption, transport require functional digestive tract, adequate protien and fat stores and adequate energy, protein and fat in the diet.
- Fat, protein and energy typically lacking in diet
- Personally, I do not support single factor nutritional interventions

Black rice

- 40 micrograms carotenoid/ g bran

Black Rice/ Golden Rice

- SE Asian poor will harvest black rice to feed children showing vitamin A deficiency (supply of black rice is limited)
- “Golden rice” is perceived as “contaminated rice” by most Asians
- International Rice Research Institute (funded by Gates Foundation) focusing delivery of golden rice to Myanmar
- Technology in search of an application

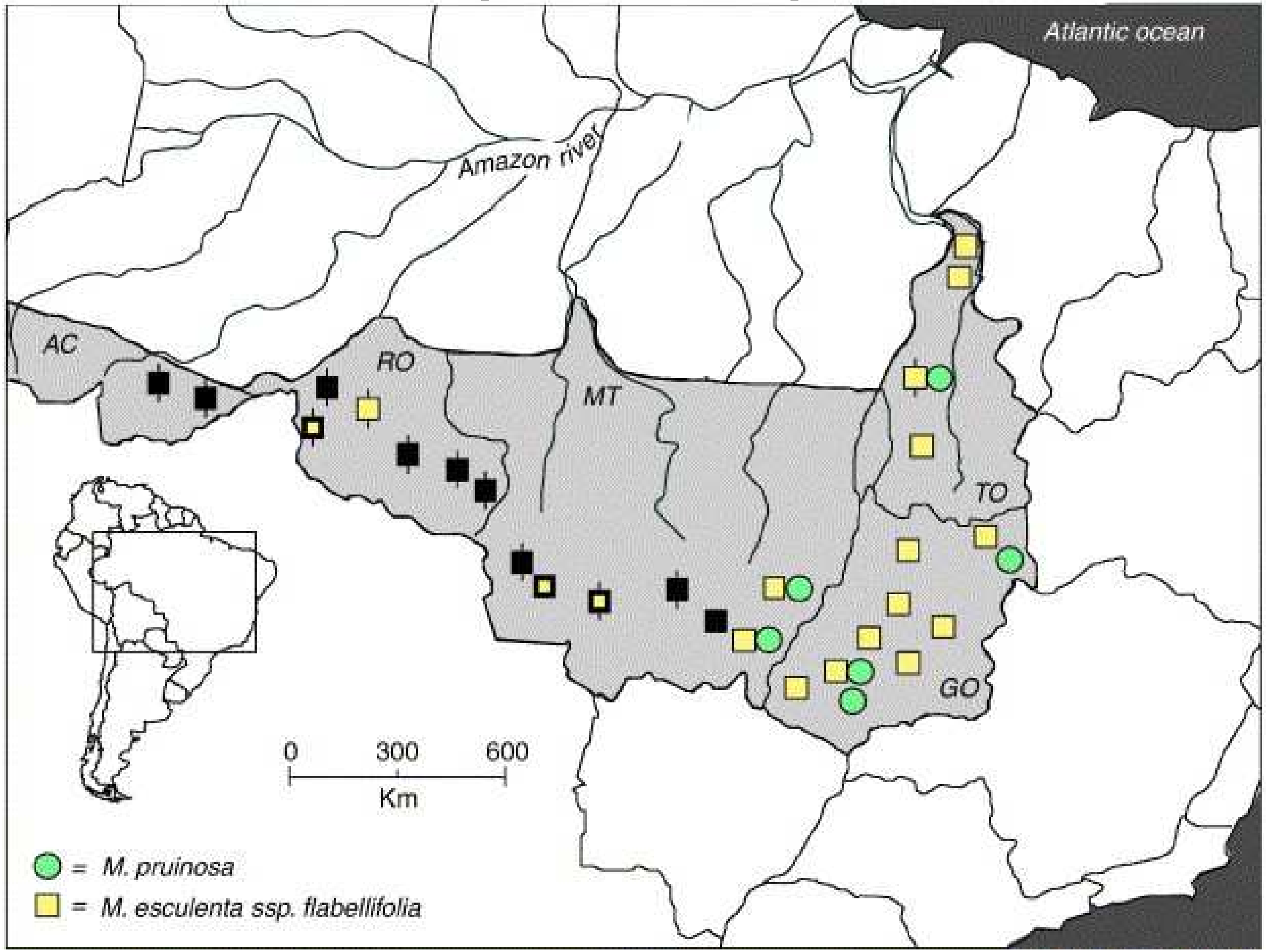
Bio-cassava Plus

Two BC Plus cassava roots fortified with beta carotene (left) next to a wild type of cassava lacking in beta carotene. (Danforth Plant Science Center)

Non-GM variation in cassava

- Nigeria

Center of Origin of Cassava (Manioc)



Tipiti squeezes manioc to extract tucupi (a yellow liquid). The liquid is cooked to eliminate the cyanide toxin common in manioc.

Pressed manioc from tipiti

Tucupi

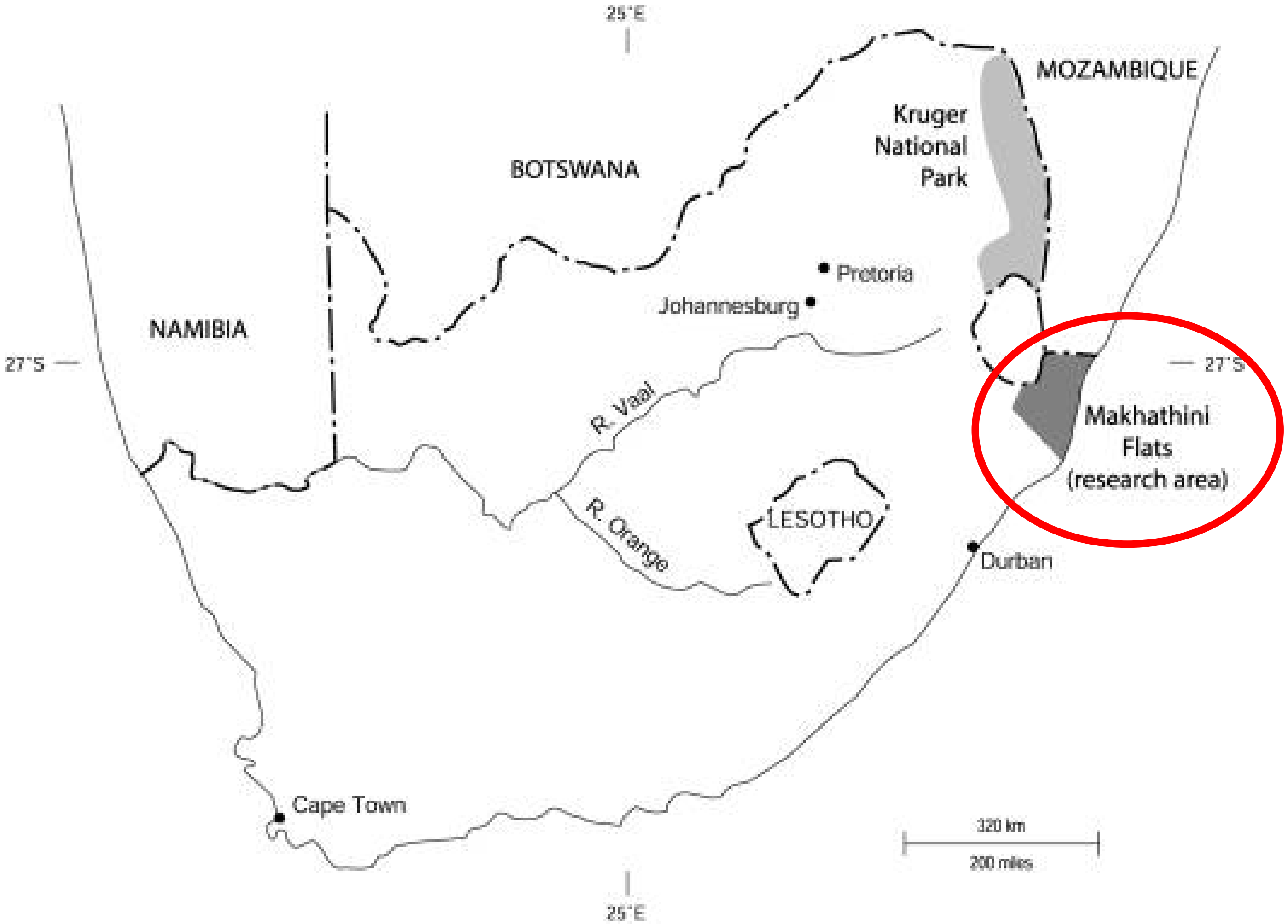
Non-GM cassava

- Tucupi is stable at tropical temperatures without refrigeration
- Yellow manioc varieties developed by Brazil's Embrapa have high carotenoid content
- Tucupi from these varieties is widely used in tropical Brazil, reducing vitamin A deficiency

Golden rice and cassava - conclusions

- Non-GM crop improvement can be used efficiently and effectively
- Enthusiasm with GM crops diverts attention, expertise, finances, and time from other effective agricultural innovations

