WHAT DOES IT TAKE TO FEED AND FUEL THE WORLD?

Dr. Ganesh M Kishore
CEO
MLSCF

Washington D.C., Dec 2010

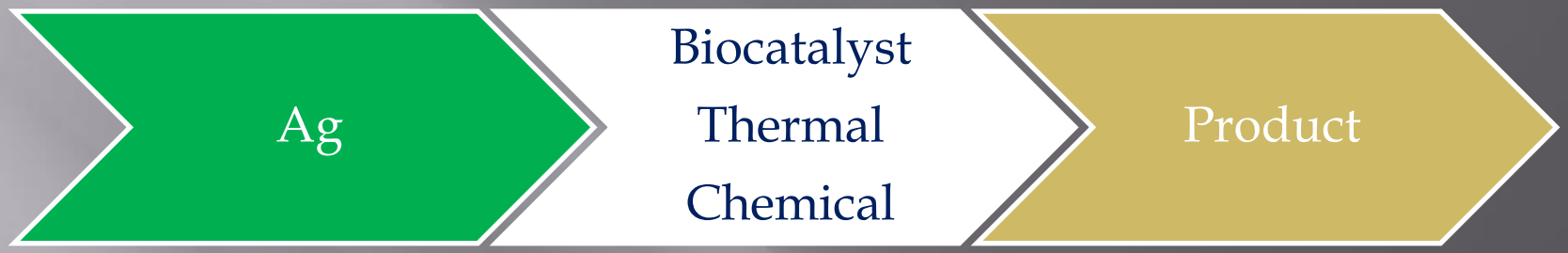
Key Messages

- Global food and nutrition security is under immense pressure; emerging economies are most vulnerable
- Technology has vast potential to meet not only global demands for food and nutrition but also address emerging issues of sustainable energy and environment
- Genetic intensity coupled with optimum nourishment of crop is key to improving productivity
- Cost of bringing new technologies to the market continues to escalate – financing innovation and commercialization critical
- A science-based, transparent, globally harmonized regulatory and trade policies are essential
- Agriculture infrastructure needs to be built and, on and off farm losses have to be reduced in emerging economies

MLSCF Portfolio

- Gevo – C4 platform (isobutanol); potential extensions
- Cobalt – C4 Platform (n-butanol); cellulosic focused
- Codexis – Broad bioprocessing platform
- Akermin – CO2 capture; Gas separations
- Abunda – Food and wellness ingredients
- Chromatin – Designer Chromosomes, feedstock
- HCL CleanTech – Cellulosic sugars (via BLSCF III)
- Glori Oil – Advance Oil Recovery Technologies
- Segetis – Ketal Chemistry for next gen monomers/oligo/polymers
- Mascoma – Consolidated Cellulosic processing

Ag and Industrial biotech are intimately linked



Sugar
Starch
Ligno-Cellulose
Fats
Proteins

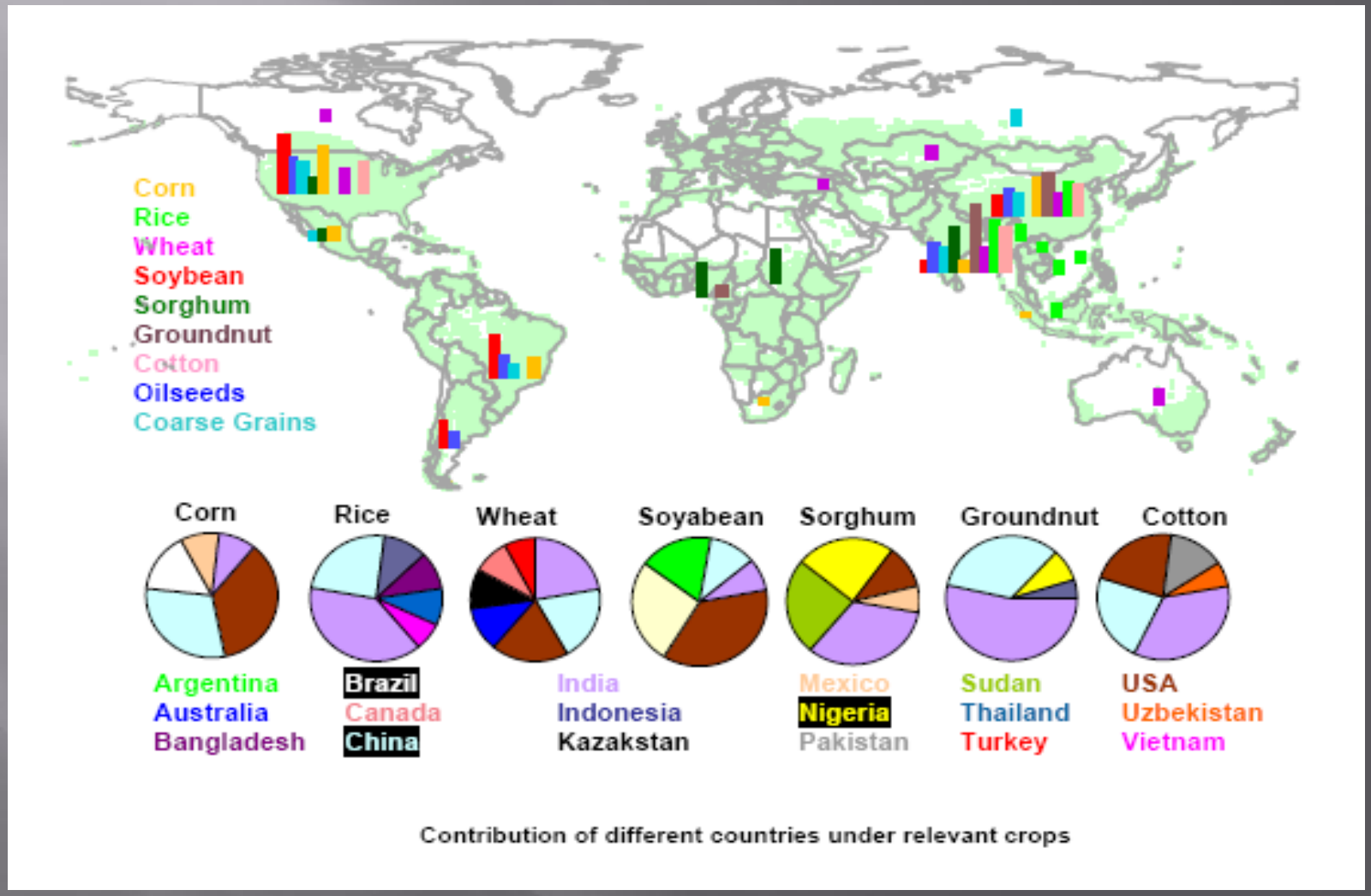
50-80% of costs
Related to feedstock cost

Electricity
Biofuels/platform chemicals
- Methane/HCs
- Alcohols
- FAEs
- Hydrogen

Monomers/Polymers
- Olefins
- Organic acids

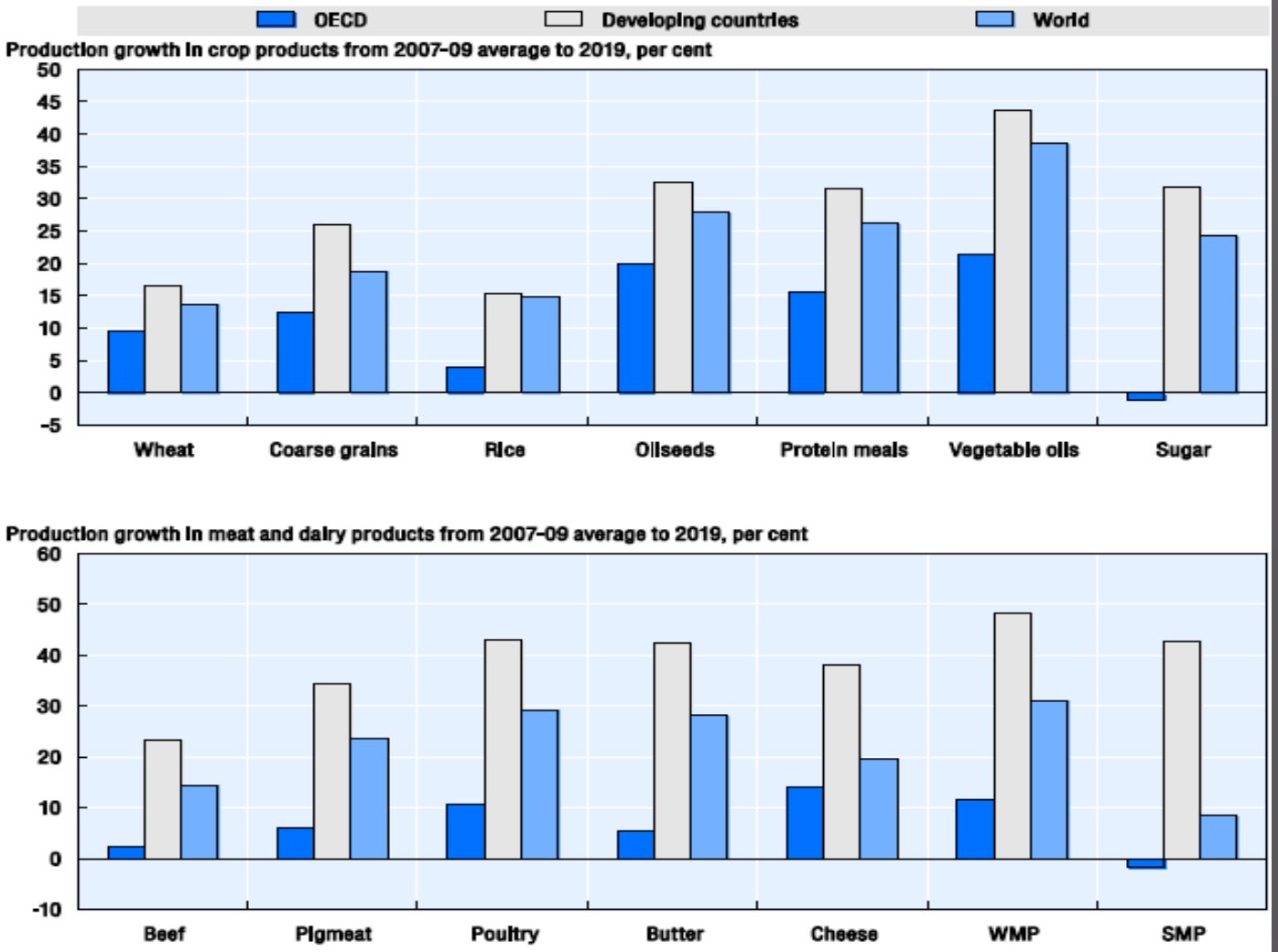
Specialty ingredients
- Cosmetics/Food/Feed
- Wellness/Health

