Agricultural Productivity and Natural Resource Endowments

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UNIVERSITY OF MINNESOTA

INSTEPP INTERNATIONAL SCIENCE & TECHNOLOGY PRACTICE & POLICY

Harvest Choice Better Choices, Better Lives

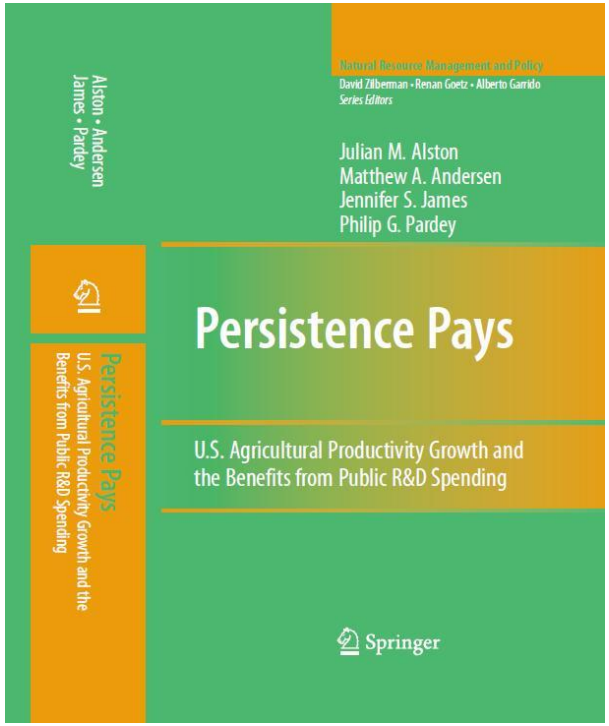
Critical Questions

- **What are the *past and prospective rates* of agricultural productivity growth?**
  - **Is growth slowing, stagnating, or increasing?**
  - **Where in the world is this happening (at what scale)?**
  - **What commodities are performing better than others?**
- **What is the (past and prospective) *relative rates* of growth of productivity (supply) vs demand**

Critical Questions (contd).

- **How has, and likely will, the *endowment* of natural resources change over time?**
  - **within and outside the extent of agriculture**
- **What is the link between**
  - **the nature, size, and location of natural resource endowments and the flows of services from those natural resources, and**
  - **the flow of services and agricultural productivity (*and vice versa*)**

Vice versa? -- Productivity to Natural Resources Linkages



Put another way, thanks to the agricultural productivity increases made possible through research and new technology development since 1990, an area greater than all the land in the 26 states east of the Mississippi River, has been spared for other uses.

Imagine the environmental disaster that would have occurred if hundreds of millions of environmentally fragile acres, not suited to farming, had been ploughed up and brought into production. Think of the soil erosion, loss of forests and grasslands, and biodiversity, and extinction of wildlife species that would have ensued!

Norman Borlaug, Foreword
***Persistence Pays* 2001**

Critical Indicators

- What is produced?
  - Crop and livestock choice (variety and breed)
- Where is it produced?
  - Location, location, location
- How is it produced?
  - Input composition and intensity
    - Land, labor
    - Capital, materials
    - Farm produced (seed, feed, traction)
    - Natural inputs
  - "Intensive" vs "extensive"
  - Continuous cropping vs rotation vs intercropped
  - Crop-livestock interactions

ECON 101 – Measures of Productivity

TFP (total factor productivity) = Q/X

MFP (multi-factor productivity) = Q_i/X_i *i* = included outputs and inputs

$q_e = Q_e/Q$ (excluded outputs as a share of total outputs)

$x_e = X_e/X$ (excluded inputs as a share of total inputs)

$$\therefore \; TFP = \frac{Q_i + Q_e}{X_i + X_e} = Q/X$$

Difference between growth in TFP and growth in MFP

$$d\ln TFP - d\ln MFP = q_e\,(d\ln Q_e - d\ln Q_i) - x_e\,(d\ln X_e - d\ln X_i)$$

Natural Inputs

- Key to the nexus between productivity and environmental endowments and flows
  - Weather (rainfall, sunlight, day length, wind)
  - Terrain (slope, elevation)
  - Soil (type, depth, organic and nutrient content)
  - Pests and diseases (Exputs)

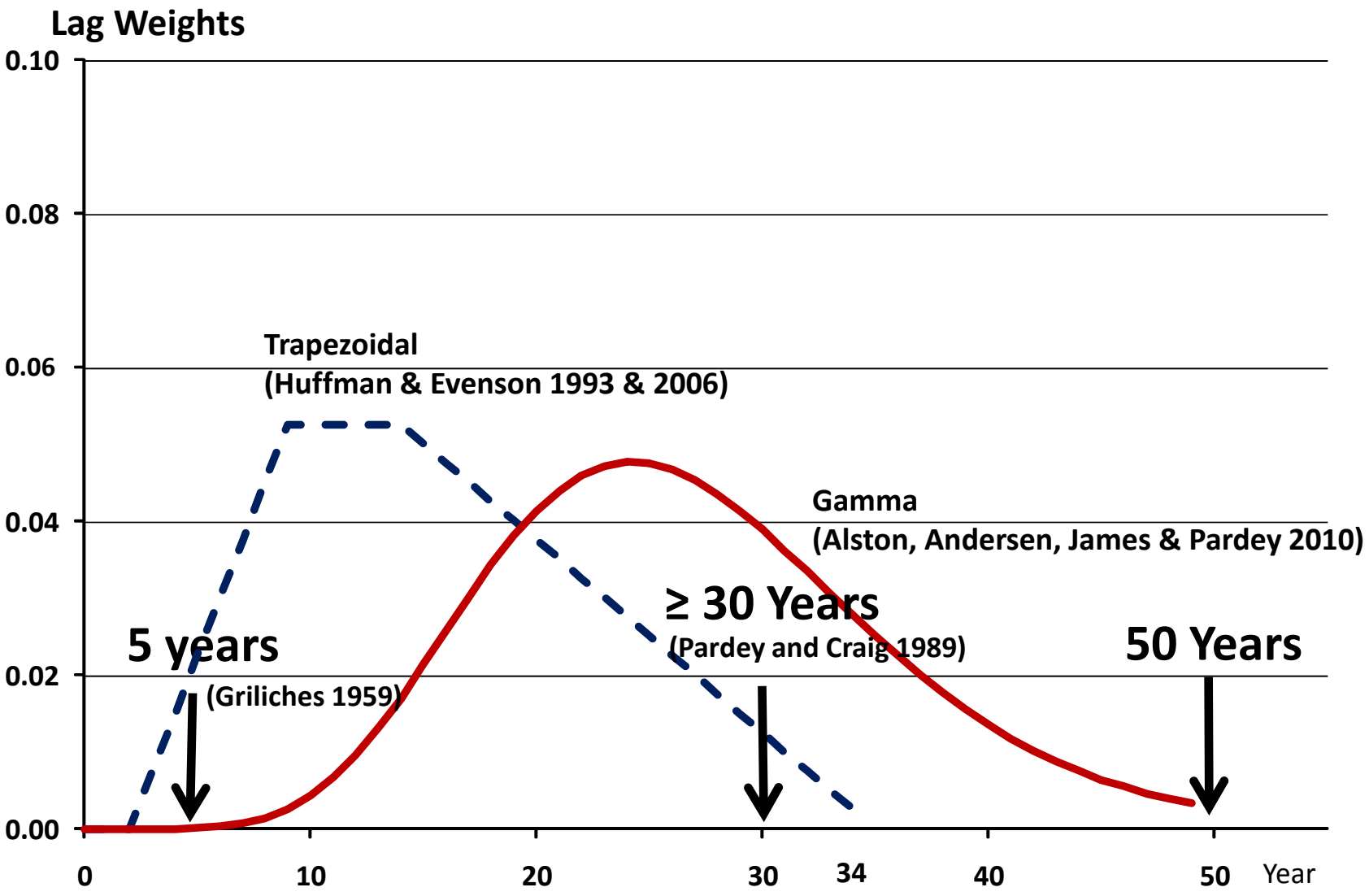
All these natural inputs vary across time and space