Makhathini Flats, South Africa
Bt cotton



Republic of South Africa

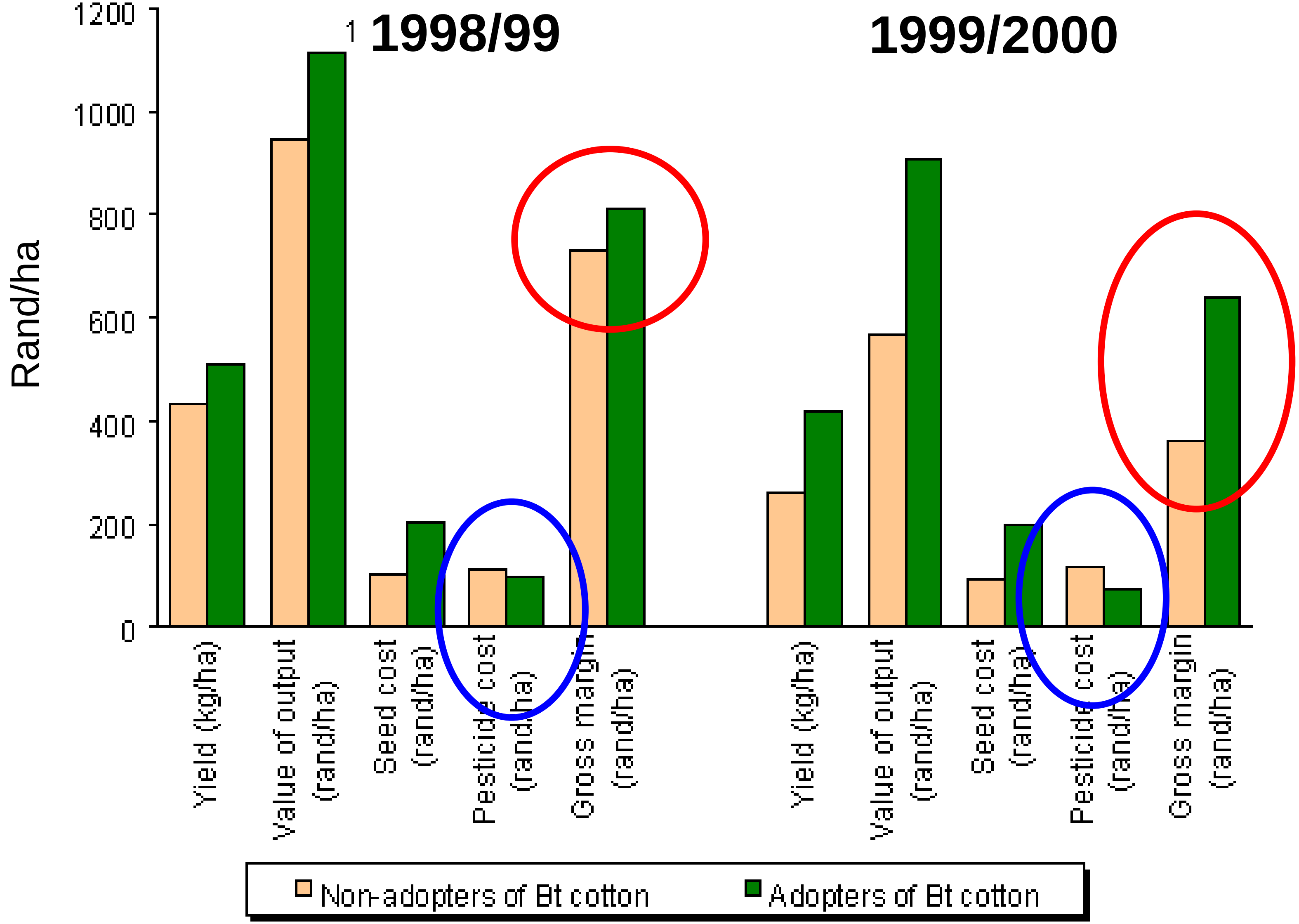
Makhathini Flats Project

- 13,000 ha area
- 85% households <R1500/mo
- 2.5-5 ha/farm
- Bt cotton (Monsanto)
- High adoption
- Farm credit and project investments $16m (Public 80%, Private 20%) to 2002

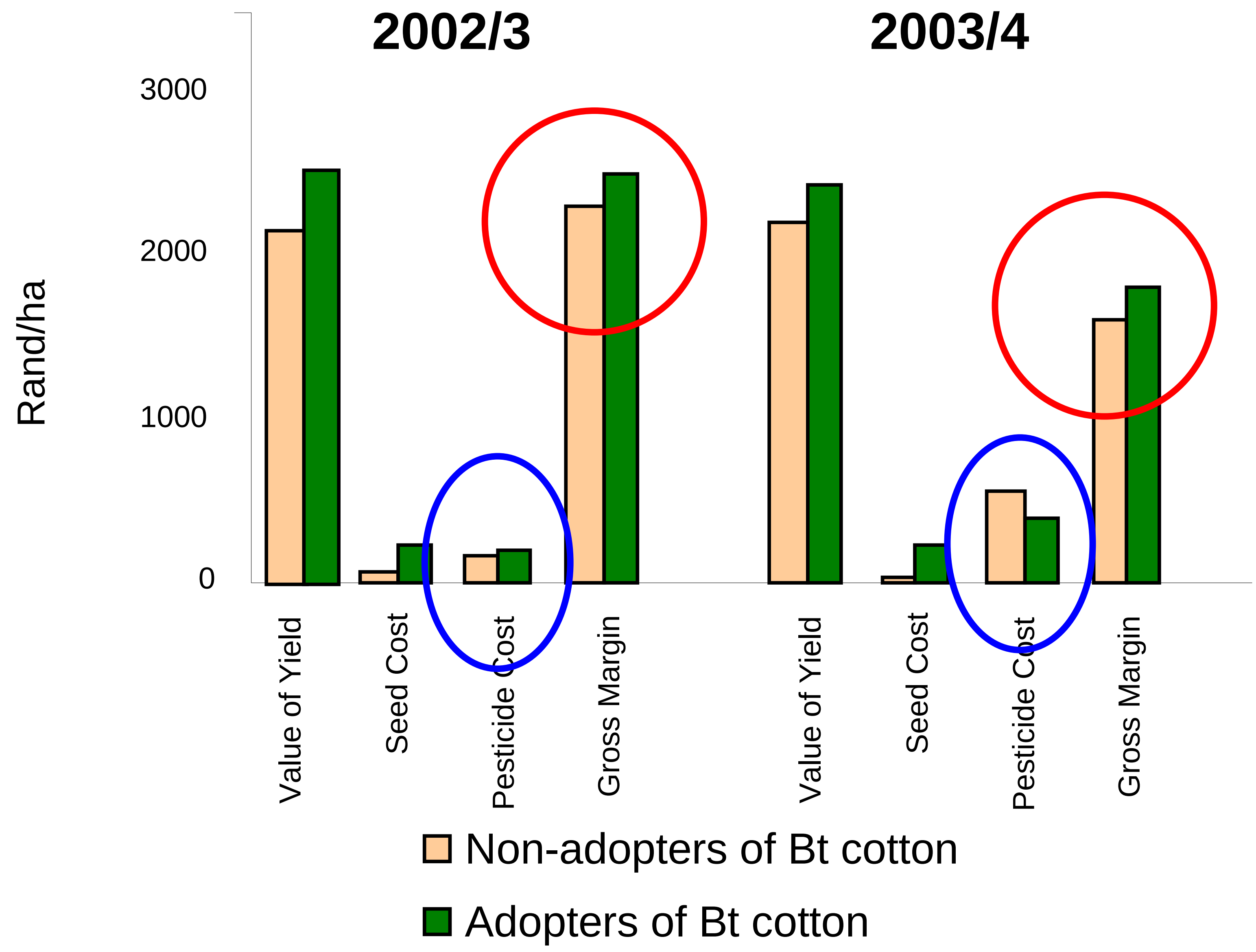
KwaZulu-Natal Context

- Cotton is a colonial and apartheid legacy
- Steady decline in dryland cotton production since 2000 (mostly poor farmers)
  - World price decline
  - Reduced emphasis on cotton self-sufficiency for the country

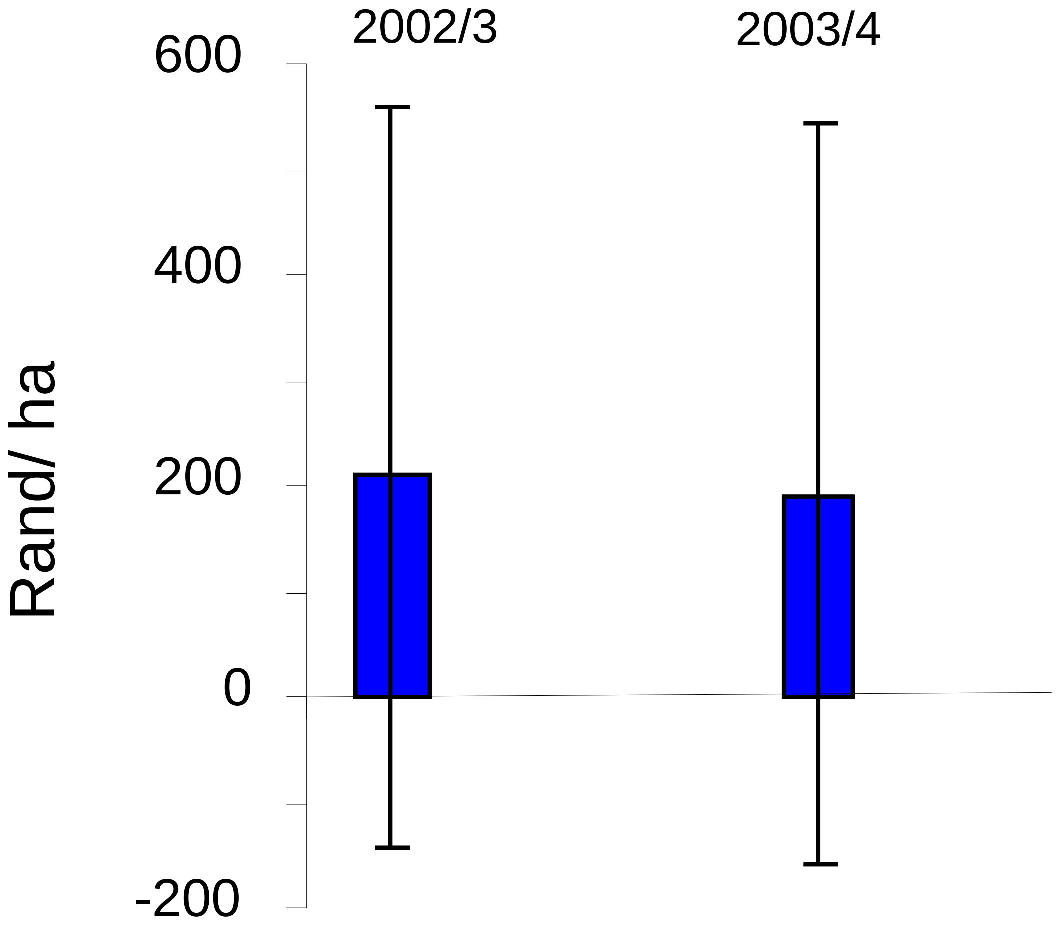
Benefits from Bt Cotton



Benefits from Bt Cotton



Expected Profit from Bt cotton



2/3 of one month income (5%)

Higher risk

Why was Bt cotton used in Makhathini Flats?