Contribution of major regions to crop production



FAO Stat

Expected production increases over the next ten years – 15 to 50%



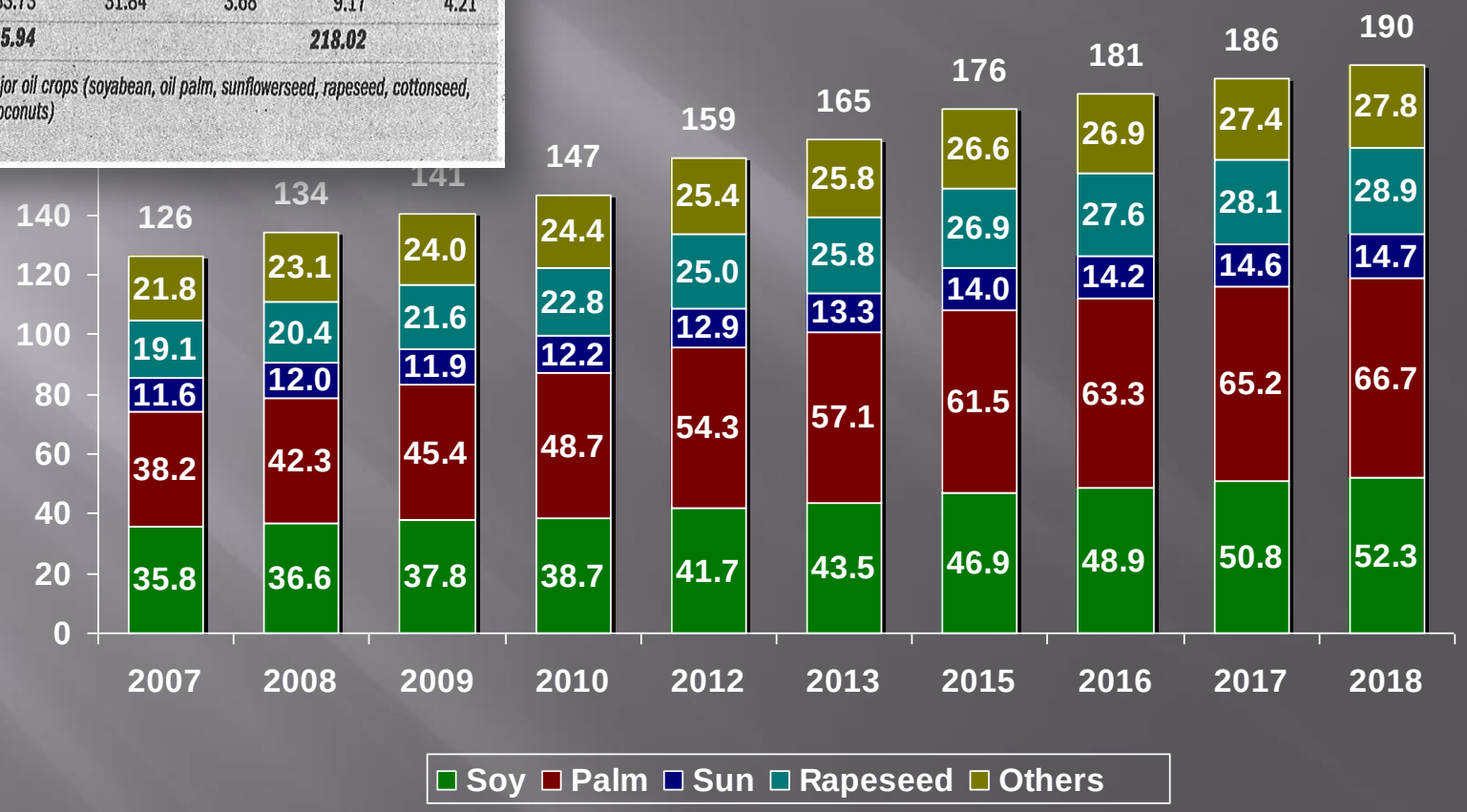
Source: OECD and FAO Secretariats.

World Veg-oil Production MMtons

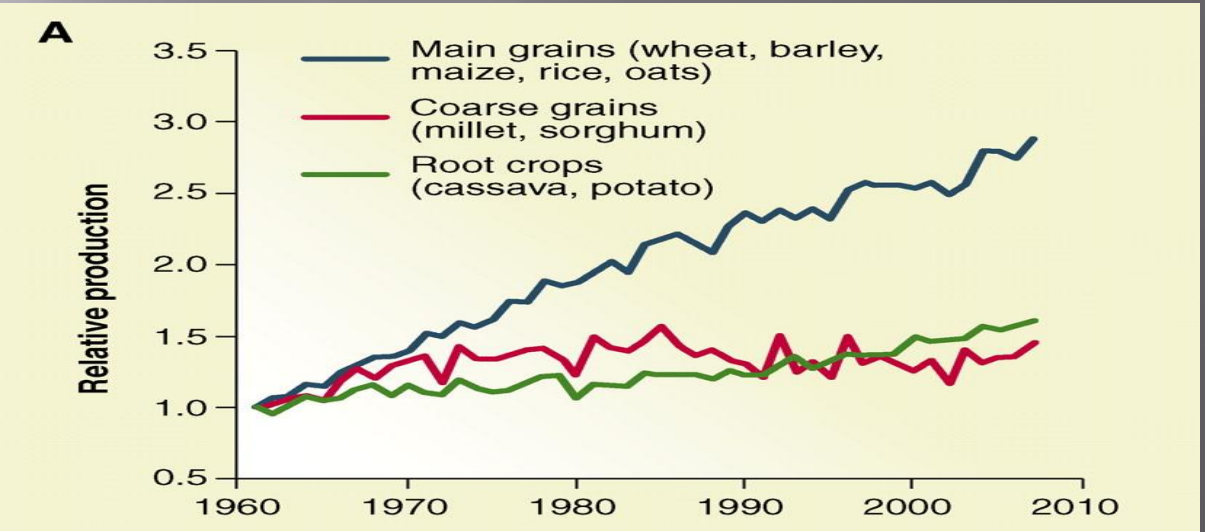
Oil productivity of major oil crops

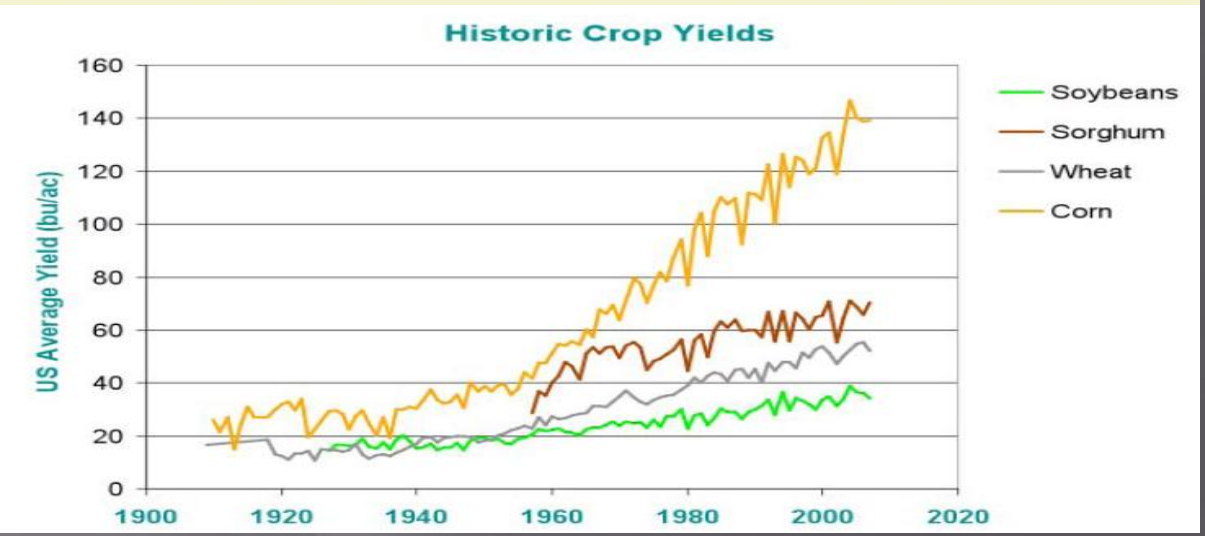
	Oil production (million tonnes)	% of total production	Average oil yield (tonnes/ha/year)	Planted area (million ha)	% of total area
Soyabean	33.58	31.69	0.36	92.10	42.24
Sunflower	9.66	9.12	0.42	22.90	10.50
Rapeseed	16.21	15.30	0.59	27.30	12.52
Oil palm	33.73	31.84	3.68	9.17	4.21
TOTAL*	***105.94***			***218.02***	

** Only for seven major oil crops (soyabean, oil palm, sunflowerseed, rapeseed, cottonseed, groundnuts and coconuts)*
Source: Oil World