Getting the Temporal Calibration Right

R&D → **Technical Change** → **Productivity Change**

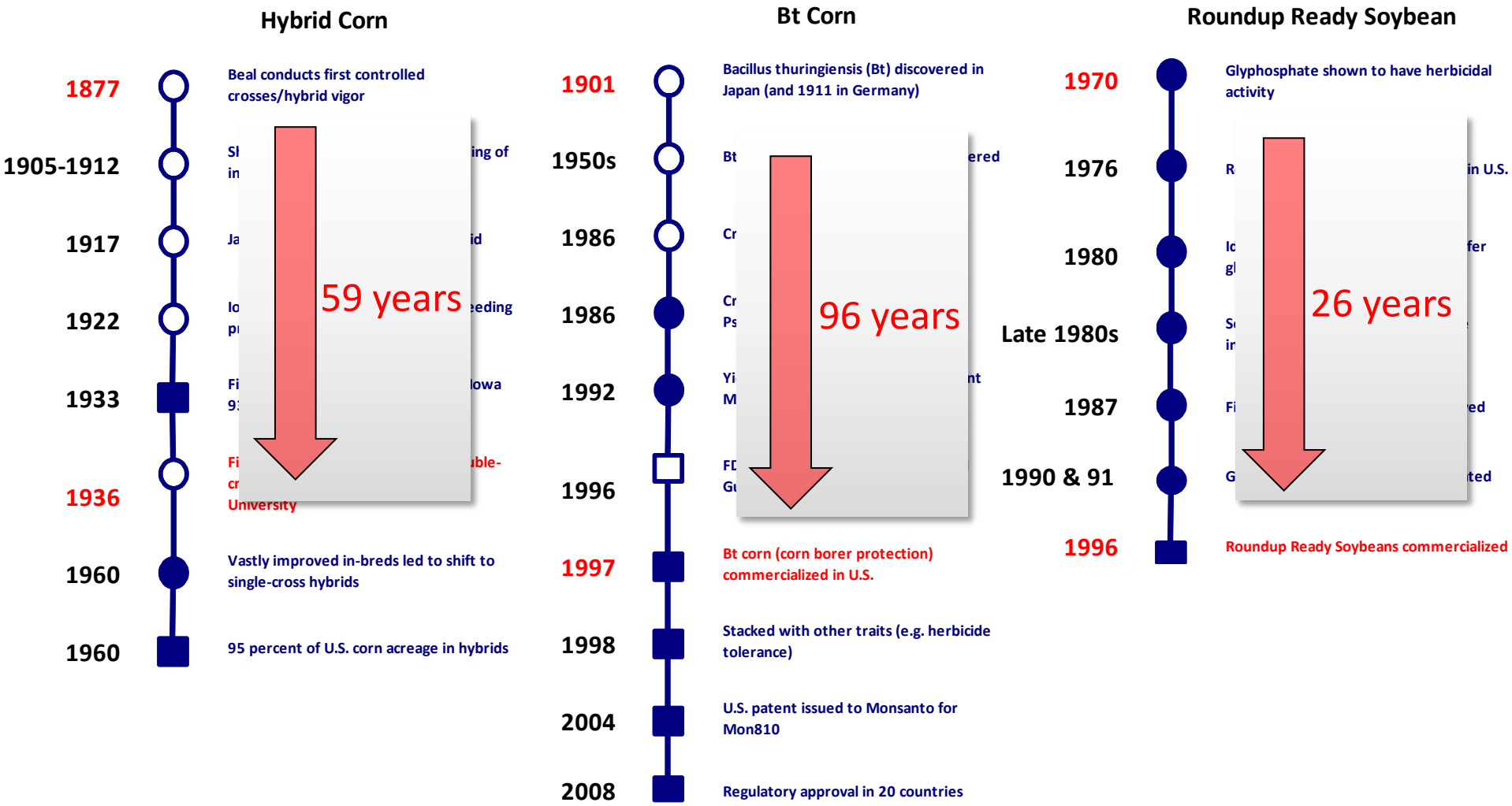
(i.e., changes the technical relationship between inputs and outputs)

Aggregate R&D Spending -Productivity Lag



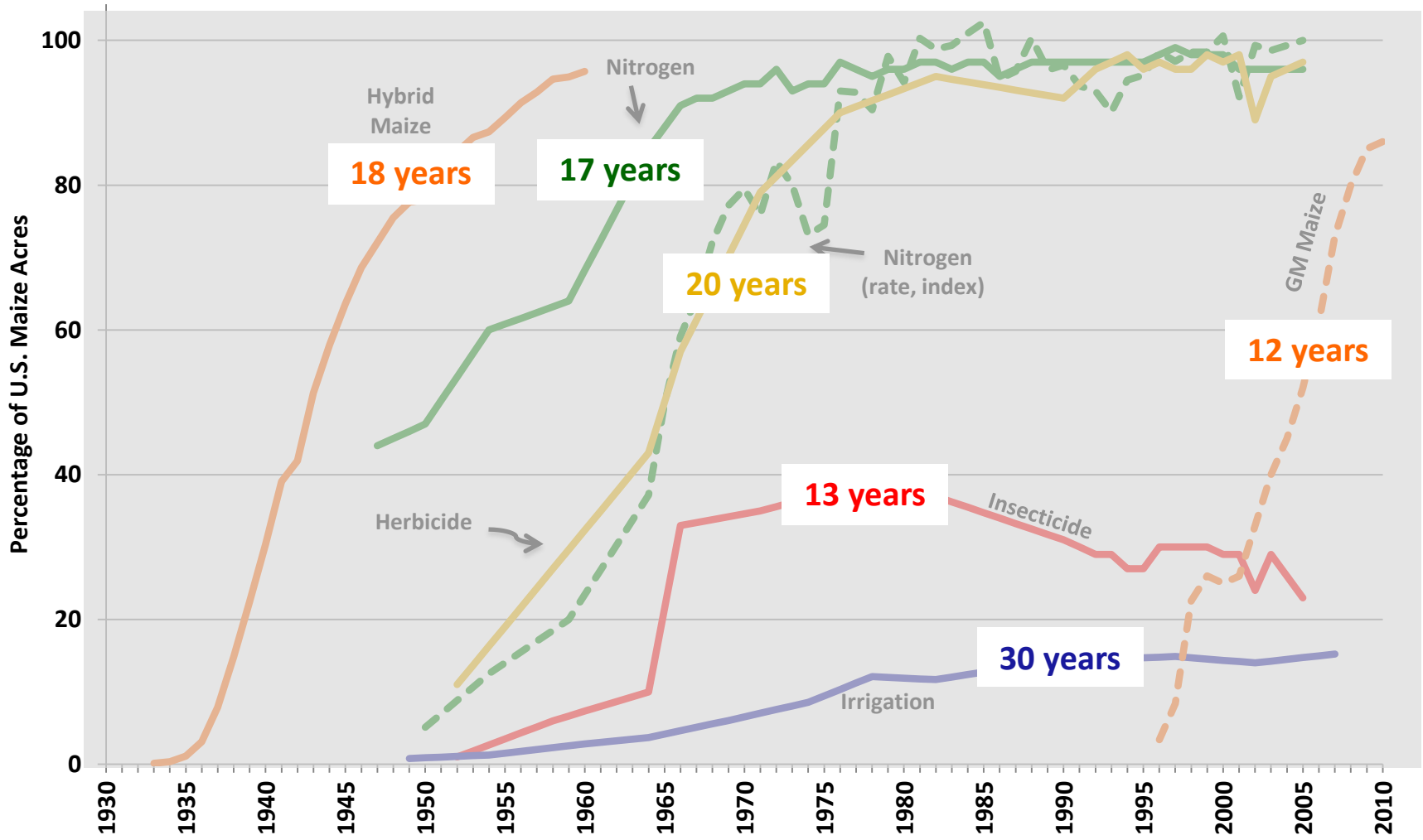
Source: Alston, Pardey and Ruttan (2008) and Alston et al. (2010)