- Small expected increase in profit
- Large increase in risk
- No consistent change in insecticide use
- Institutional arrangements favored Bt cotton
- After 1993, only through cotton could farmers access credit (moral hazard of farmers claiming to be cotton farmers)

Makhathini Cotton Corporation (MCC)

- Founded 2002
- Embodies the post-apartheid discourse
  - Privatization and the role of private capital in economic development
  - Redistribution of economic opportunities to previously disadvantaged individuals
- Vision is to bring enduring development to Makhathini Flats
- Agricultural Black Economic Empowerment company

Economic Position of MCC Precarious

- MCC owns the only cotton gin in the area
- Gin will be profitable only when 10m kg cotton can be ginned.
- 5.5m kg produced in entire KwaZulu-Natal region (8-yr average)
- MCC owns, leases and subleases land for cotton (has realized R141.63/ha on best land)
- MCC promotes high-yielding cotton varieties and high-yielding cotton production systems (Bt cotton under irrigation)

Limited availability of non-Bt cotton seed

- Non-Bt sold in sizes too large for a small-scale producer (25kg bag instead of 5kg bag)
- MCC wants to limit licensing ‘violations’ and the illegal distribution of patented seed
- MCC regulates this by providing labeled baling sacks at the time of seed sale.
- MCC will only buy cotton in the labeled sacks. By doing so, MCC limits seed saving.

Conclusions – Makhathini Flats

- High adoption of Bt cotton related to access to credit and limited options, not production benefits
- Small-scale farmers are making the best choices in a bad and deteriorating situation
- GMOs cannot be made to work by pouring financial credit at the “problem”
- Institutional arrangements can outweigh technical considerations

Decision-making and GMOs

- The Value of Culture
- Value Conflicts
- Should Utility Matter?
- The Last Animal Alive Will be a Cockroach

- Main conclusion: Decision-making criteria need to be expanded.
- Question is how?

Risk Assessment

WORLD TRADE ORGANIZATION

– GATT – SPS Agreement

– Cartegena Protocol – Annex 3

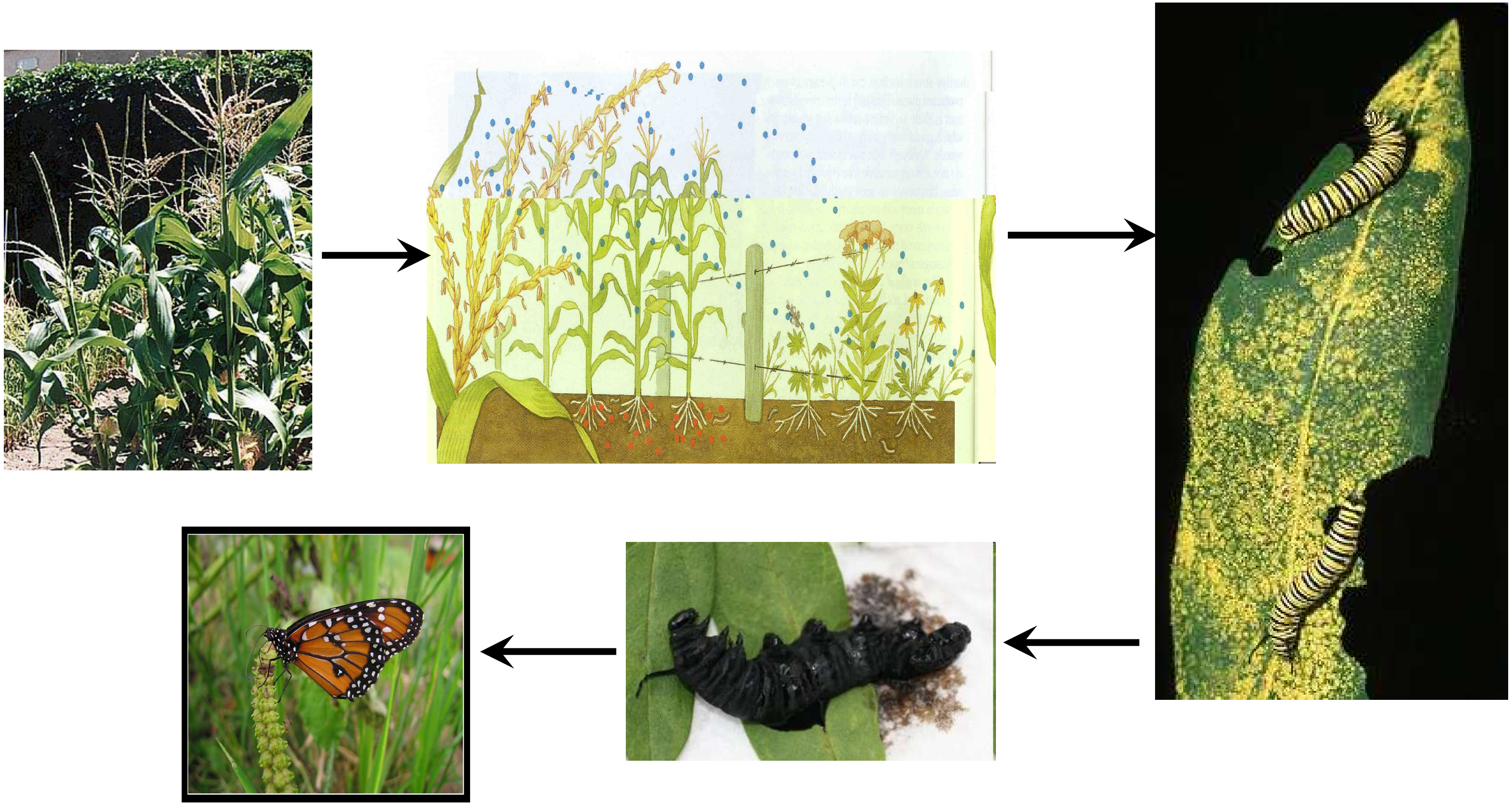
Risk Assessment

- Human health
  - Acute and chronic toxicity
  - Carcinogenicity and mutagenicity
  - Allergenicity (Food sensitivities)
- Environment
  - Unintended effects on organisms and ecosystem processes
  - Gene flow and consequences
  - Evolutionary responses