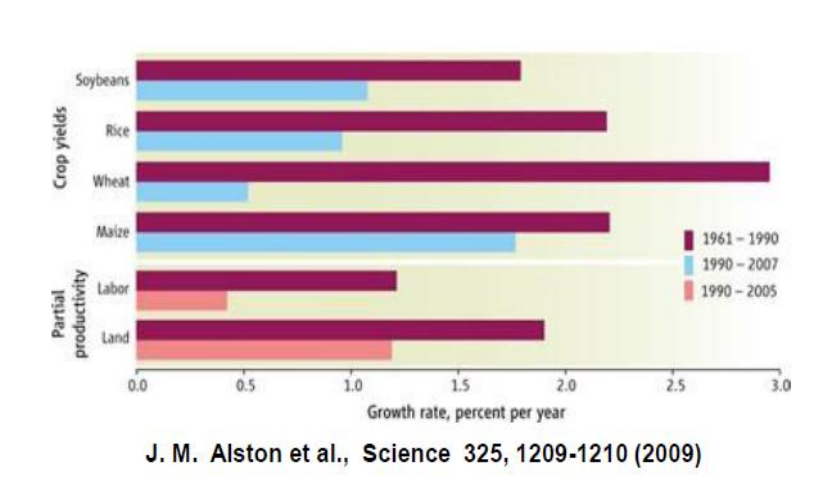


Our Track Record since 1960





H. C. J. Godfray et al., Science 327, 812-818 (2010)



J. M. Alston et al., Science 325, 1209-1210 (2009)

Global Population and Agricultural Land Area Available

Population (billions); Land (hectare/capita)

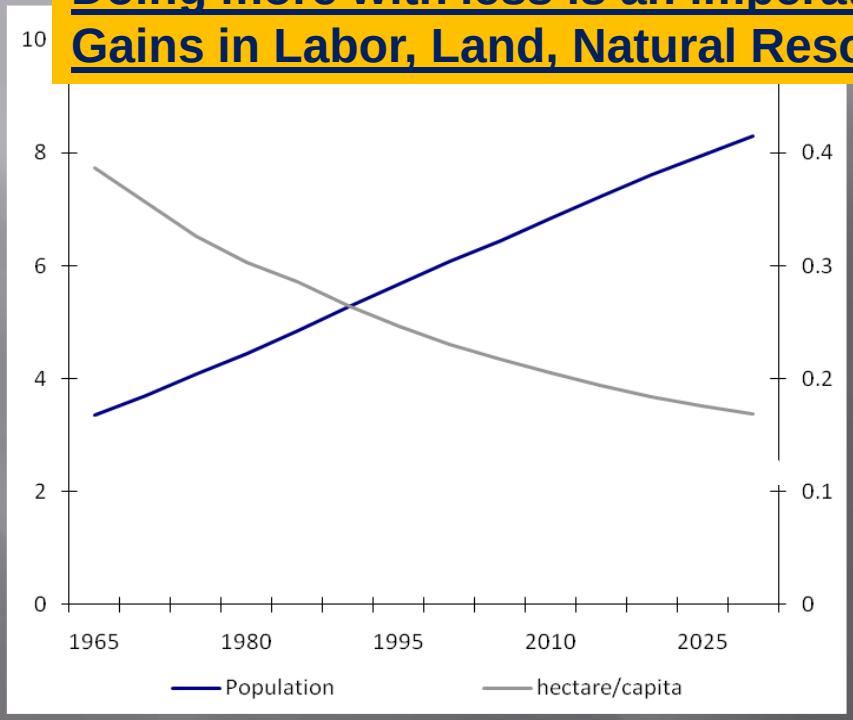
Sci Am, Oct 2009

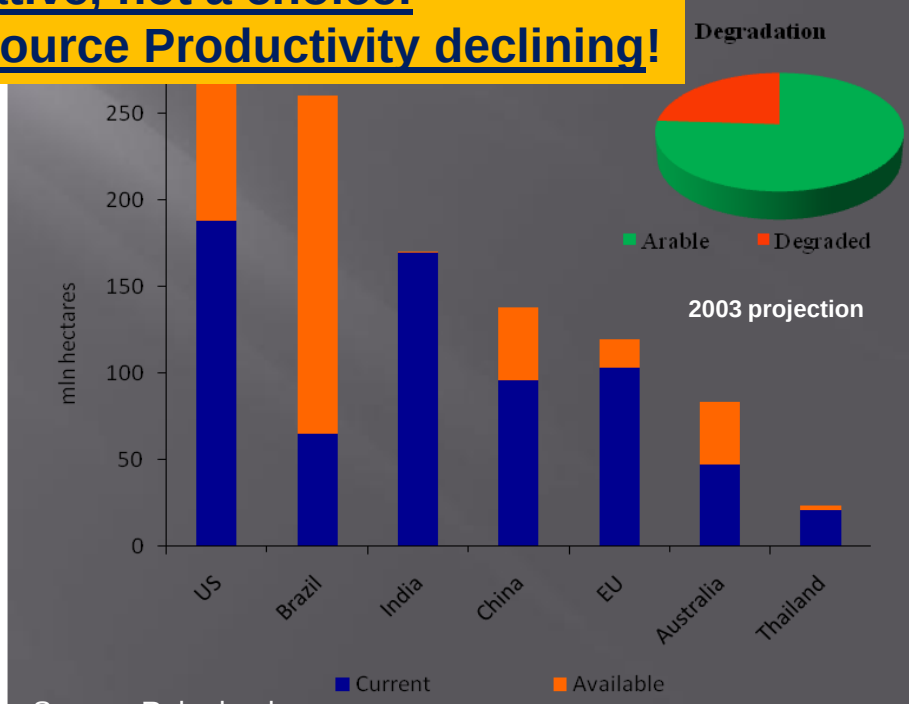
Agricultural Land Resources, Selected Countries

Index Value: 1985 = 1000

Doing more with less is an imperative, not a choice!

Gains in Labor, Land, Natural Resource Productivity declining!



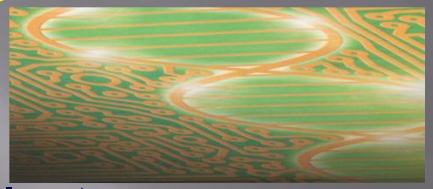


Source: Rabo bank

Chemistry of the seed and chemistry on the seed – Future of Agriculture

Breeding Traits

Green Bio



BioTech Traits

Agrobacterium

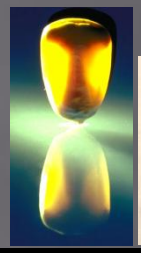
Gene Gun

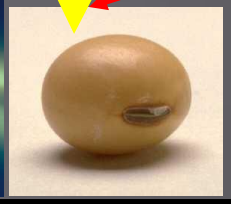
- ↑ productivity (complex)
- ↑ reliability
- ↑ quality
- Integration of native and biotech traits

- Pest protection
- Stress alleviation
- Superior nutrient use
- High nutrient density
- Elevated safety
- Processor efficiency

Chemistry

- Pest control
- Nutrition
- Growth regulators





Seed - carrier of genetic information

Nearly 150 M acres not in corn Cultivation !

Source: DuPont

Pest Protection is a key target

Monsanto

Disease resistance – a major need

Anthracnose Stalk Rot (ASR)

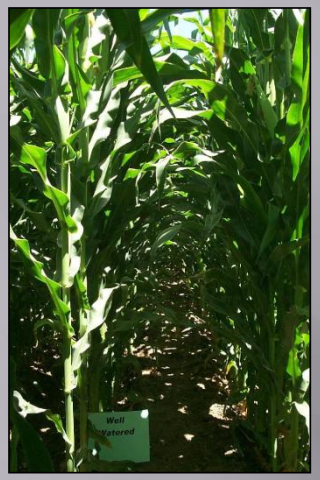
Potato late blight

Wheat stem rust

Rice Blast

Source: Science; DuPont

The Impact of Water Stress on Productivity



Well-Watered

20 day Pre - Flowering Stress (mild)

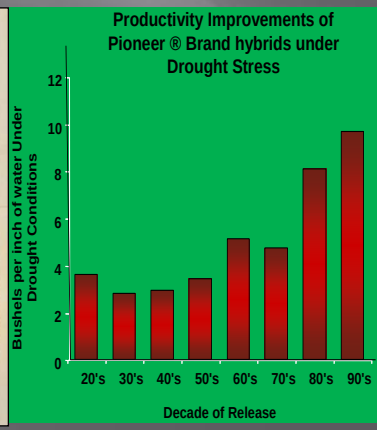
35 day Pre - Flowering Stress (moderate)

Full Irrigation | Mild Stress | Moderate Stress

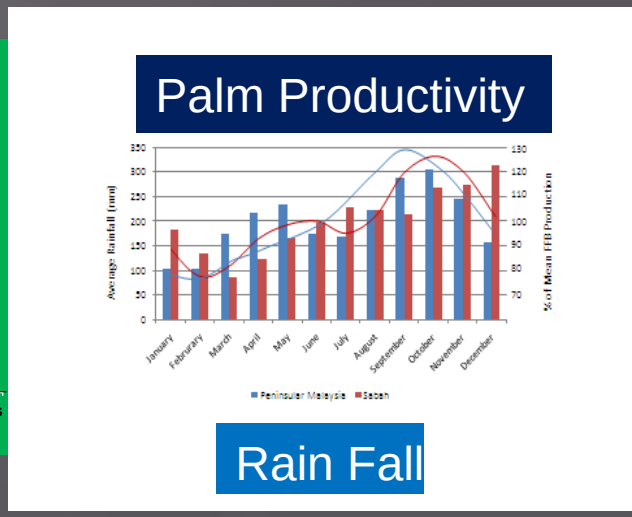
Plant Height

Ear Size

Kernel Number



Source: DuPont

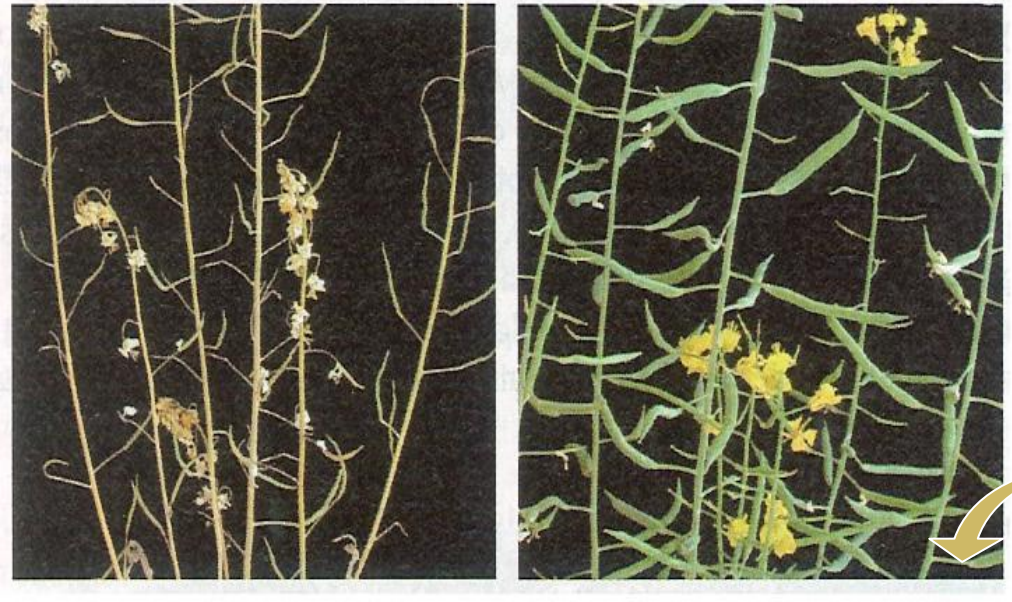


Drought – affects 50% of acres, an ~ $8B loss p.a in corn

A Blue revolution is under way!