Illustrative Technology Development Lags



Source: Alston, Pardey and Ruttan (2008) and Alston et al. (2010)

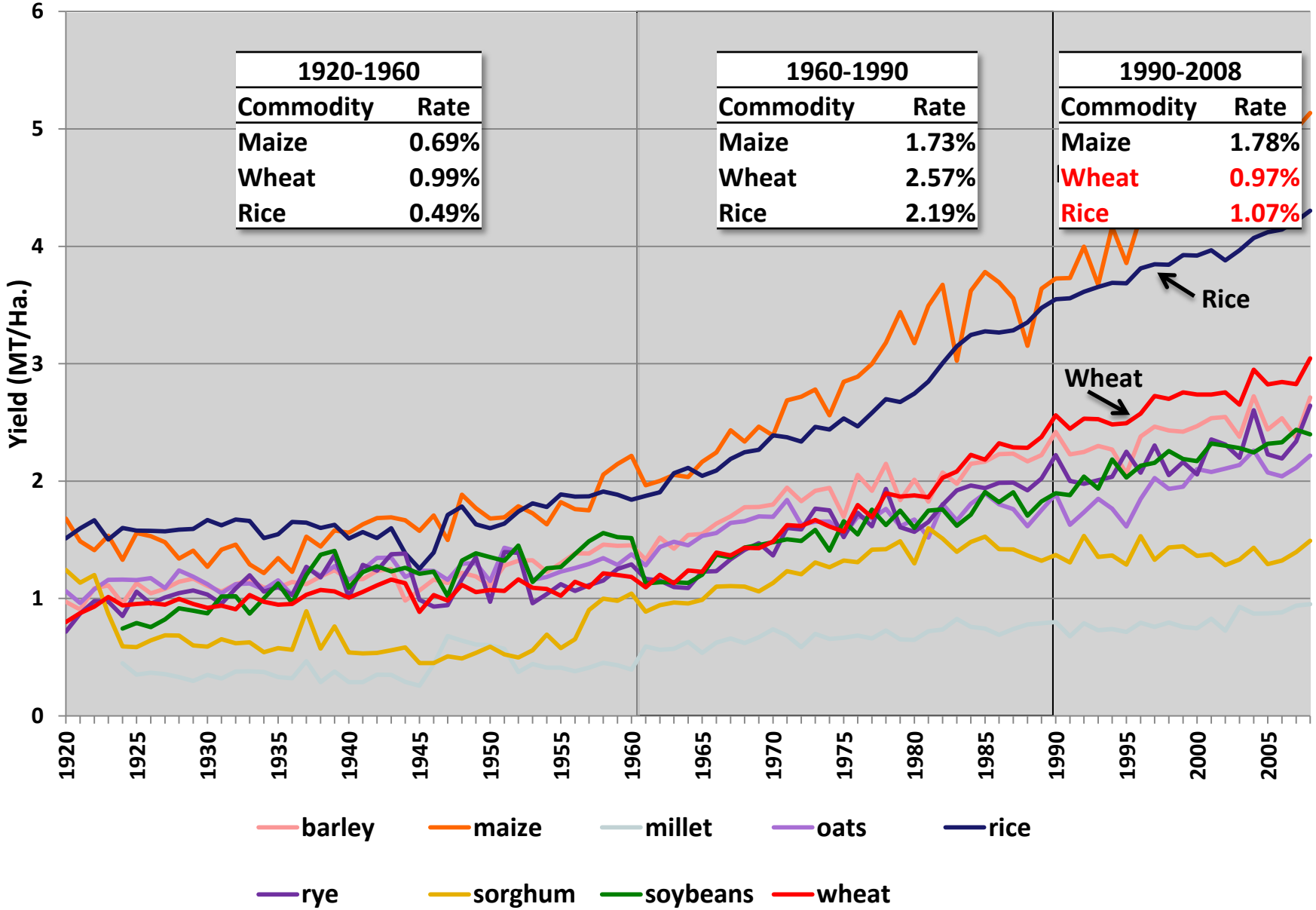
U.S. Maize Technology Adoption Lags



Source: Beddow (2011 forthcoming)

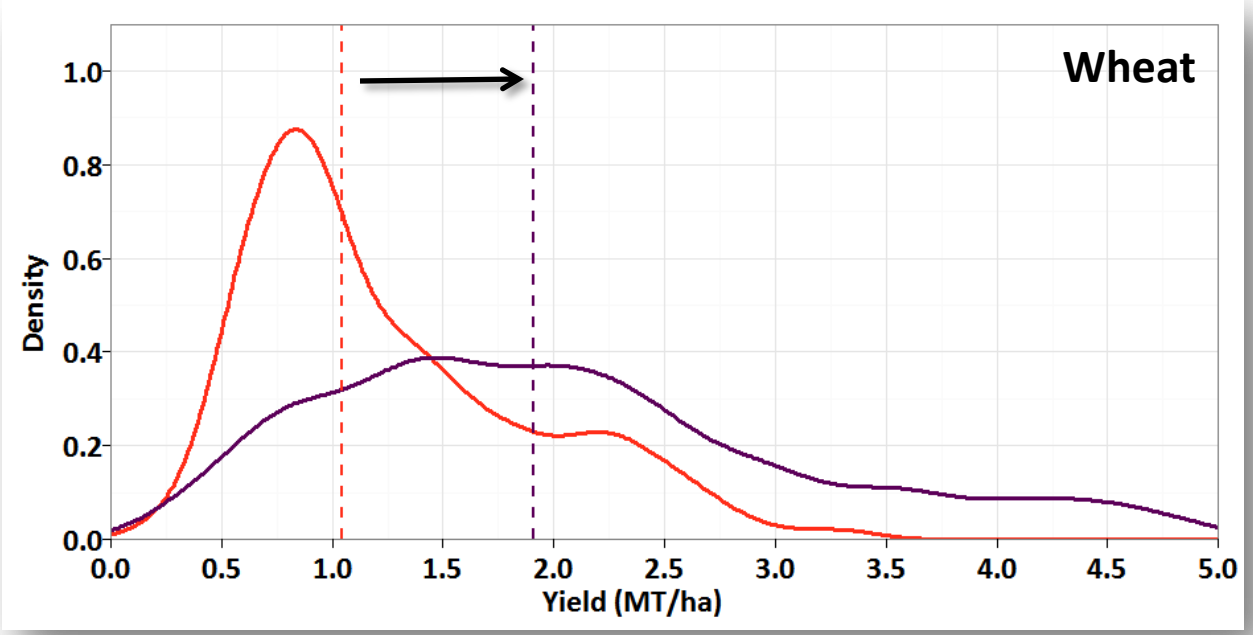
Some Indications of (Global) Productivity Patterns