First Story

The Value of Culture

Monarch butterfly and Bt maize in the US



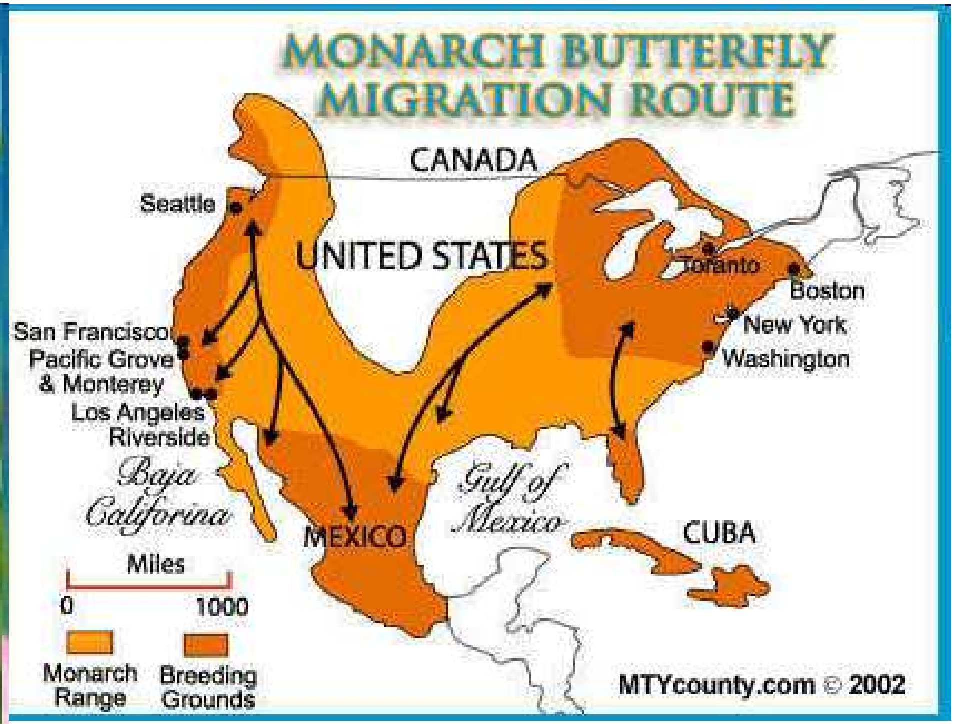
Main Result: No serious risk

Overlooked

Monarchs were

overlooked by
both the USA and Canada

Monarchs are Amazing



>3000 km

Monarchs are Amazing

Aggregate in winter
>100 million
in Mexico

Cultural Significance in N. America

Second Story

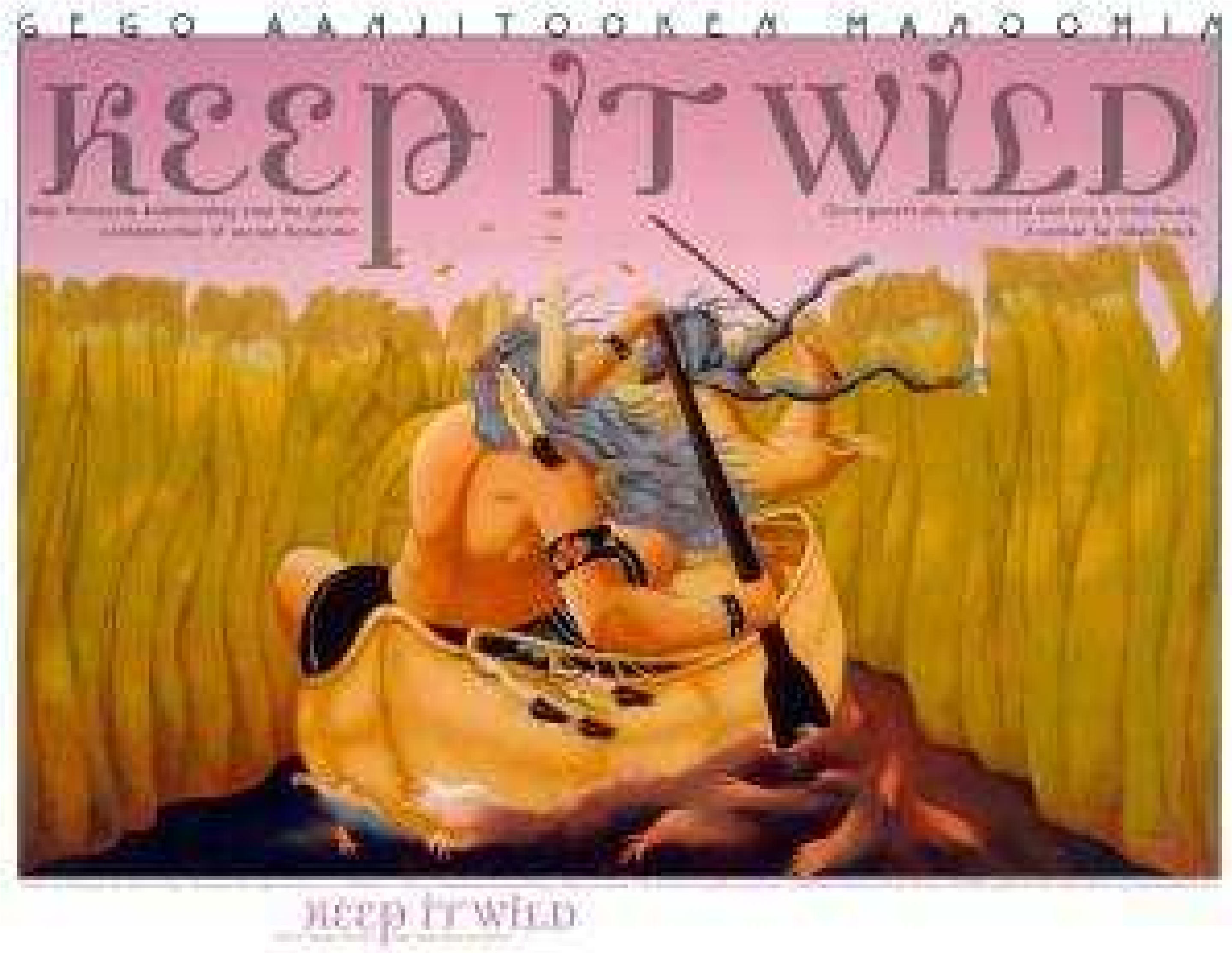
Value Conflicts

Wild rice – Manoomin

Anishinaabeg live in Minnesota because of wild rice. Eons ago a series of prophecies led the Anishinaabeg westward from the Atlantic coast.

"We consider it to be sacred, because it's a gift from the creator", says White Earth elder Earl Hoaglund. "It was foretold in those prophecies that as the ice melted we were to move westward and food would be provided for us on the water. And that's what happened."

No Genetic Engineering



Raymie Porter, a University of Minnesota researcher, says Ojibwe people are entitled to their beliefs, but he says no group of people should expect their religious beliefs to shut down scientific inquiry.

Who will judge?
How will it be judged?

Second Story

Should utility matter?

Bt brinjal in India

Insecticide Use

- Efficacy of Bt brinjal varies from 38% to 97% kill of the Brinjal Fruit and Stem Borer population, with an average of 73% kill
- Insecticides are still necessary to control the borer

Farm Yield

Location	Size of farm	Proportion of farmers	Maximum potential yield benefit (q/ha)
West Bengal, Orissa, Bihar	Mostly small-scale resource-poor	0.61	0
Rest of India	Large-scale commercial	0.04	84.2
Rest of India	Small-scale resource-poor	0.35	13.9

Returns to Farm

Location and Technology	Farm-scale	Increase in Gross Return
West Bengal		
Brinjal IPM	Small-scale	34.6 Rs/are
Bt brinjal	Large-scale	23.4 Rs/are
Gujarat		
Brinjal IPM	Small-scale	83.0 Rs/are
Andhra Pradesh & Karnataka		
Bt brinjal	Large-scale	23.4 Rs/ are
Bangladesh		
Brinjal IPM	Small-scale	82.7 Tk/ are
Brinjal IPM	Small-scale	141.8 Tk/are

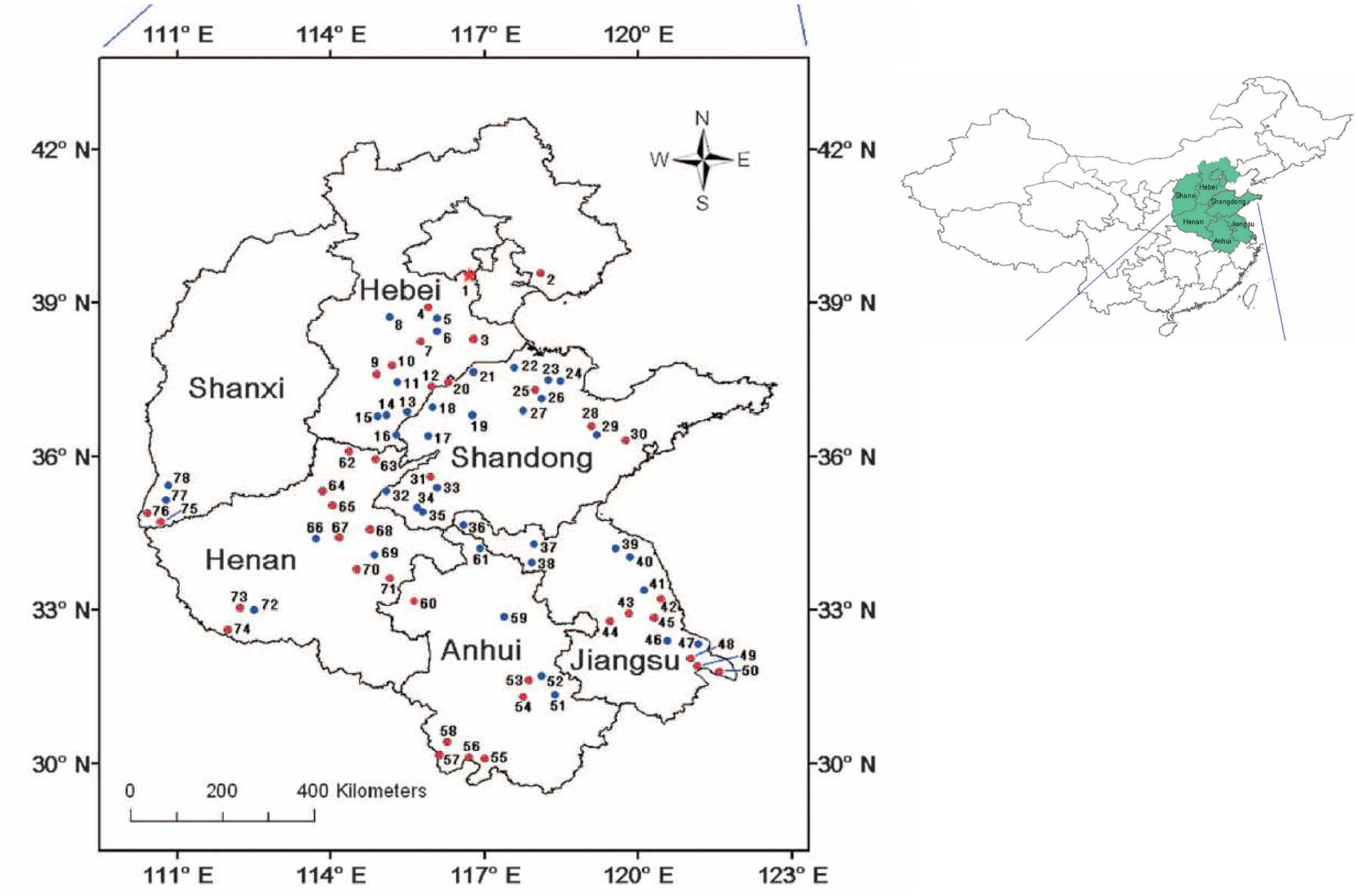
Social Economic Surplus: Who benefits?