Rice (China)

Maize (Monsanto)



Canola (Performance Plants)

Water stress is not just about water shortage – it is also flooding!

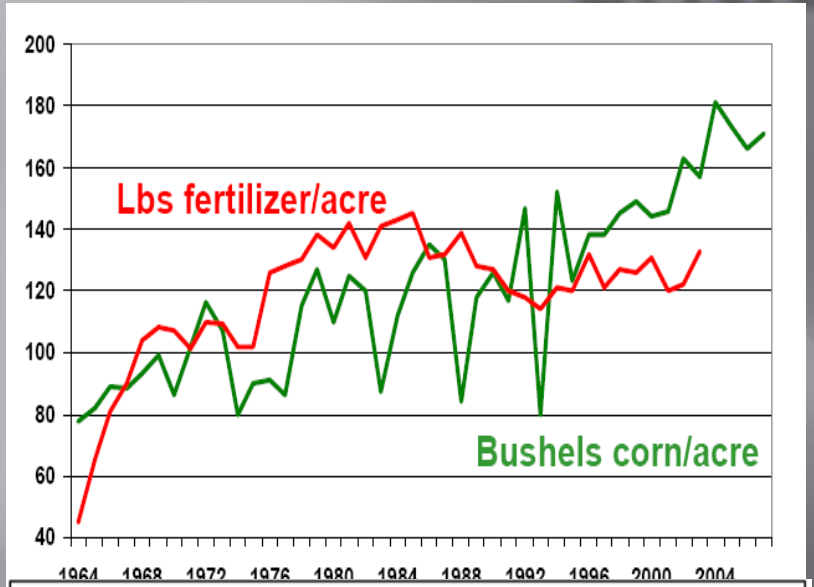
Field plot of rice submerged for 17 d two weeks after transplantation
Sub1A is sufficient to confer tolerance to nearly all intolerant varieties (5-6 fold yield increase)

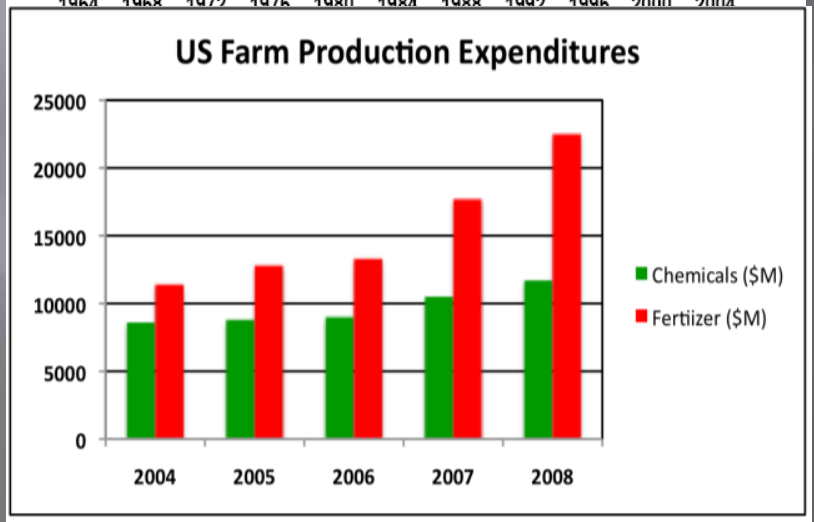
Abdel Ismail and Dave Mackill, IRRI

Saline Water Agriculture taking roots

N. V. Fedoroff et al., Science 327, 833-834 (2010)

Nitrogen Responsiveness Critical Trait





Source: USDA-NASS
(http://www.nass.usda.gov/Charts_and_Maps/Farm_Production_Expenditures/maj_exp.asp)

With trait **Without trait**

Source: Arcadia

Enhanced Yield – Major Advances

Without Trait With Trait

Source: DuPont and Monsanto

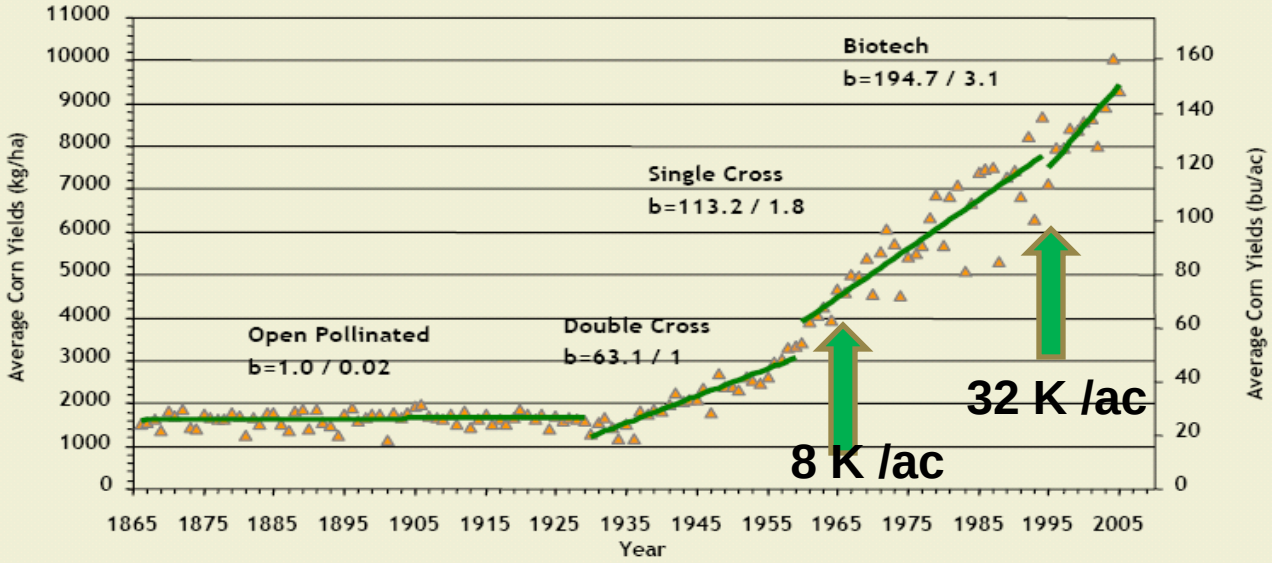
Key Features:

- ***Increasing Harvestable Yield***
- ***Reducing Foot Print***
- ***Improving Consistency***
- ***Products likely commercial around 2012/4***

Significant potential for Yield & Sustainability Enhancement

Better seed delivers results

- Actual Breeding Plus Cultural Practice Gain:
- Corn Yields Continue to Advance, Tremendous Gains Made Over Last Ten Years