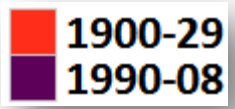
Global Crop Yields Averages, 1920-2008 (Beta version)

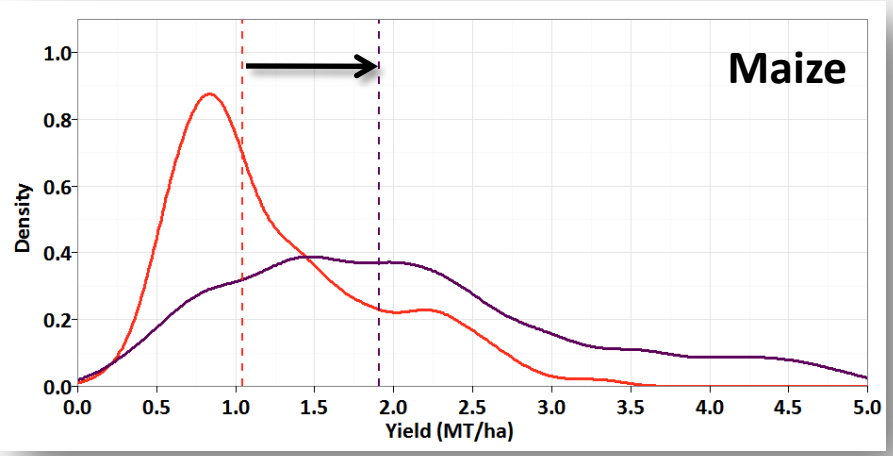


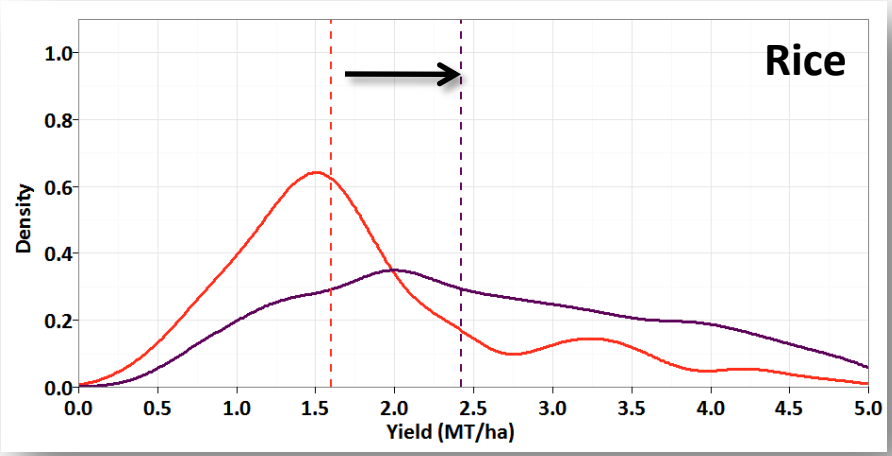
Source: Pardey, Beddow, Xudong and Hurley (forthcoming)

A Century of Global Crop Yield Distributions (Beta version)









Source: Pardey, Beddow, Rao and Hurley (forthcoming)

Partial Factor Productivity Growth, 1961-1990 vs 1990-2008

Groupings	Land Productivity			Labor Productivity		
	1961-90	1990-08	Difference	1961-90	1990-08	Difference
	Percent per year					
World (simple av.)	1.78	1.55	-0.23	1.74	1.84	[0.09]
World	1.95	2.01	0.06	0.92	1.52	0.62
World minus China	1.79	1.53	-0.26	1.09	0.75	-0.35
80% (N = 22)	1.98	2.21	0.23	0.97	1.78	0.82
80% minus China	1.96	1.88	-0.08	2.68	3.06	0.38
< 80% (N= 158)	1.82	1.17	-0.64	1.11	0.24	-0.87

Source: Pardey (forthcoming)

Global Slowdown in Multifactor Productivity Growth?

"I see no evidence of a general slowdown in sector-wide agricultural TFP [growth]. At least through 2006. If anything, the growth rate in agricultural TFP accelerated in recent decades….

Despite this generally optimistic conclusion, it is also clear that agricultural productivity growth has been very uneven… TFP growth may in fact be slowing in developed countries while accelerating in developing countries."

Fuglie (2008, p. 440)

Sample of Regional and Global Productivity Studies

Authors	Publication year	Data		Method
		Year(s)	Countries	
Hayami and Ruttan	1970	1955, 1965 & 1970	38	Econometric
Antle	1983	1965	45	Econometric
Lau & Yotopolous	1989	1960, 1970	43	
Bloc				
Craig, Pardey & Roseboom	1997	1961-1990	98	Econometric
Fulginiti & Perrin	1998	1961-1985	18	Econometric Malmquist
Coelli & Rao	2005	1980-2000	93	Malmquist/DEA
Fuglie	2008	1961-2006	171	Growth accounting
O'Donnell	2010	1970-2001	88	Hicks–Moorsteen/DEA

Common Denominator– FAO and World Bank Data

FAO and World Bank Data

Land – count of arable, permanently pastured and cropped area

Labor – head count of economically active population in agriculture

Capital – count of tractors in use/on farm
– percent of irrigated acres

Livestock – weighted head count of buffalo, cattle, pig, sheep, and goat

Materials – fertilizer (nitrogen, phosphate and potash and use in units of active ingredients)

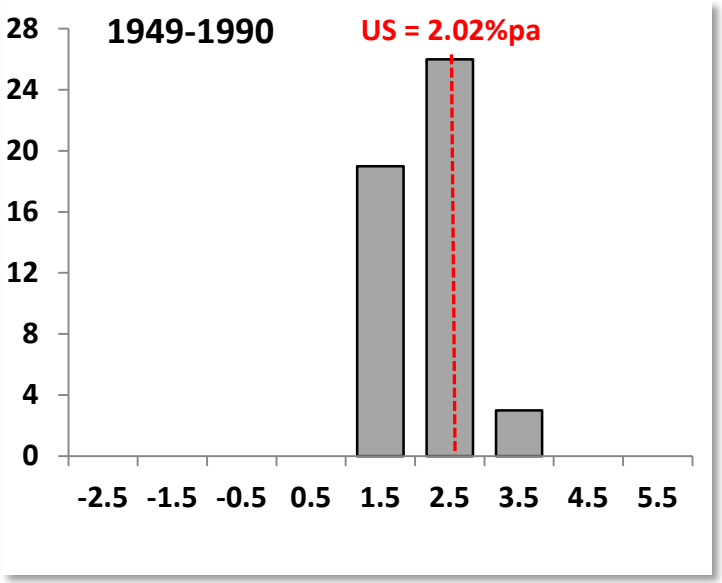
Estimated U.S. Aggregate Input and MFP Growth Rates, 1961-2006