	Brinjal IPM	Hybrid Bt Brinjal
Total Economic Surplus (Rs. million)	326[1]	1,008[2]
Consumer surplus (%)	37	41
Farmer surplus (%)	63	10
Company surplus (%)	0	48

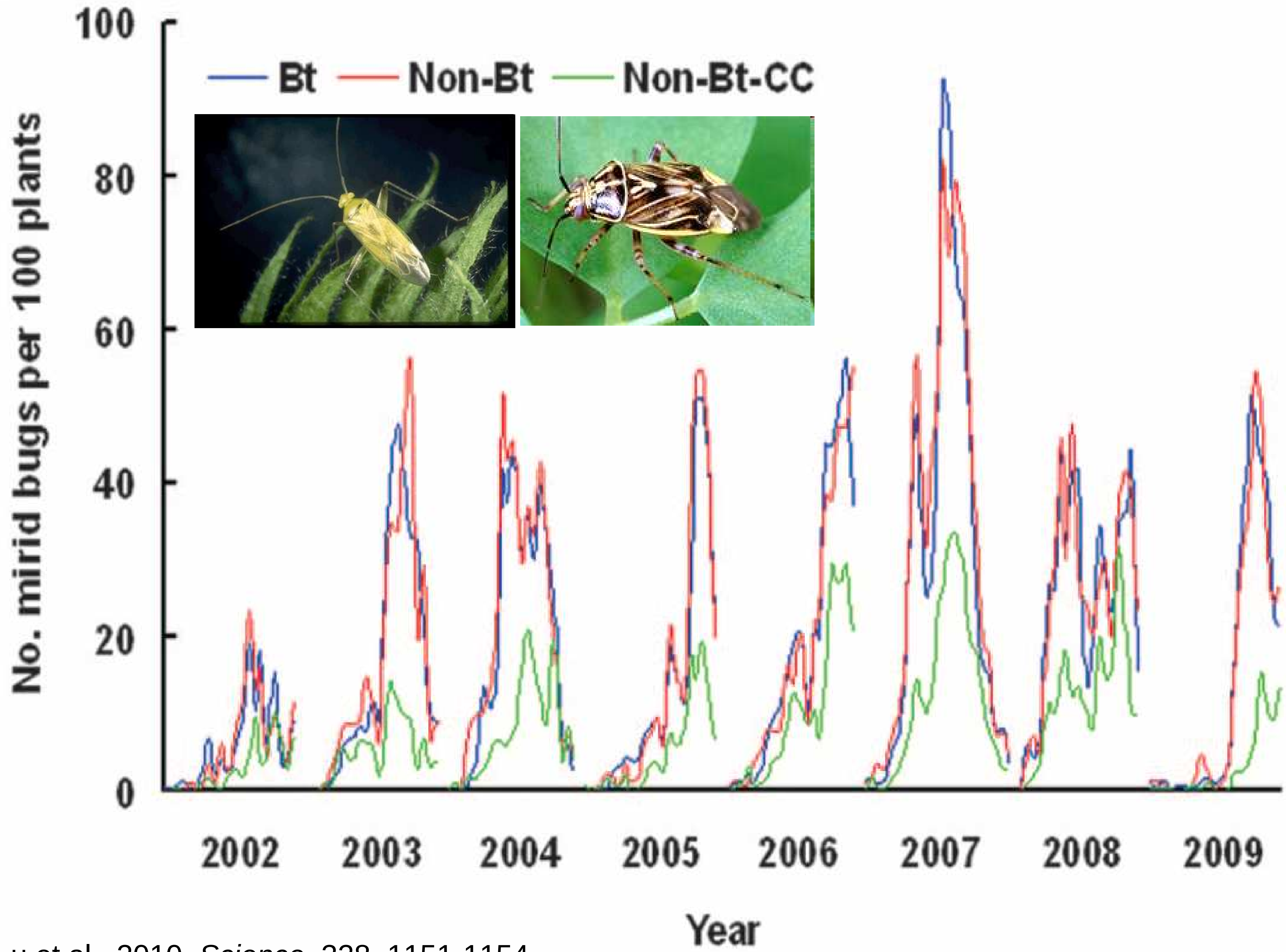
1 East Bengal only
2 All of India

Fourth Story

The Last Animal Alive Will be a Cockroach



Lu et al., 2010, *Science*, 328, 1151-1154.



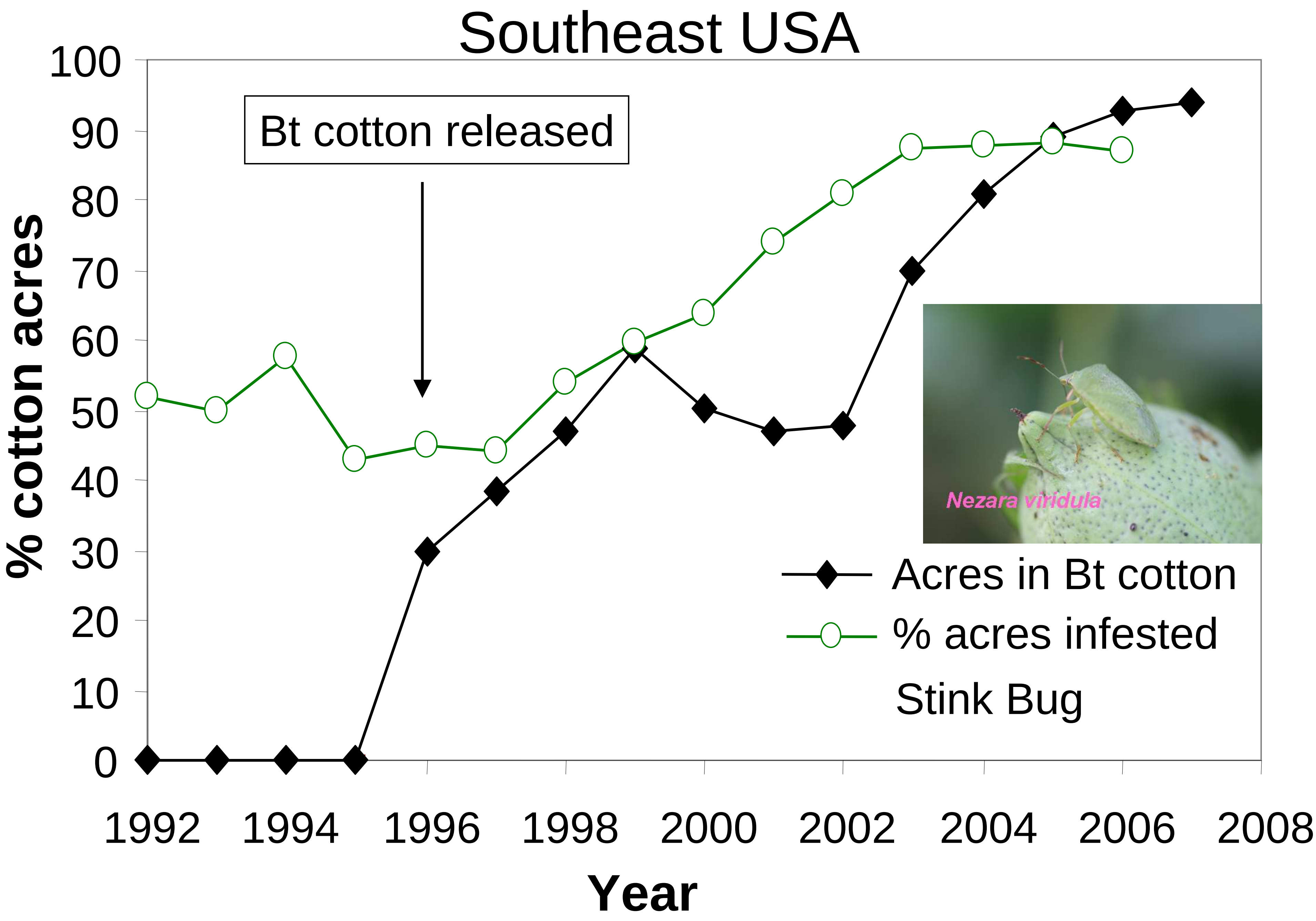
Lu et al., 2010, *Science*, 328, 1151-1154.

Consequences in China

- Crop losses
- Increased insecticide applications
- Poor extension system

= Financial and environmental benefits of Bt cotton have been lost

Lu et al., 2010, *Science*, 328, 1151-1154.