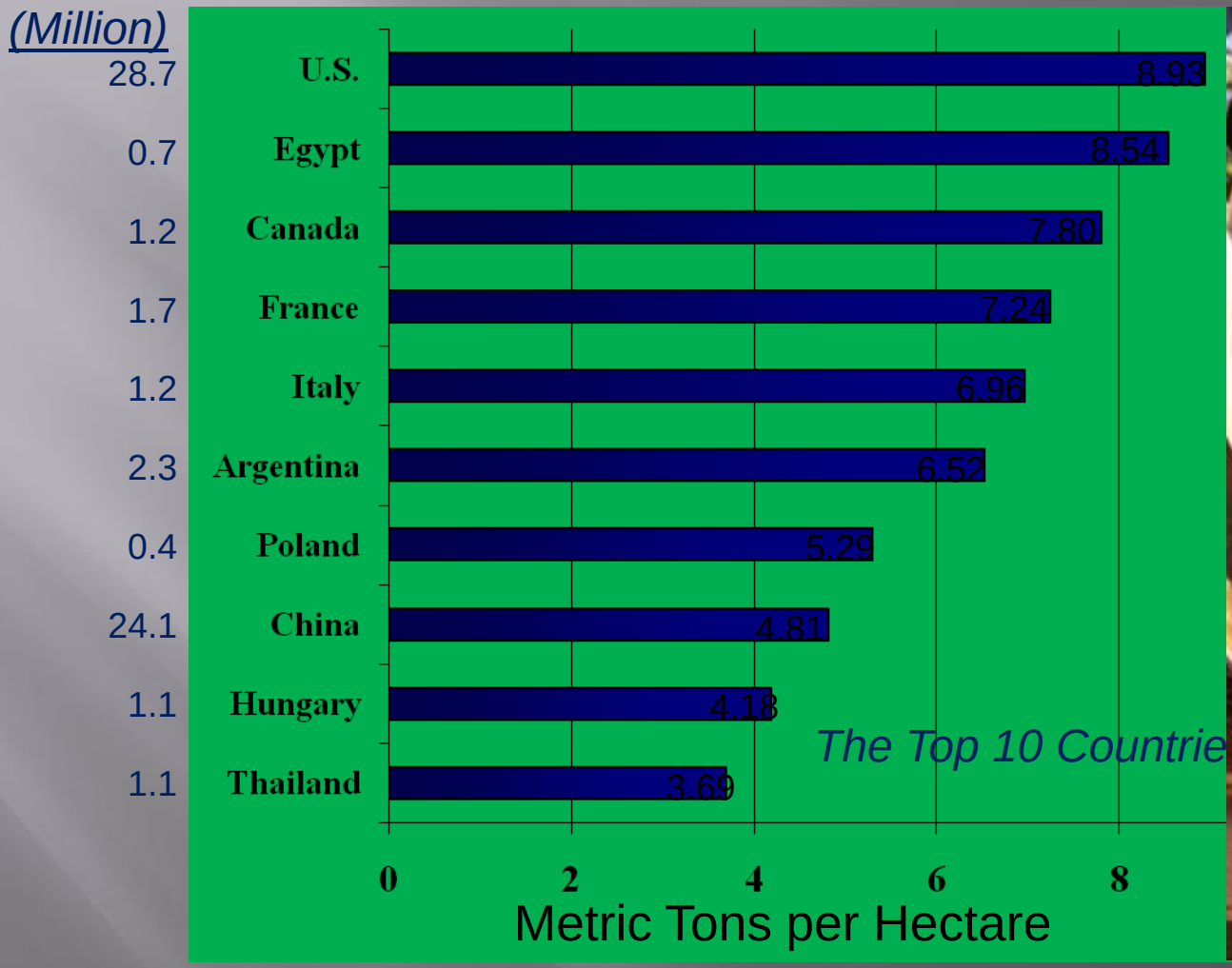


Fertilization
Crop Protection

Source: March 2006. Crop Science. Ref# 46:528-543

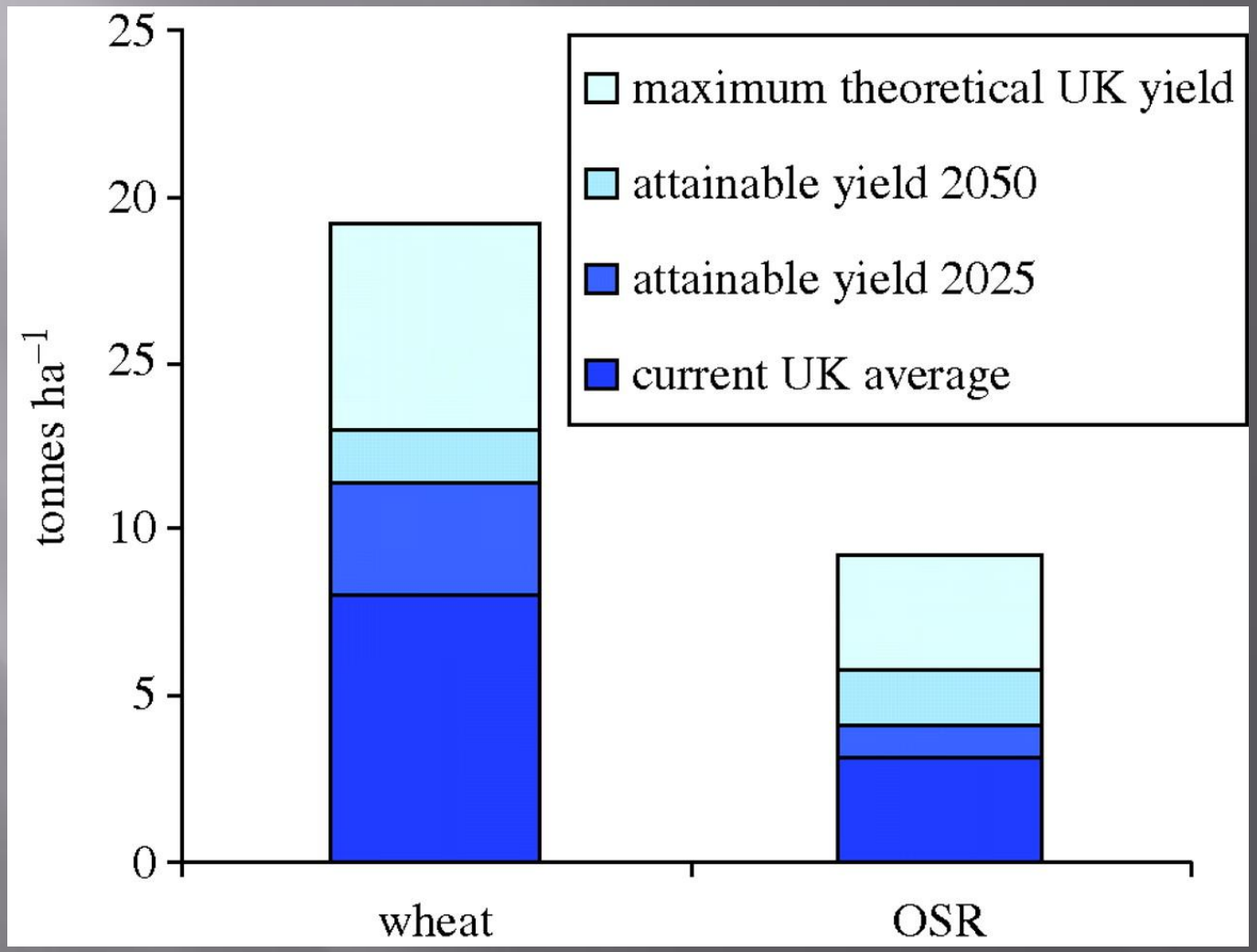
Corn Yield Varies Tremendously by Country

… Creating a Significant Opportunity for enhancement



2006 data

The theoretical and obtainable potential yields for wheat and oilseed rape (OSR) in the UK (from Berry & Spink 2006; Sylvester-Bradley et al.



Beddington J Phil. Trans. R. Soc. B 2010;365:61-71

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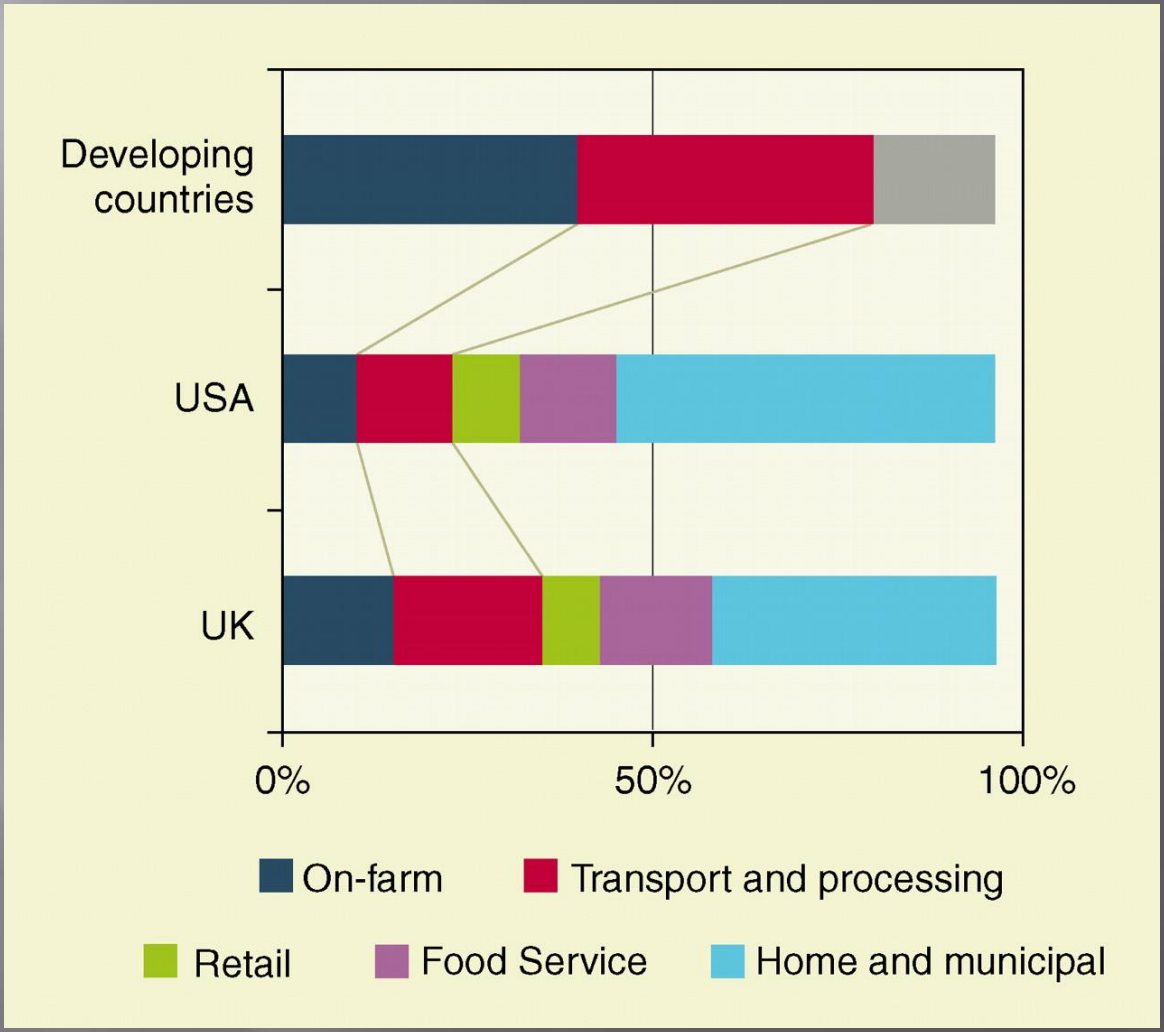
Significant food is wasted in developing economies



H. C. J. Godfray et al., Science 327, 812-818 (2010)

Sequenced Plant Nuclear Genomes and Bioinformatics

Plant	Base Pairs	Genes
Arabidopsis thaliana	125 million	28,000
Rice Sorghum	390 million 736 million	37,544 ?
Maize	2500 million	50,000
Poplar	480 million	32,000
Palm	~ 1800 million	?