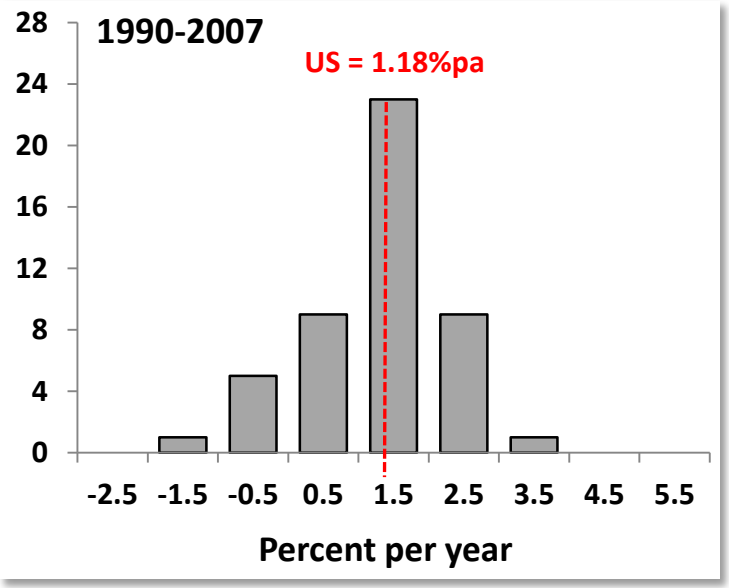
	Fuglie Factor Weights			
	Developing	World	U.S.	InSTePP
	(percent per year)			
Agg. Input	-0.22	0.07	0.54	-0.07
MFP	1.94	1.65	1.18	1.73

Source: Pardey (forthcoming)

U.S. Multifactor Productivity, 1949-2007

State MFP Growth Distributions





InStePP Production Accounts

Outputs

- Crops 61
- Livestock (9)
- Miscellaneous (4)

Inputs

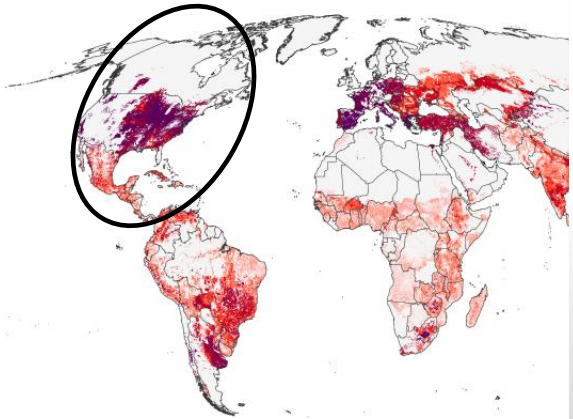
- Land (3)
  - Cropland, irrigated cropland, pasture and grassland
- Labor (32)
  - Family labor
  - Hired labor
  - Operator labor (30)
    - Education: 0–7 years, 8 years, 1–3 years of high school, 4 years of high school, 1–3 years of college, 4 years or more of college
    - Age: 25–34, 35–44, 45–54, 55–64, or 65 or more years of age
- Capital (12)
  - Machinery (6)
    - Automobiles, combines, mowers and conditioners, pickers and balers, tractors, trucks
  - Biological capital (5)
    - Breeding cows, chickens, ewes, milking cows, sows
  - Buildings
- Materials (11)
  - Electricity, purchased feed, fuel, hired machines, pesticides, nitrogen, phosphorous, potash, repairs, seeds, miscellaneous purchases

Some Big (Largely) Unknowns

- **The Location of Production**
- **The Spatial Dynamics of Agriculture**
- **The Prevalence (and consequences) of Pests and Diseases**

Spatial Distribution of Crop Yields, 2000 (SPAM ver 3.0)