Zeilinger et al. 2011, in press

Consequences in the US

- Crop losses
- Insecticide applications
- Excellent extension system

= Financial benefits and some environmental benefits of Bt cotton have been sustained

- These are secondary pests

- Target pests evolve resistance to Bt.
  - Bt maize South Africa
  - Bt cotton India
  - Bt cotton China
  - Bt maize Puerto Rico
  - Bt maize USA

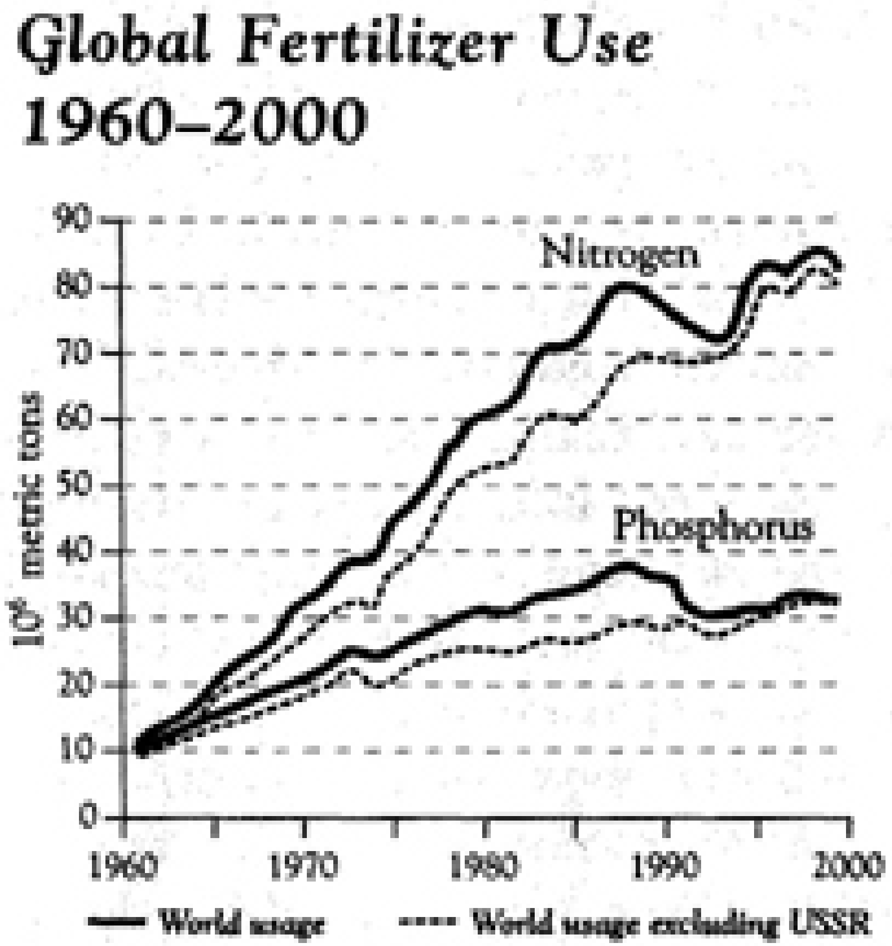
Humankind should not expect to win the war against crop pests

Are GMOs the Second Green Revolution?

- What made the first Green Revolution effective?
  - Technology package transferable to many grain crops
  - Had been worked on since 1930s
  - Global scientific consensus by 1950s
  - But ignored social issues, which limited its value

Green revolution

Required Nitrogen Fertilizer to Grow Fast Early

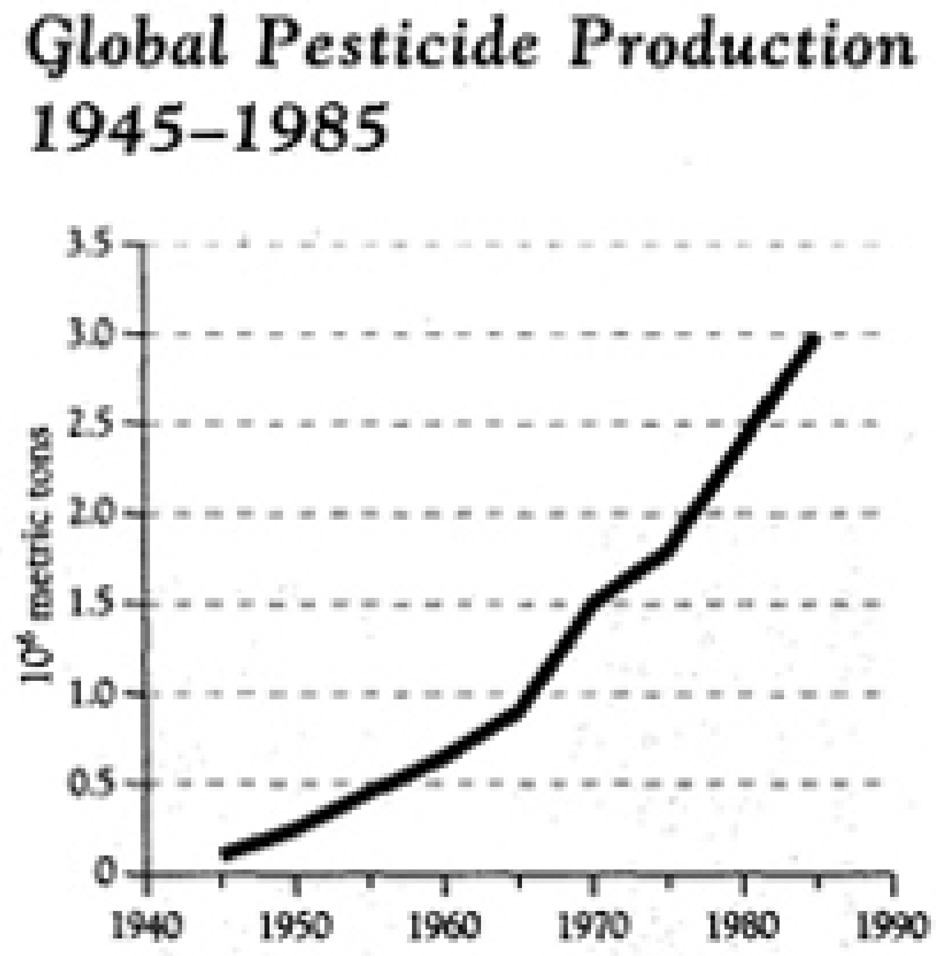


Weed Challenges – Need for Herbicides

Water Critical

Induced Pests – Pesticide Use

Pesticides were used to control unexpected pests



Technology Package – Green Revolution

- Short-statured plants
- Higher fertilizer use
- Increased herbicide use
- Timely availability of water
- Increased pesticide use

Seizo Matsushima, Japan

1930s

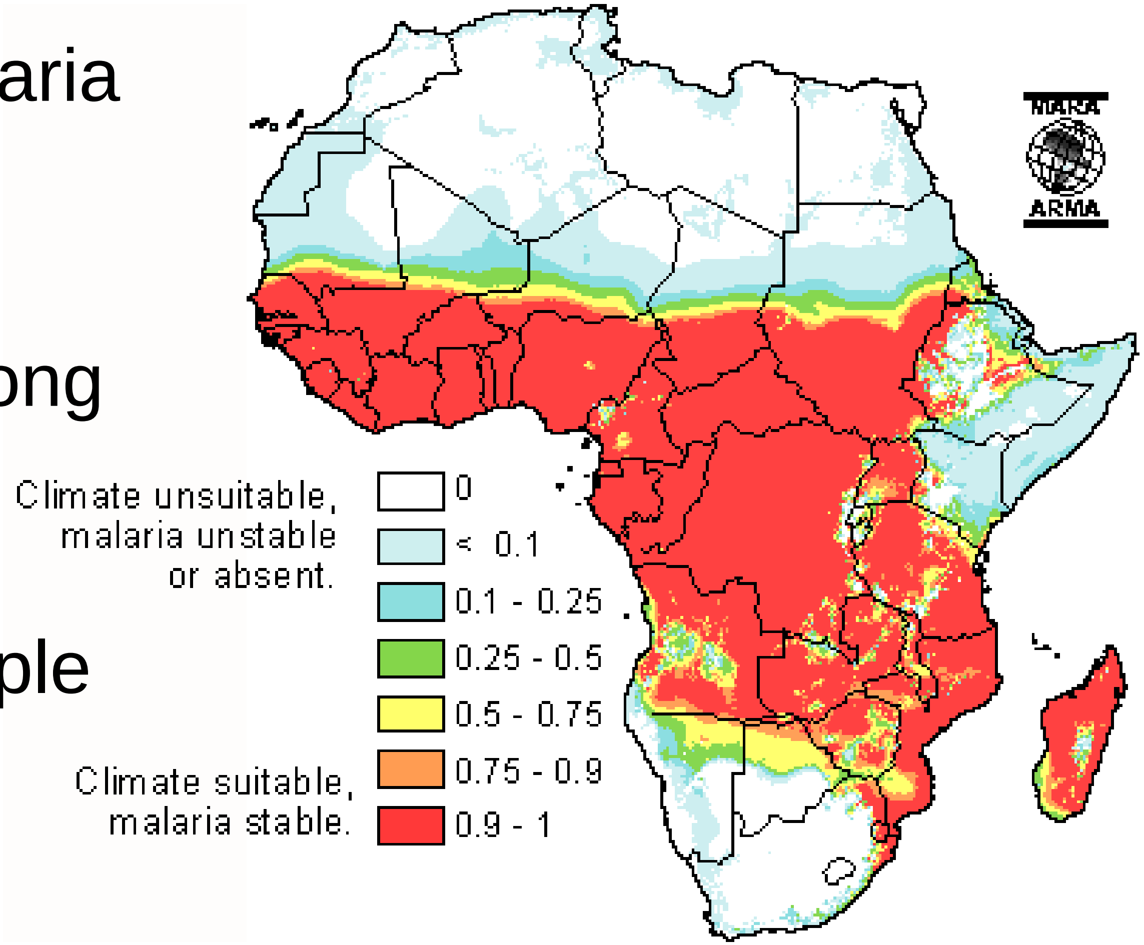
- Ideal Plant Type
  - Short stature
  - High early tillering
  - Needs irrigation
- Decades to be tested and gain support