Several photosynthetic eukaryotic unicellular genomes also sequenced

Arabidopsis thaliana

Rice

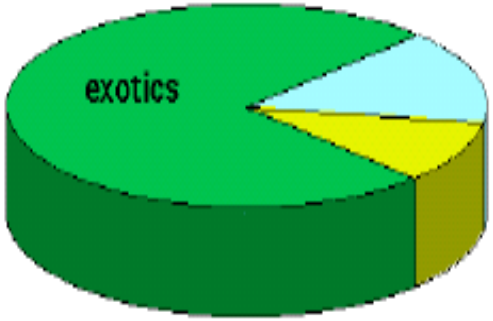
Maize

Poplar

Palm

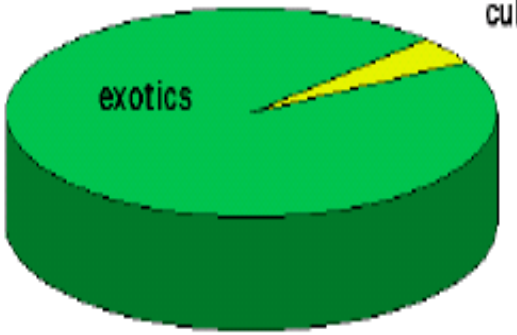
Has the potential to accelerate trait discovery and breeding

Conventional Breeding has only accessed a narrow allelic pool



cultivated rice

cultivated tomato



- *H. annuus* modern varieties
- *H. annuus* land races
- *H. annuus* wild accessions
- Other wild species (section *Helianth*

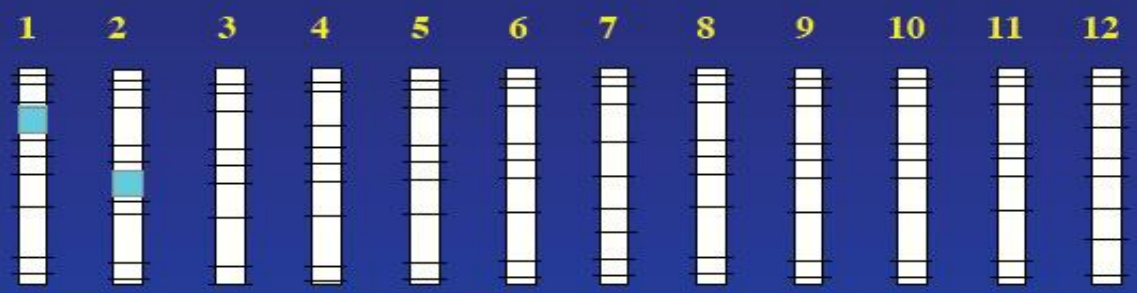
Plant breeding:

Phenotype Based breeding to Genotype Breeding Facilitated by Genomic Information
The cost of phenotyping Across environments is Still an issue!

Courtesy: Steve Tanksley

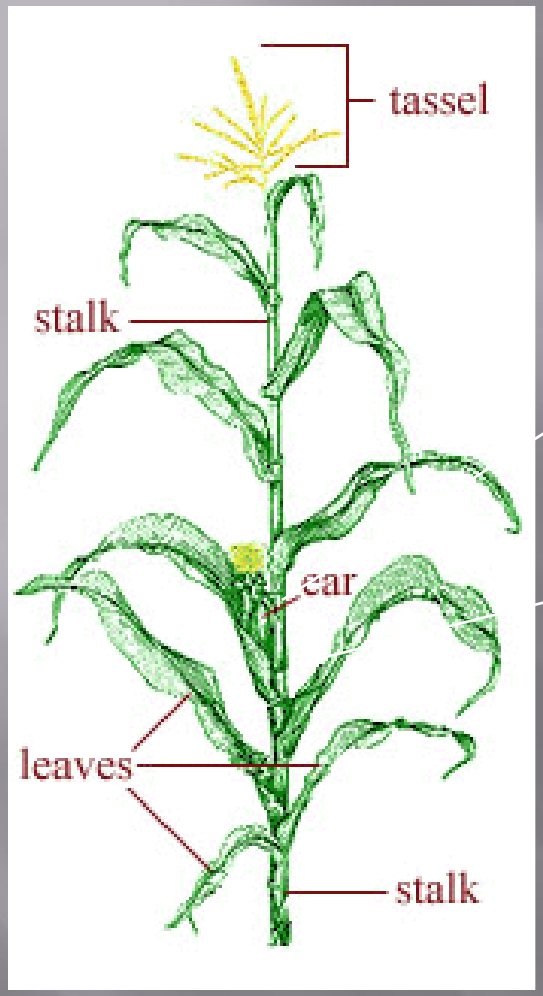
Harnessing Hidden Alleles

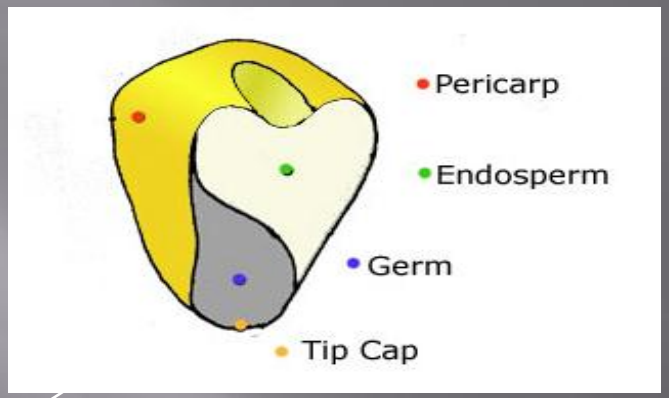
Finding the Hidden Genes -- Fast Growth Alleles from Slow Growing Wild Tomatoes

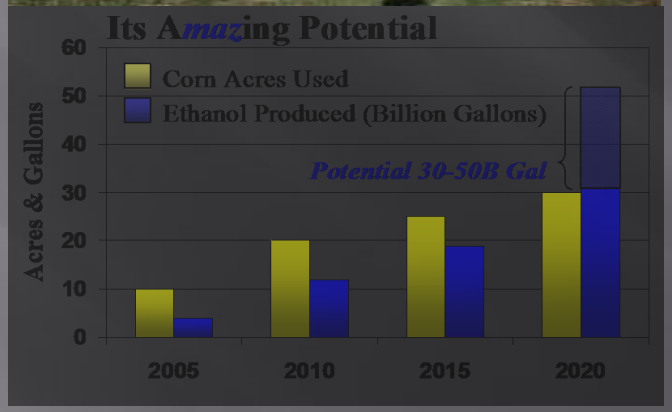


Source: Steve Tanksley

Significant Potential Exists to Boost the Productivity of Biomass and Transform Biomass to Better Fuels - - Corn the Model Grass







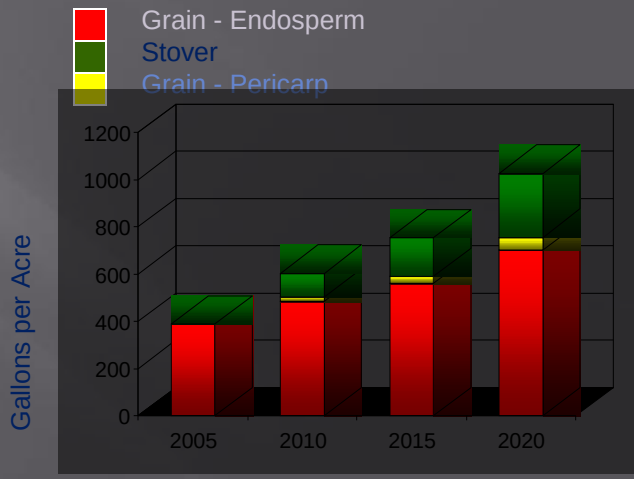
<u>Ethanol Productivity</u>

18 Gal/Acre

390 Gal/Acre
@ 150 bu/ac grain yield

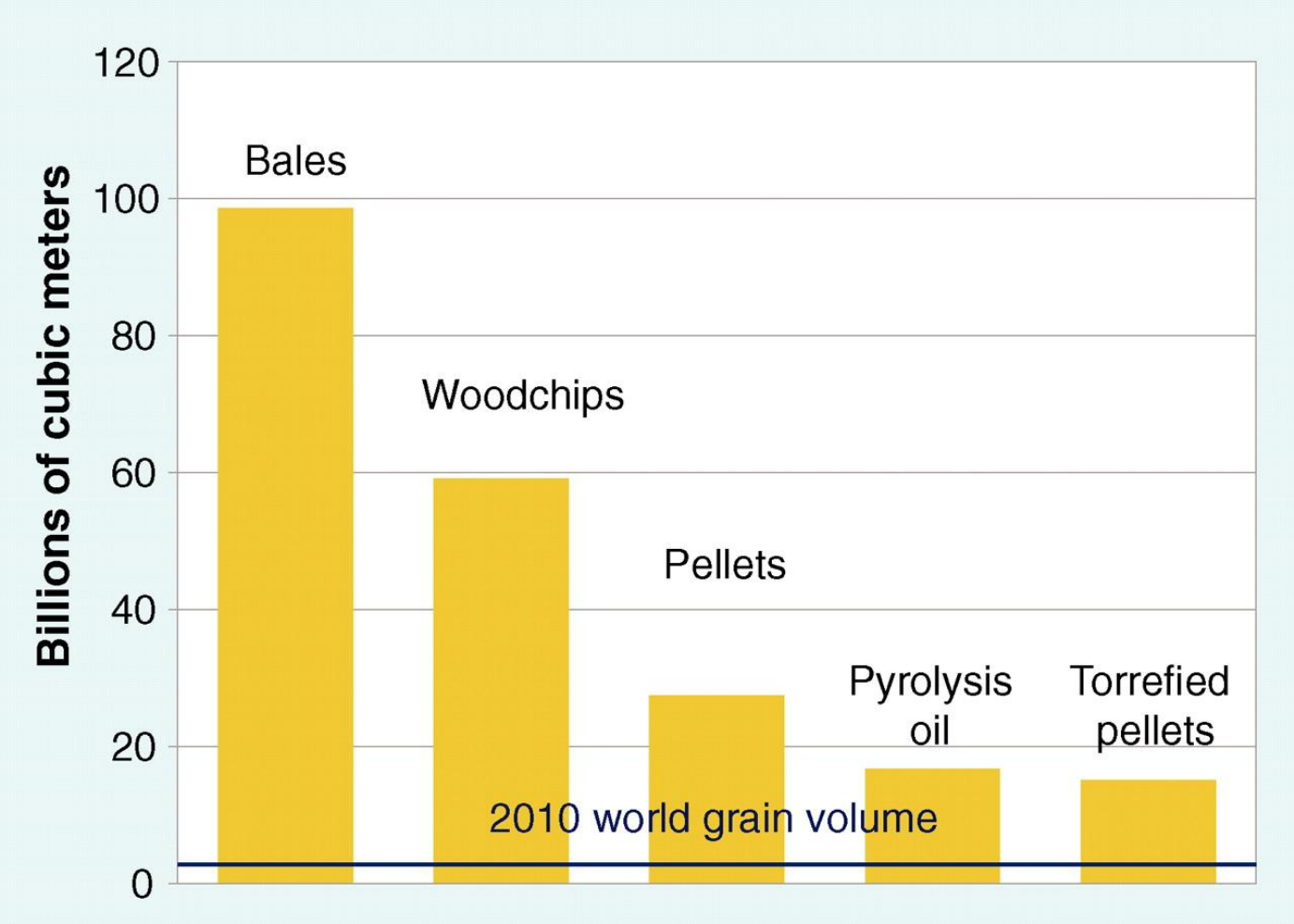
100 Gal/Acre

The Potential



Increase grain yield to 250 bushels per acre
Increase stover conversion to ethanol

Fig. 1 Global biomass volumes required to achieve a 50% reduction in greenhouse gas emissions by 2050



T. L. Richard Science 329, 793-796 (2010)

Transportation of Feedstock and Products

On Farm Processing?
Return other organic/inorganic
Matter to soil?