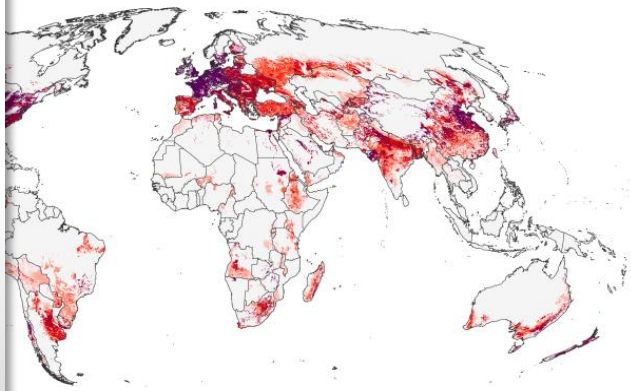
Panel a: Maize



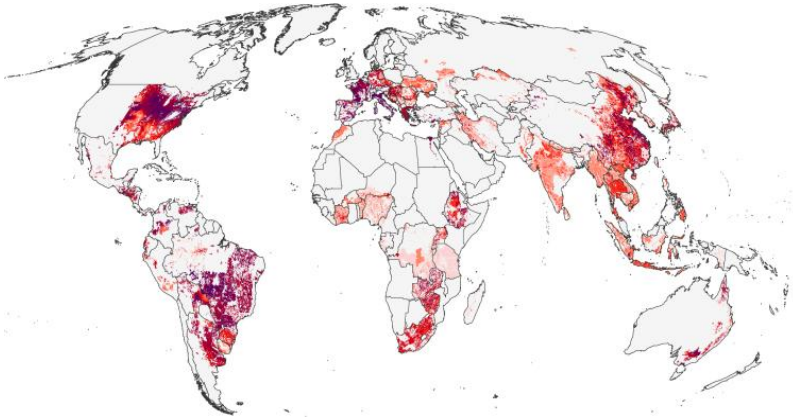
Share of World's High-Yielding Area

	US	Africa
	(percent)	
Maize	32	2.5
Wheat	28	3.6
Soybean	25	5.6
Rice	5.3	5.7

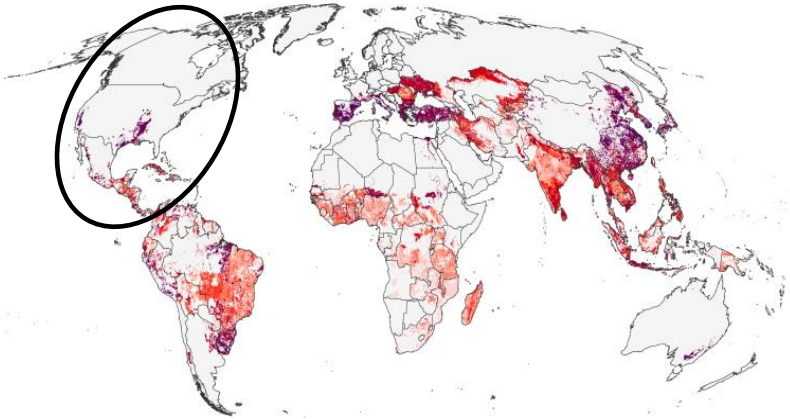
Panel b: Wheat



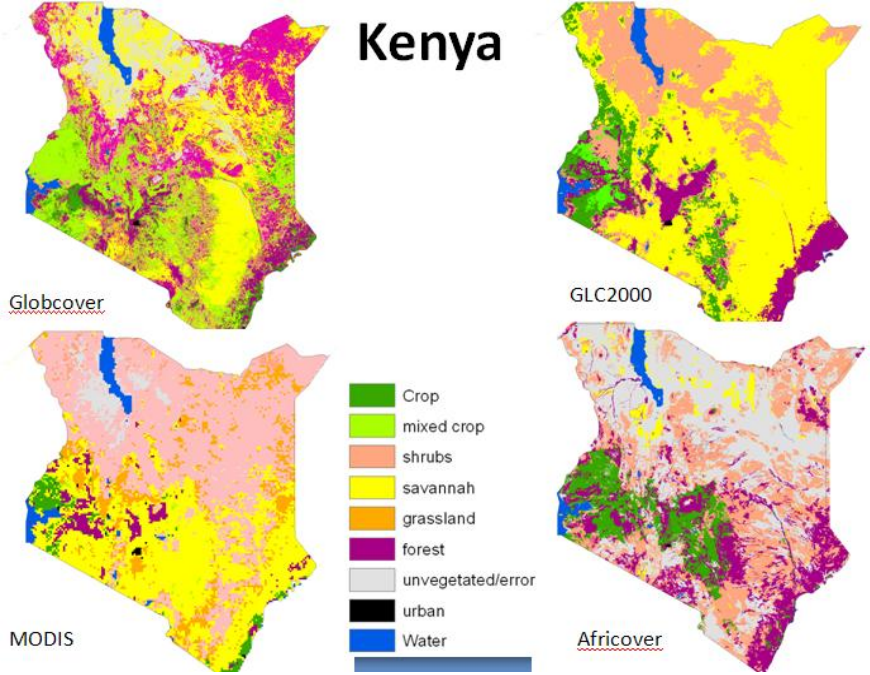
Panel c: Soybean

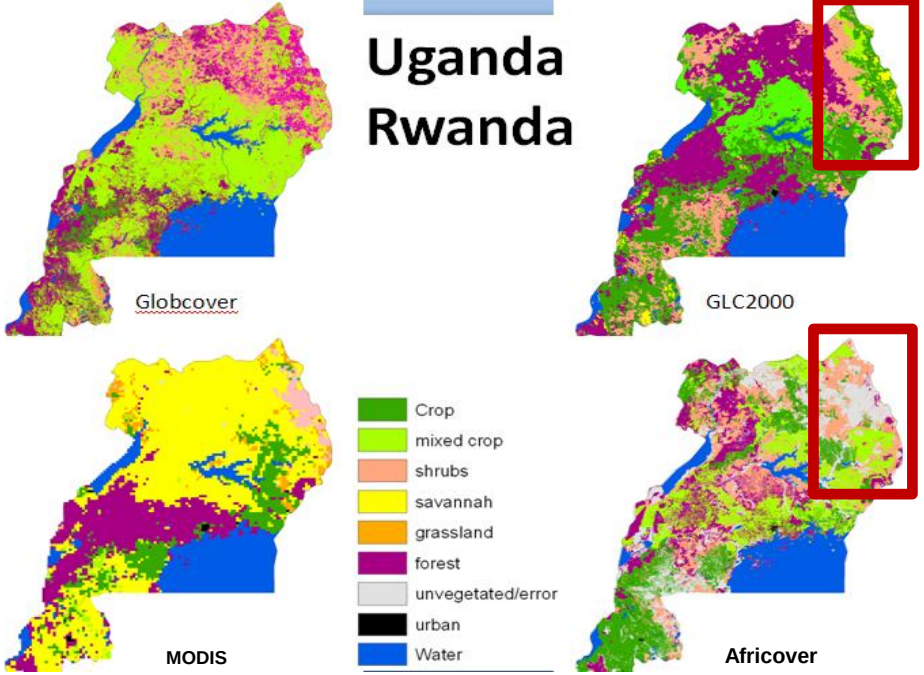


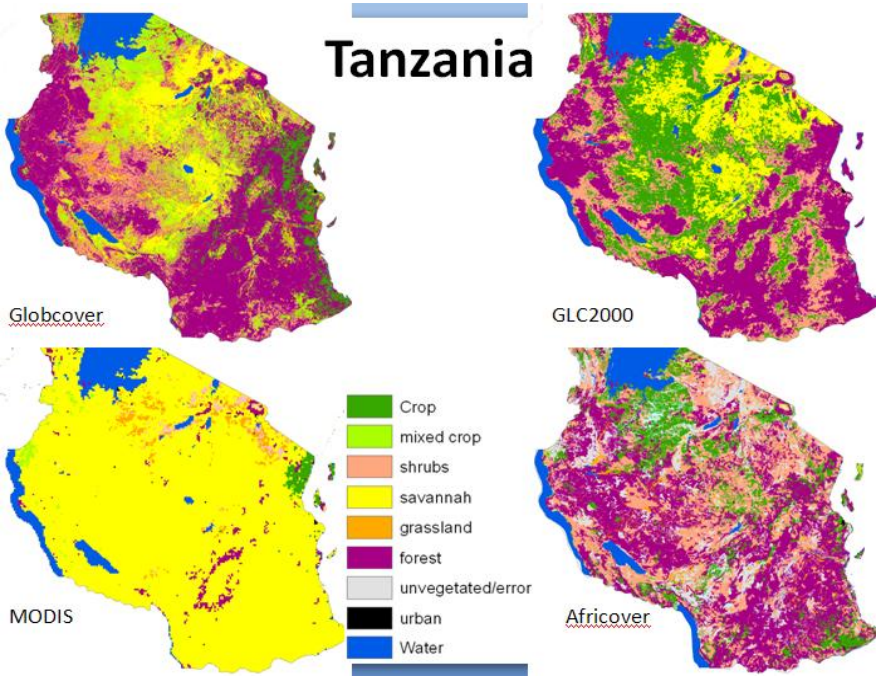
Panel d: Rice

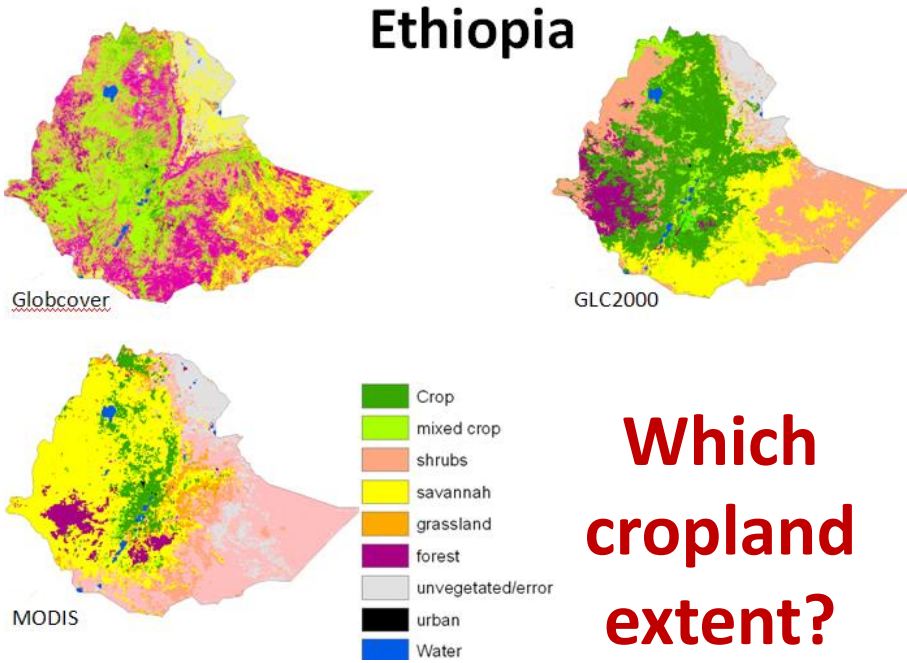


Source: HarvestChoice (2010)