GM Crops – not a revolution

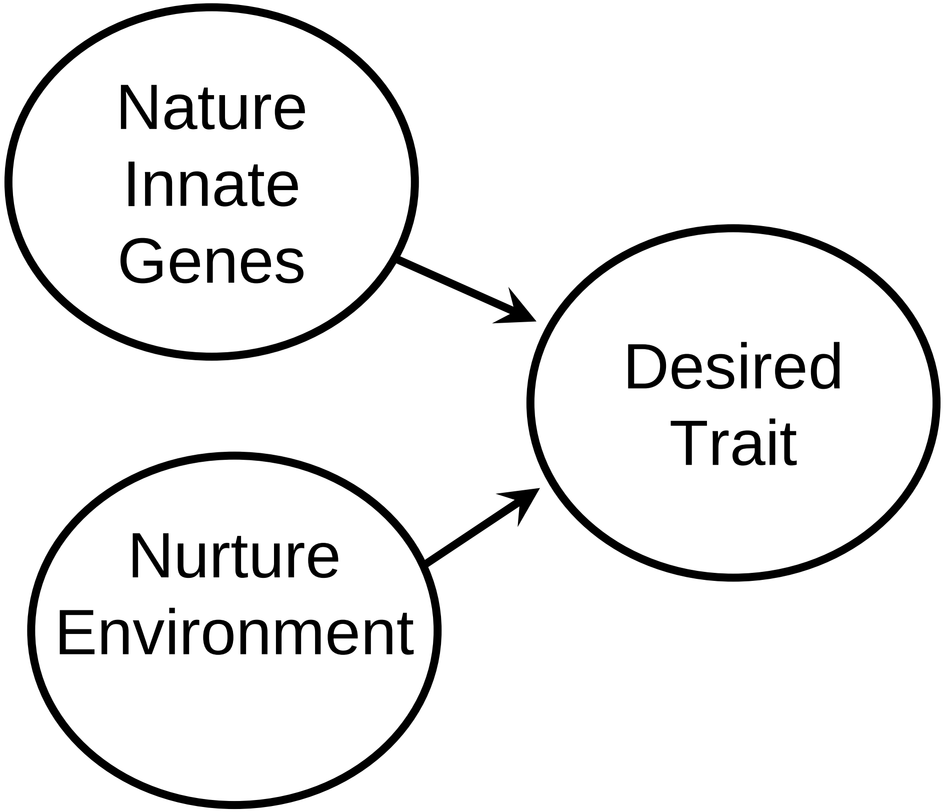
- Share none of the essential characteristics with the Green Revolution
- Not a single transferable technology; many different technologies
- Not a package; considered a seed
- Rapidly commercialized, no time to simmer
- No scientific consensus
- Still little consideration of social issues

Can GMOs be used to improve food security?

- GM mosquito
  - Suppress malaria
  - Sterile mosquitoes
  - Hopeful, but long ways to go
  - Just an idea, proof of principle still lacking



How NOT to think about GMOs



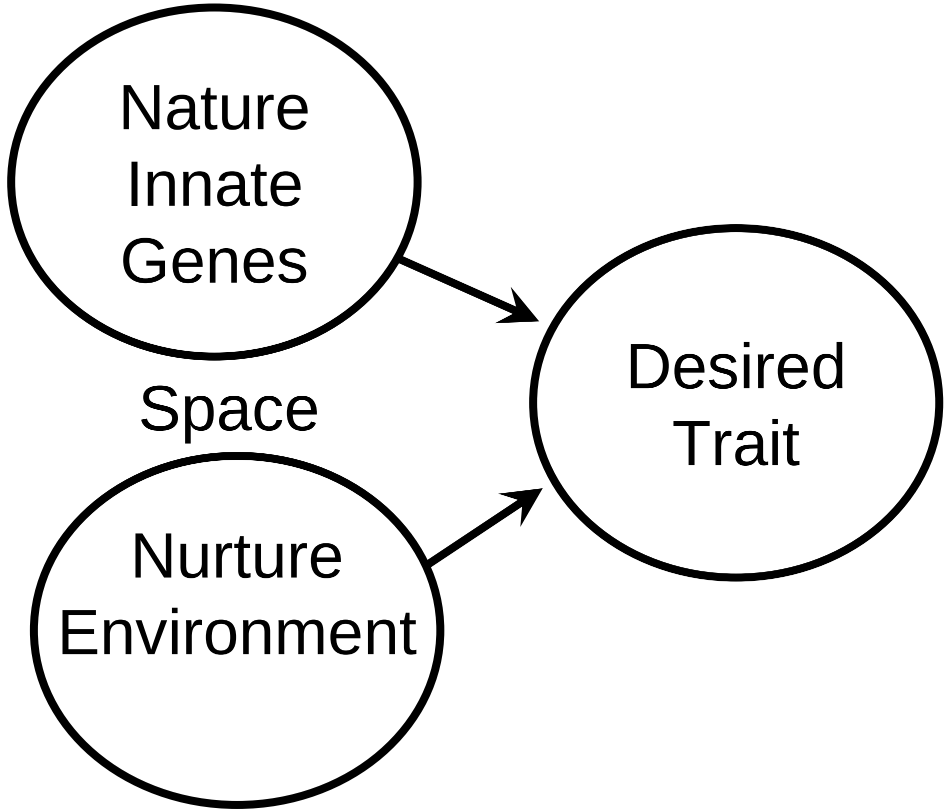
Nature or Nurture?

Frances Galton, 1874

Mirage of a Space between Nature and Nurture

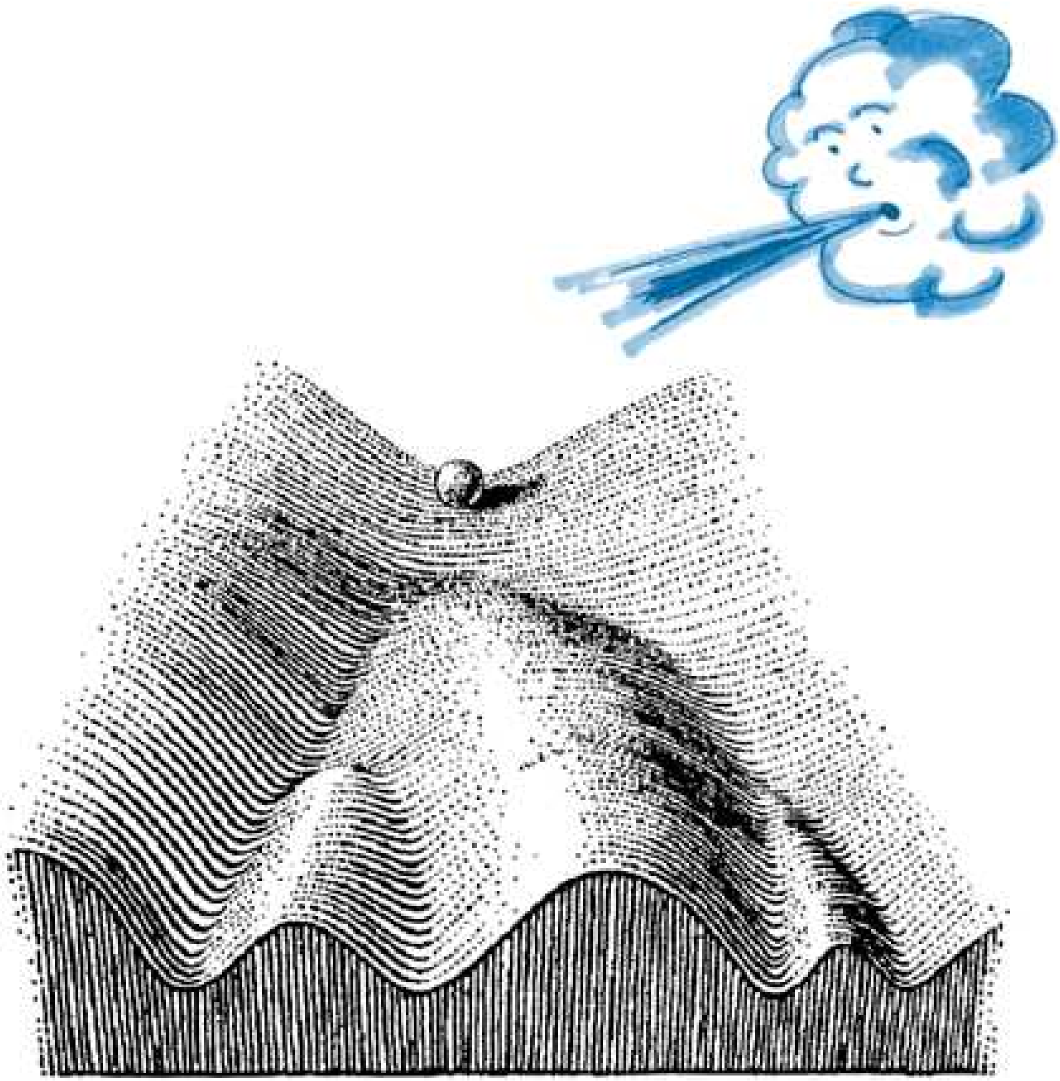
How NOT to think about GMOs

- Not independent factors
- Cannot partition effects in any meaningful way



Nature or Nurture?