Science, 2010

Fig. 3 Wet (top and middle) and dry (bottom) biomass storage configurations for lignocellulosic grasses

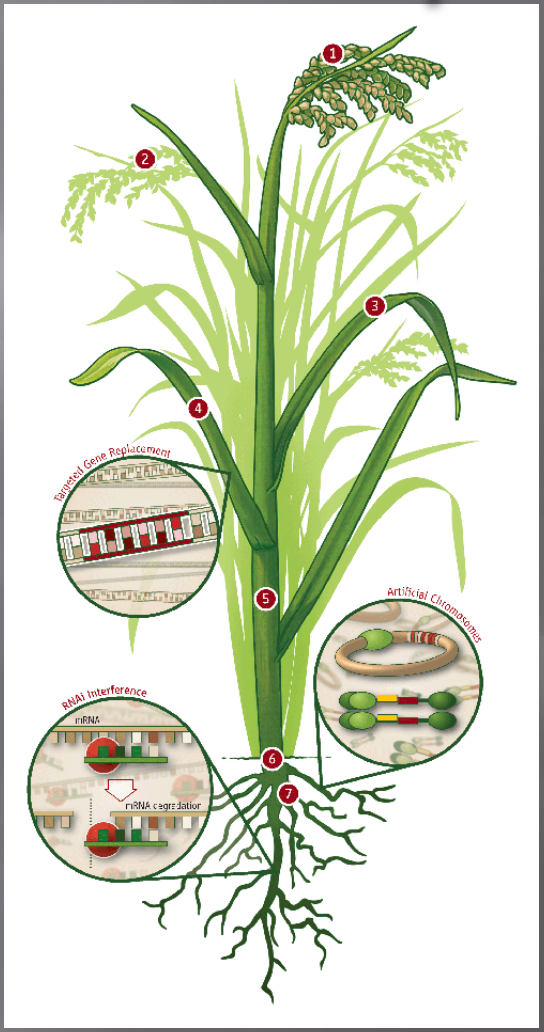
T. L. Richard Science 329, 793-796 (2010)

Opportunities for Crop Improvement

No sex

Pest resistance

More crop
Per drop



Nutrient content & quality

Indicators of stress;
stress tolerance

light response/efficiency
- Duration of Photosynthesis

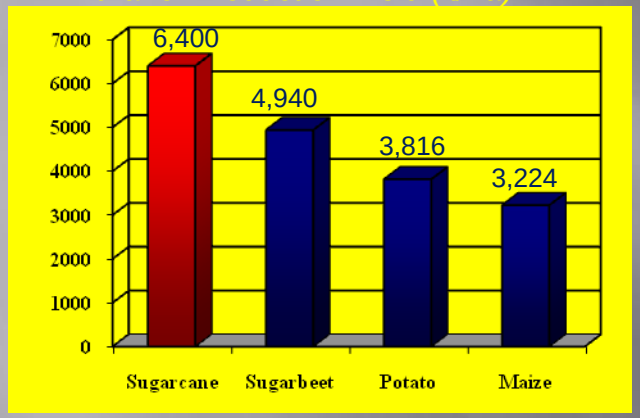
Shelf life

Nutrient response

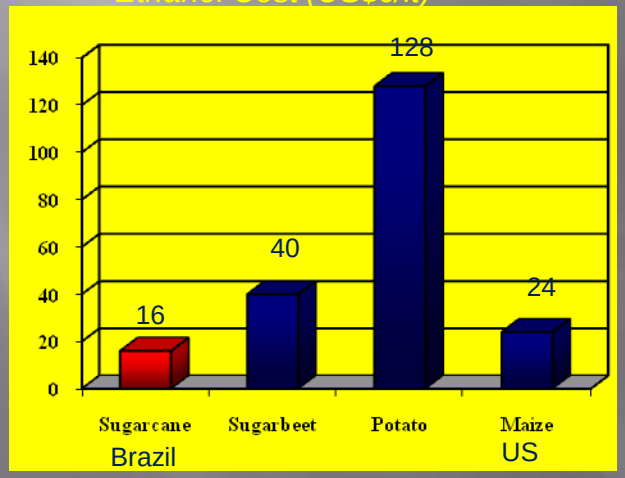
Modified from E. Pennisi Science 327, 802-803 (2010)

Sugarcane is the most efficient biomass crop and most competitive biofuel option – at this time!

Ethanol Production Yield (lt/ha)

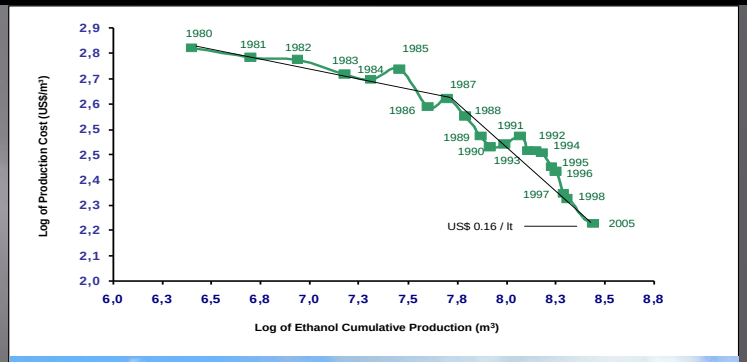


Ethanol Cost (US$c/lt)



2006 Data

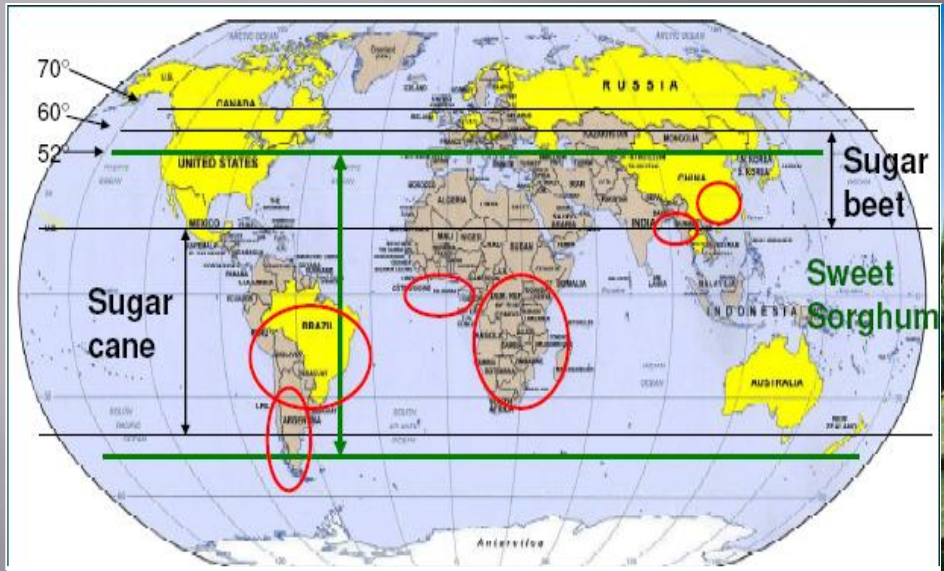
Ethanol Production Learning Curve in Brazil



There is still room to improve

The choice of the crop – depends on the region!

Sweet Sorghum – a crop that deserves attention



Energy content (toe / 1000 t cane)	Sugarcane (Brazil)	Sweet Sorghum
Sugar (Stalk)	51	51
Bagasse	55	60
Leaves	55	27
Grain	0	30
Total	**161**	**168**

Source: EUBIA Website

Energy output / fossil energy input	Energy Balance
Sugarcane (Brazil)	8.3
Sugar beet (EU)	1.9
Corn (US)	1.3 – 1.8
Wheat (Canada)	1.2
Fossil-Fuels	0.8
Sweet Sorghum (Shapouri, USDA)	**8.0***

** Estimate from Hosein Shapouri at USDA, assumes manual harvest.*
Source: ICRISAT, "Sweet sorghum for food and fuel". August 2007

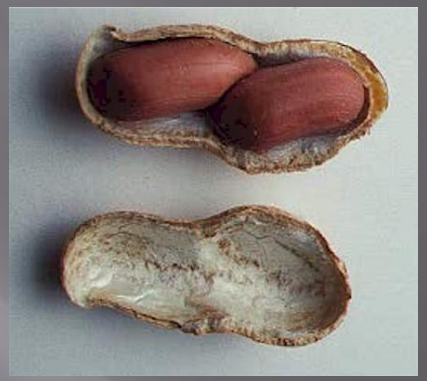
Mineral loss per ton of crop (kg)	N	K_2O_5	K_2O
Sugarcane	1	0.1	2
Sugar beet	5	1 - 2	5 – 6
Sweet Sorghum	**0.9**	**0.9**	**1.3**
Corn	10	4	5