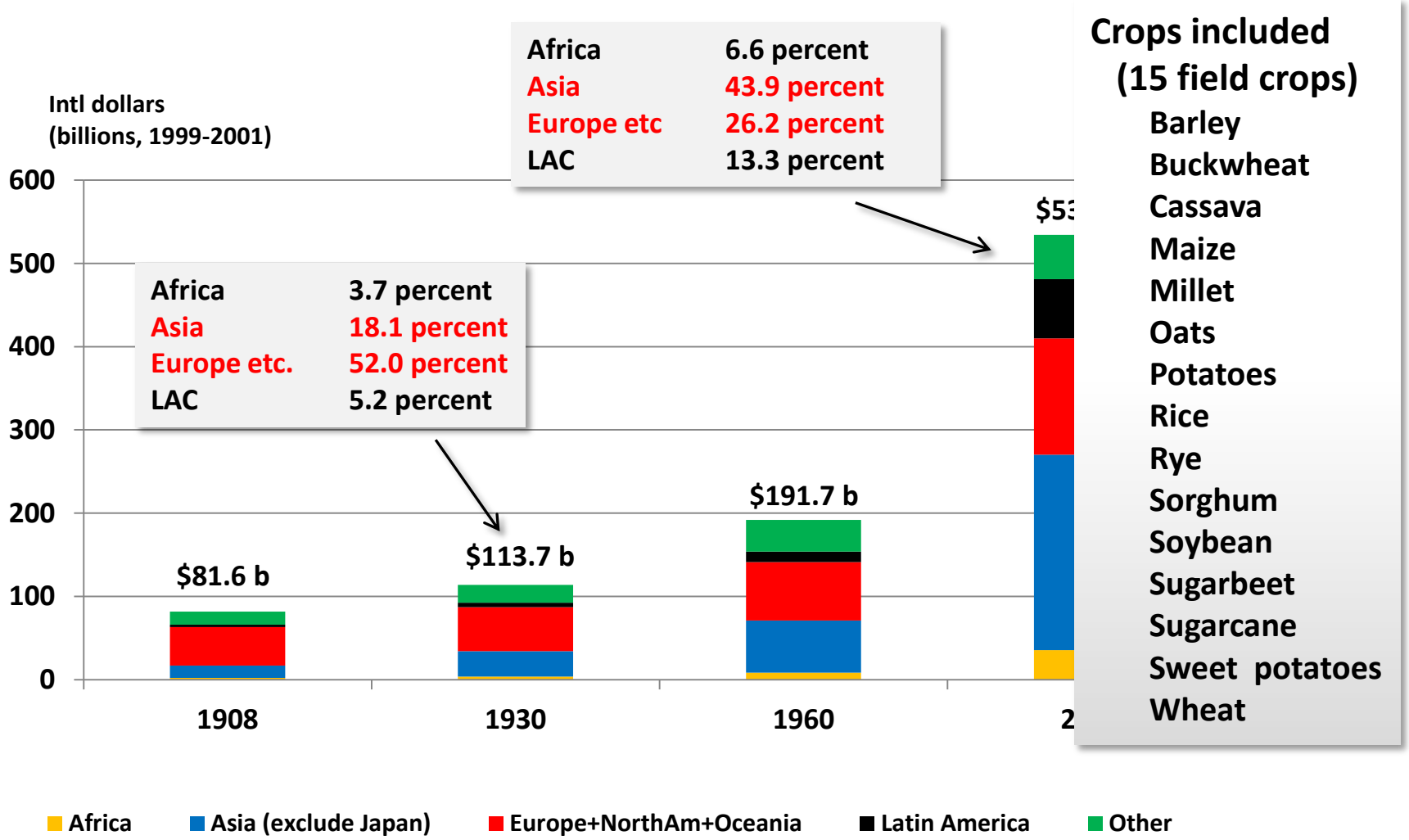






Which cropland extent?

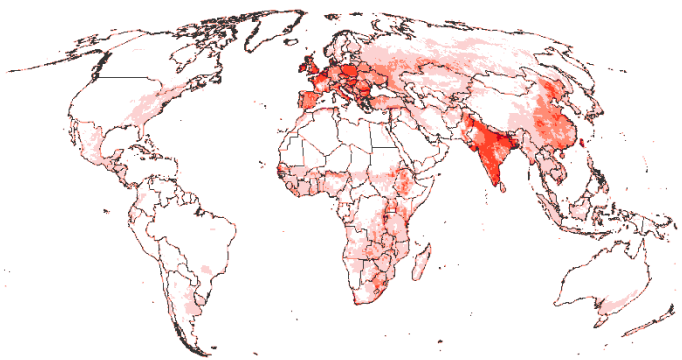
Global Value of Field Crops Production, 1908-2008 (beta)



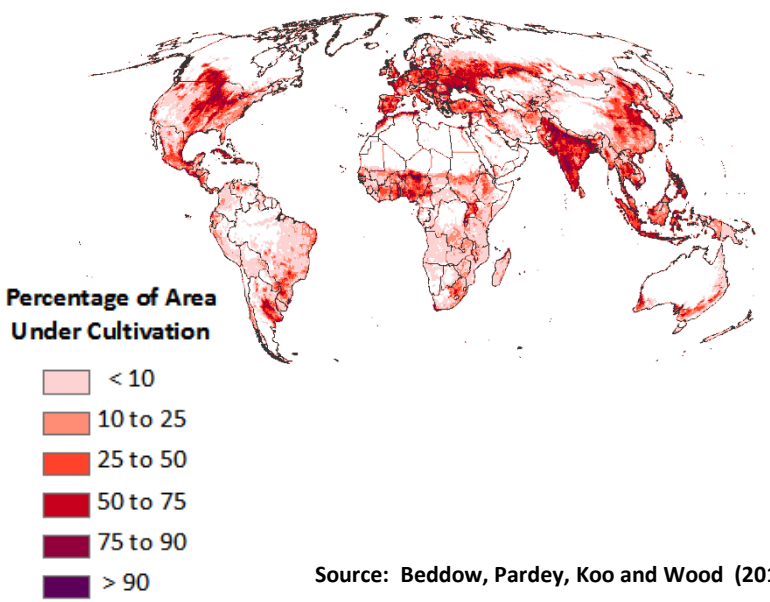
Source: Pardey (forthcoming)