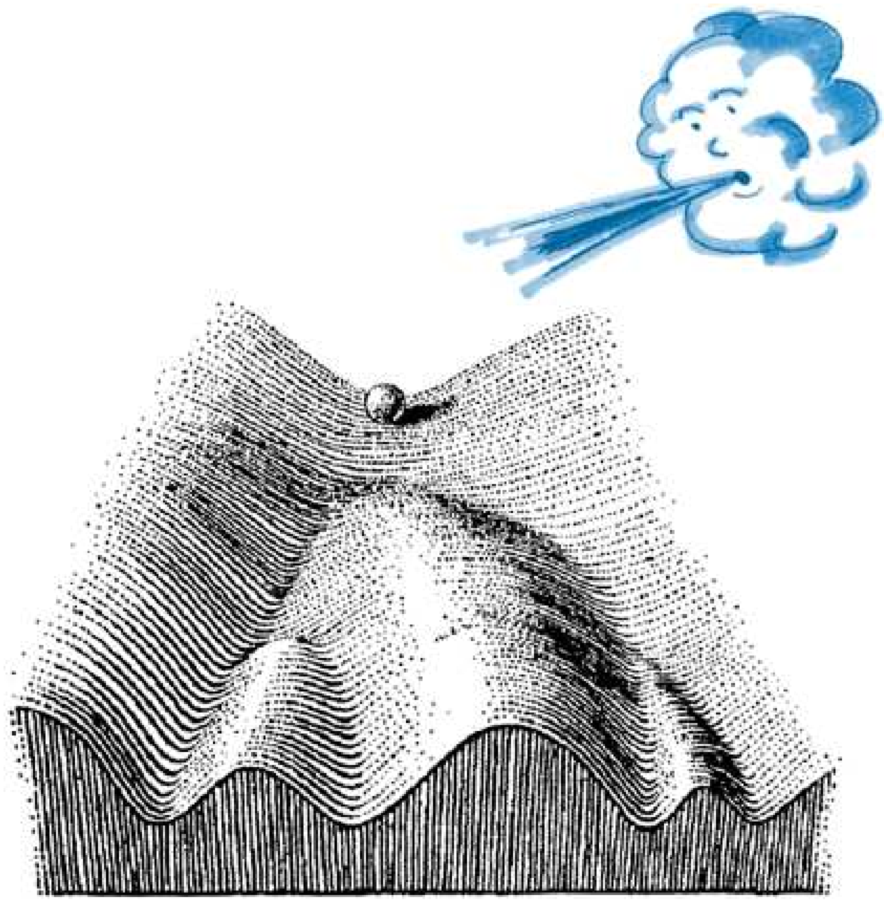
How to think about GMOs



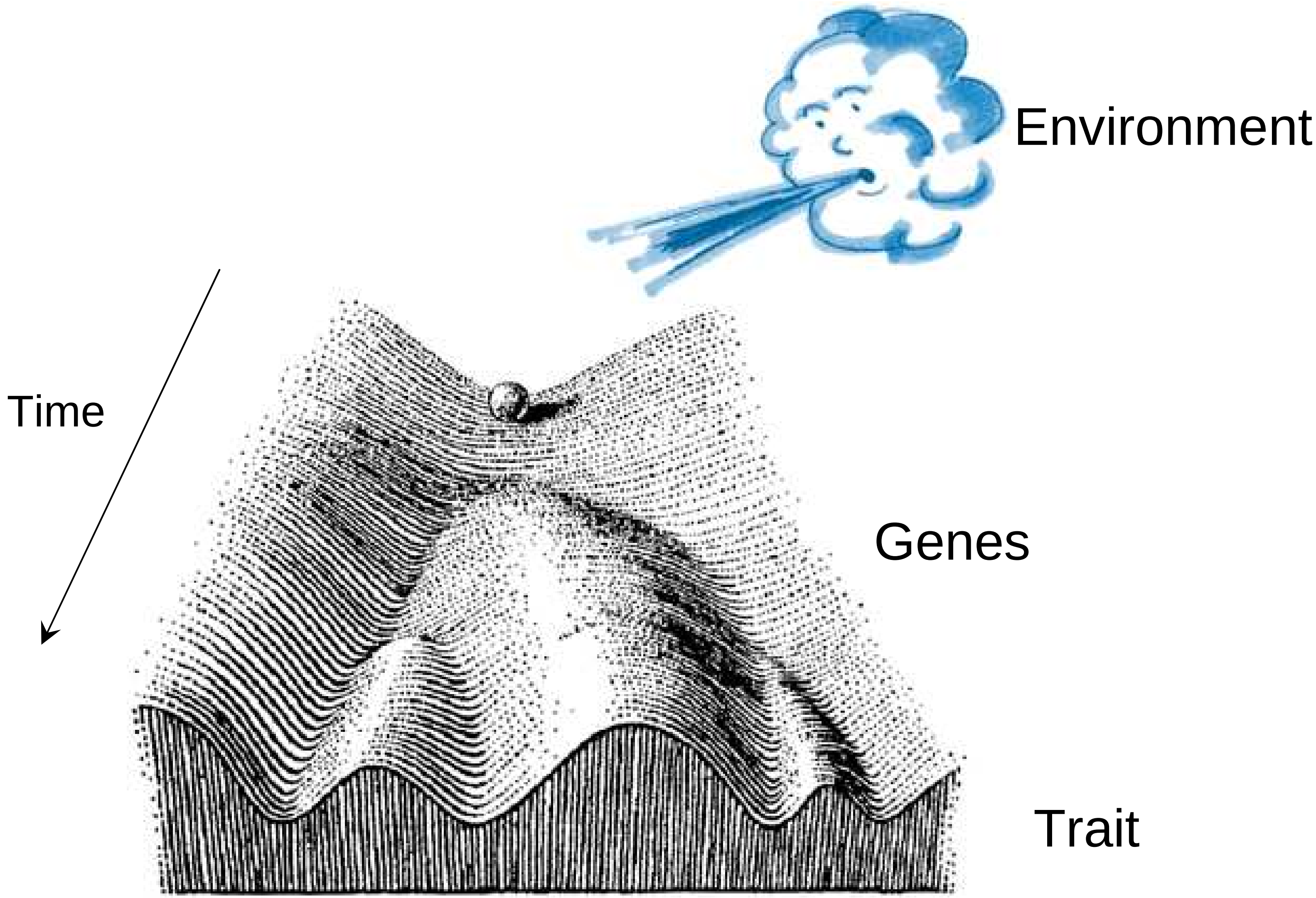
Cannalization; C.H. Waddington 1942

How GMOs might be used

- GMOs may be useful when the desired trait is
  - simple (so it can be strongly genetically controlled)
  - the trait does not occur in the species (so it must be from another species)



A Closing Thought



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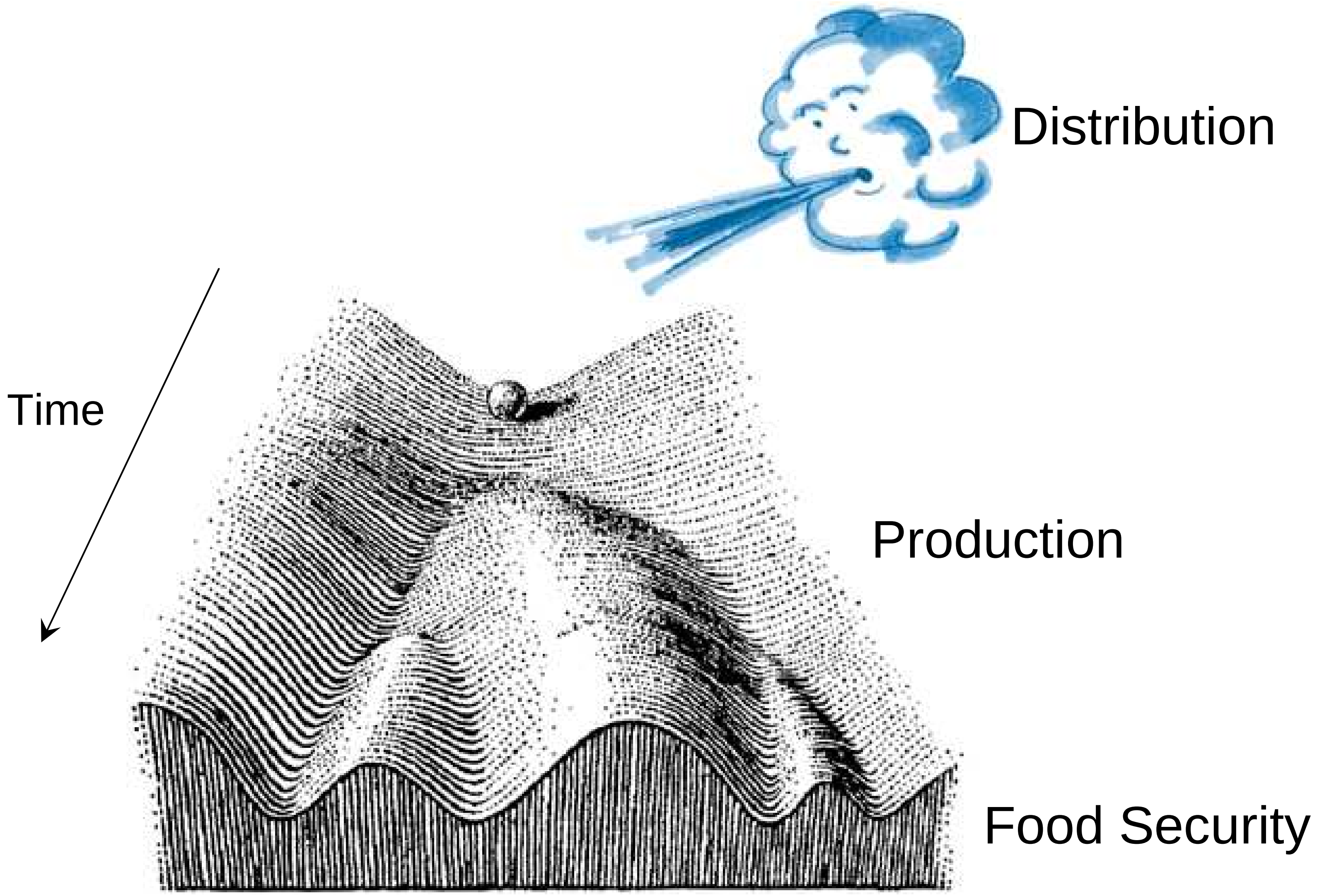

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