Source: Grassi, "Bioethanol - Industrial world perspectives". 2002

Oleaginous Crops - Considerations

Soybean
(18-21% oil)
400Kg/ha

Sunflower
(45-55% oil)
800Kg/ha



Peanut oil
(40-50%)
900Kg/ha

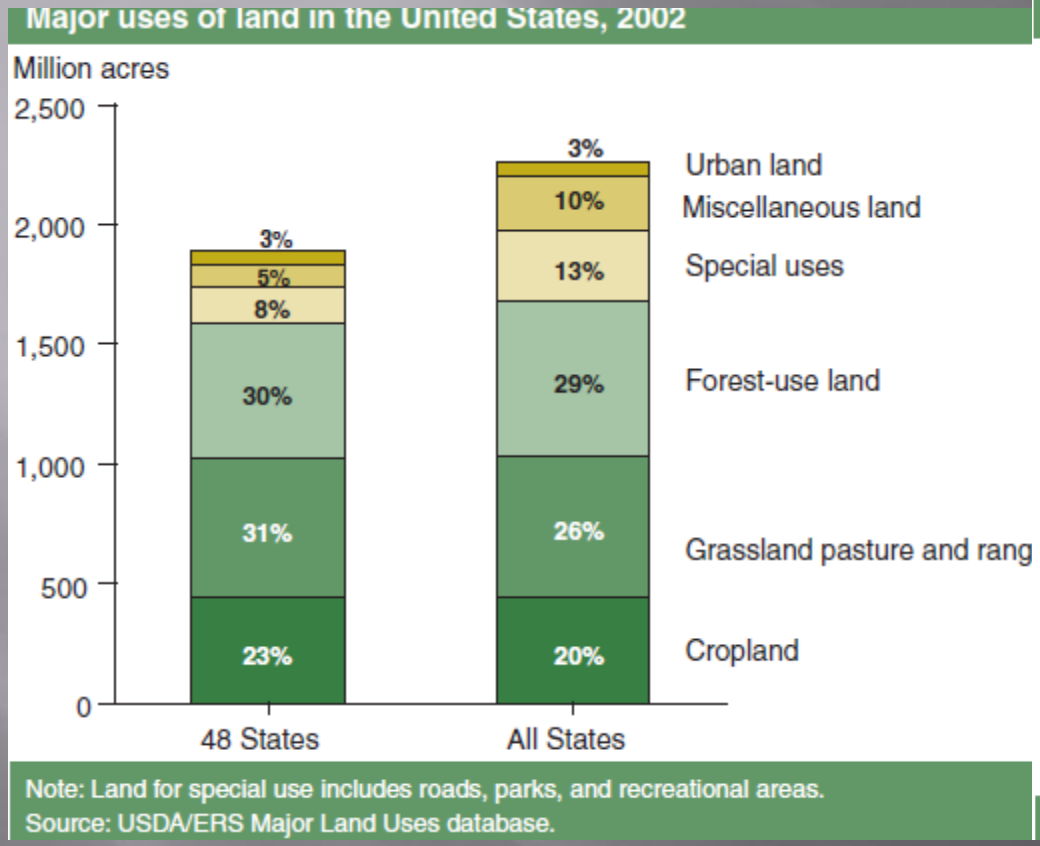
Castor oil
(45-55%)
1200Kg/ha to
4400 Kg/ha

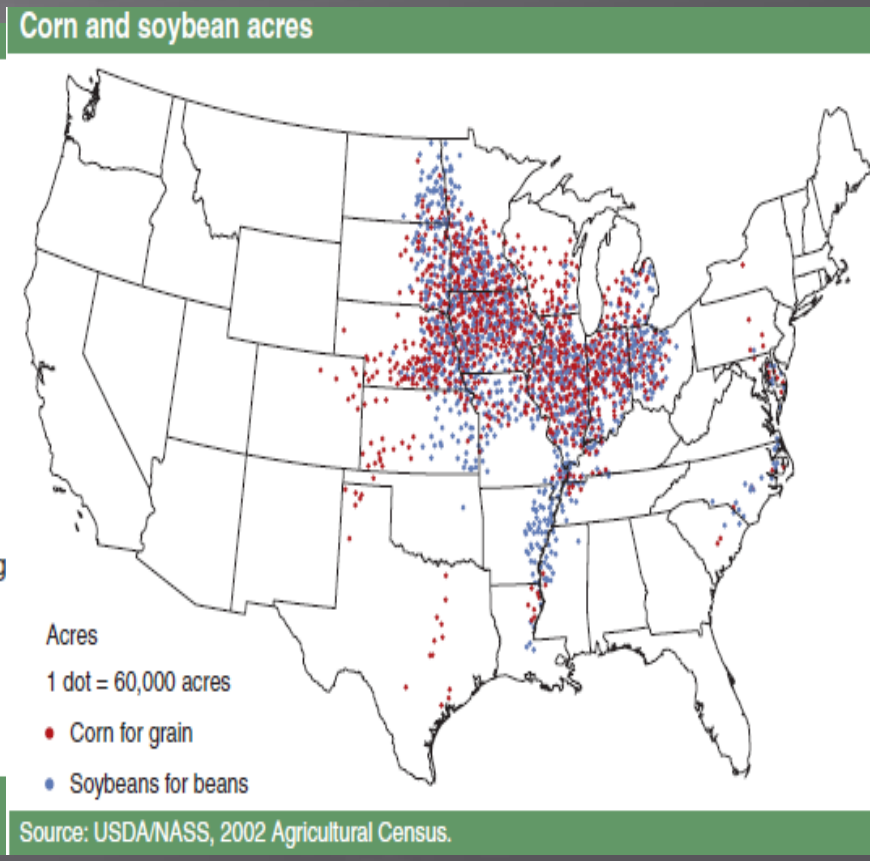
Palm oil
(35-45%)
5900 Kg/ha
Cultivation
potential in
US!!

Castor needs consideration as a crop for US – removal of ricin; allergens; yield and oil enhancements; oil modification

Source: modified from LADETEL/USP - ABIOVE

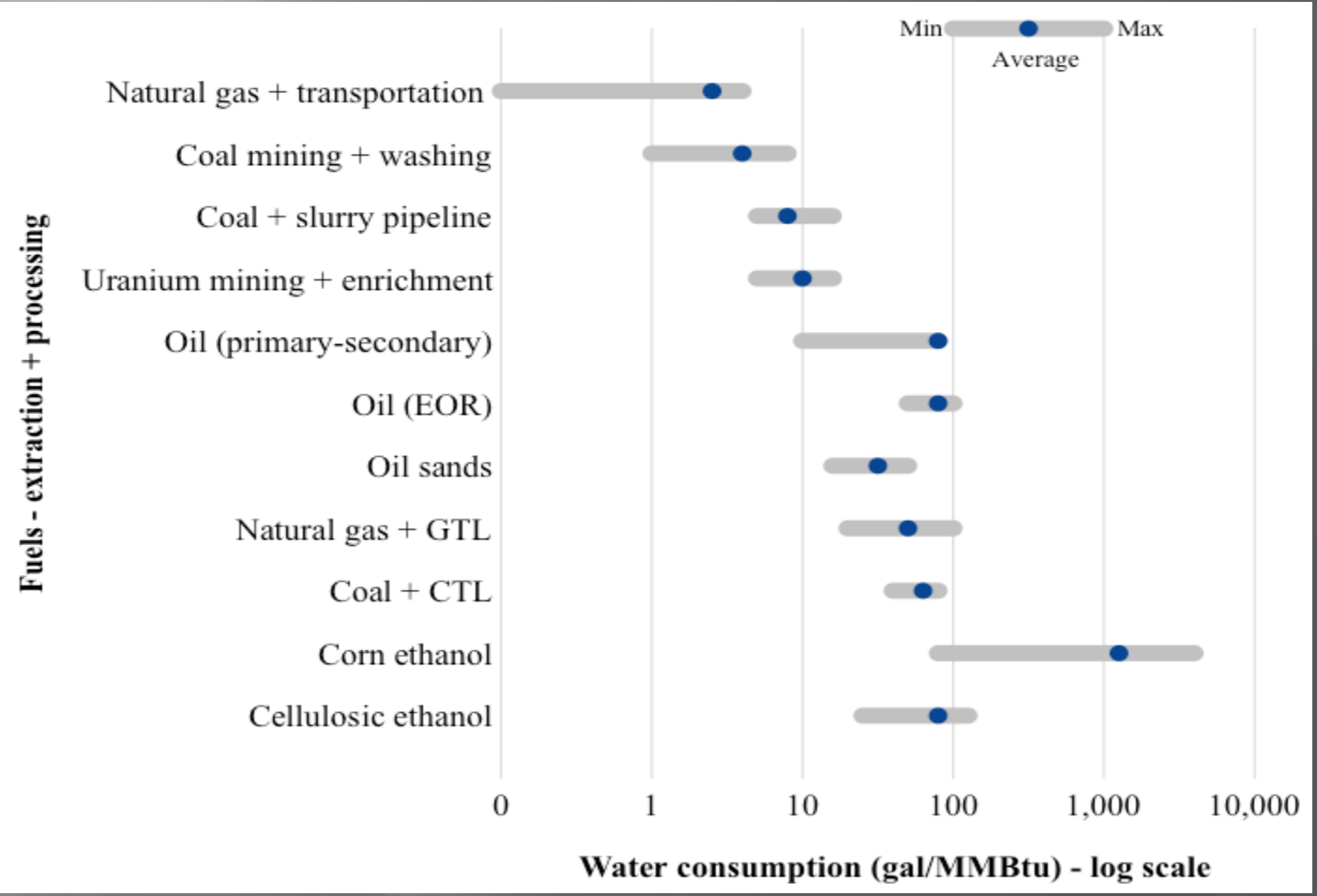
Agriculture in US is largely in the Midwestern States





Corn Ethanol is mostly a Midwestern Industry!

Water & Energy - Interlinked



Financing Innovation

- Global life Sciences investments - $320 B
- **Global Ag Tech investments - $10 B**
- **Global Ag VC investments - $140 M**
- **Subsidies in Ag - $250 B**
- Costs for bringing new chemistry in Production Ag - $300 M
- Costs for biotech traits - $100 M
- Duration of research – 10-15 years!
- Food industry's innovation is process or presentation research

Conflicting Visions!

Old Byzantine Proverb:

'He who has bread may have troubles
He who lacks it has only one'

Source: Science; C. Leaver

Multiple Opportunities and Options

Thank You