Changing Location of Agriculture

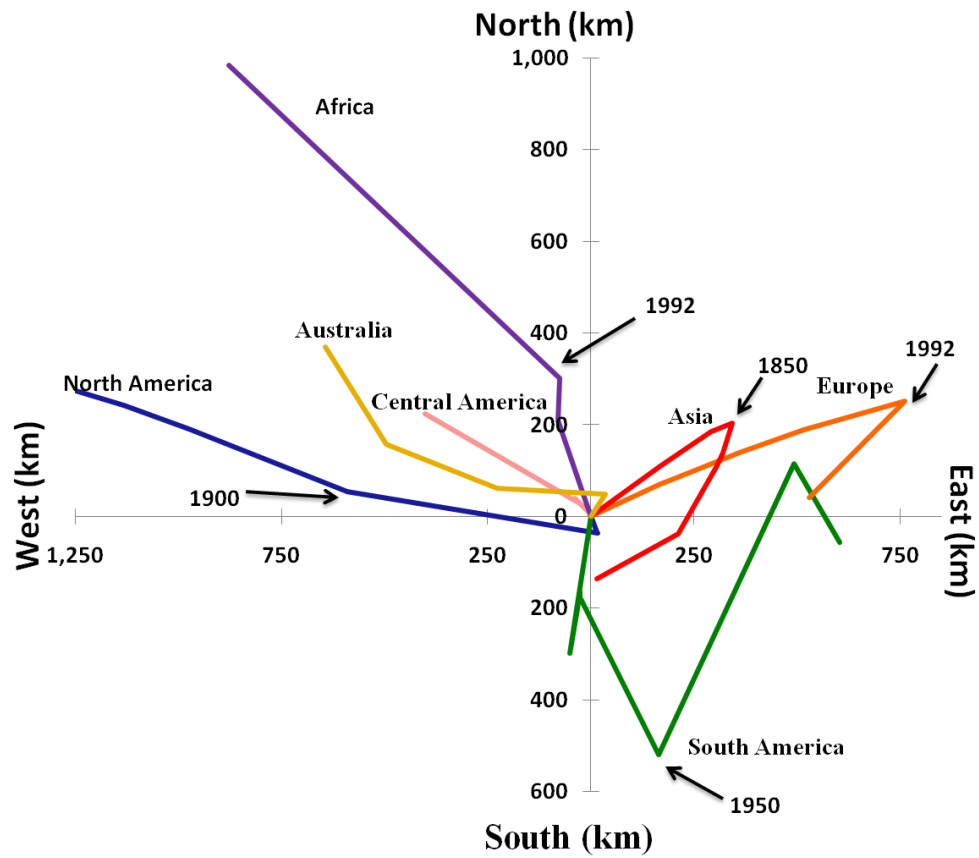
Panel a: Cropland Extent, 1700



Panel b: Cropland Extent, 2000

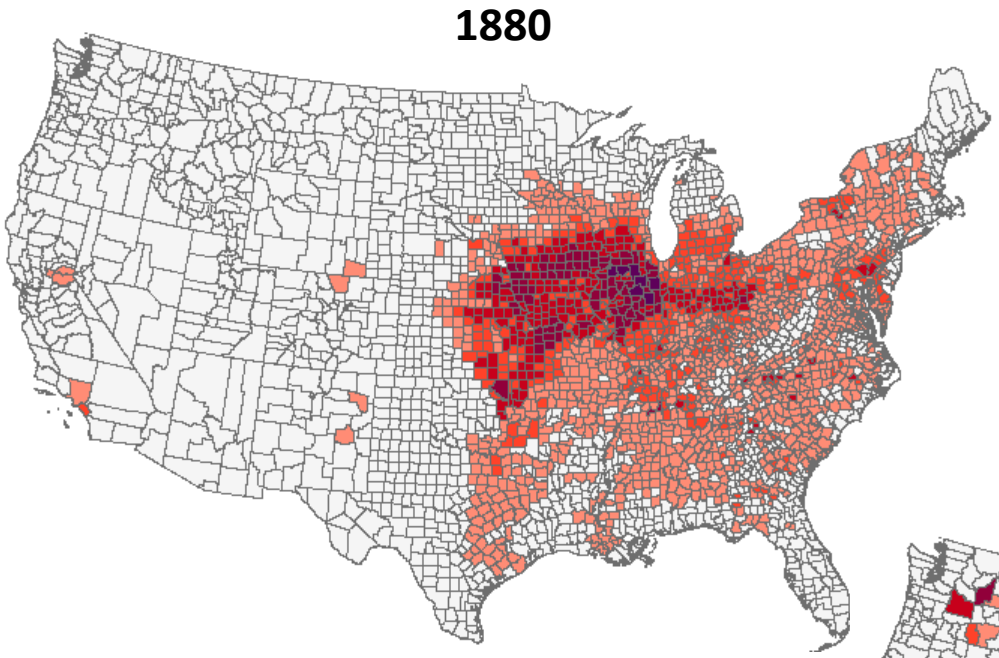


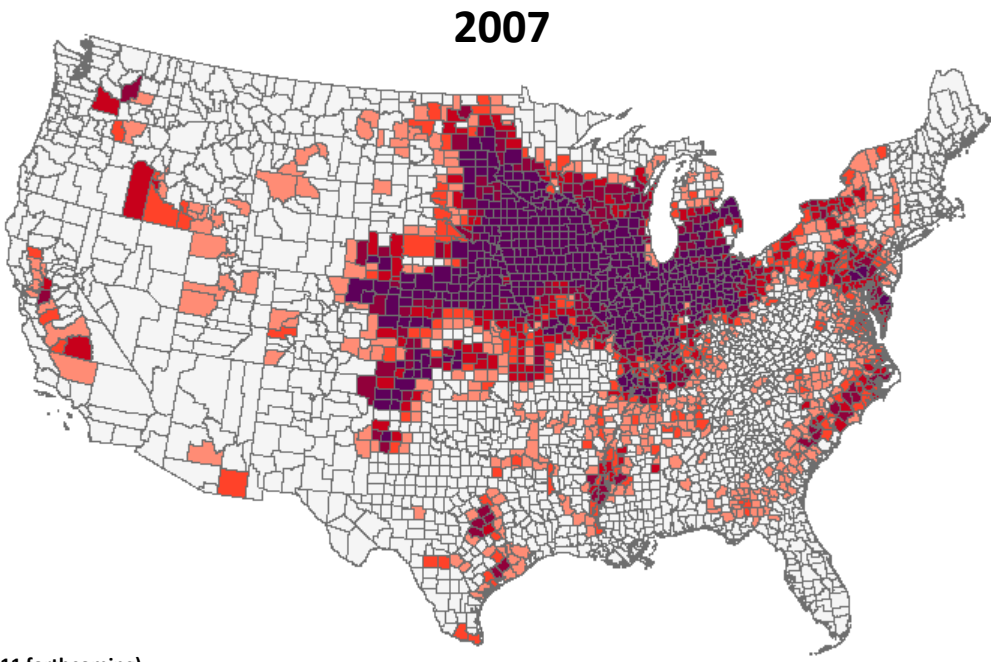
Panel c: Movement of Regional Cropland Centroids, 1700 – 2000

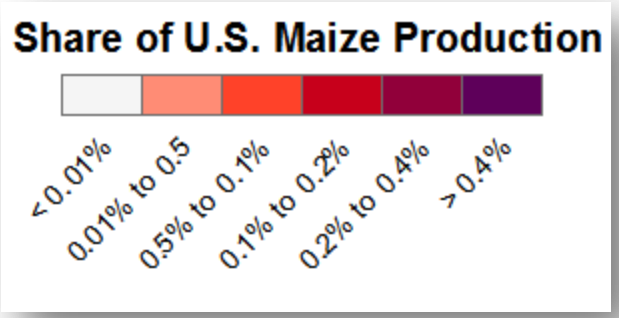


Source: Beddow, Pardey, Koo and Wood (2010)

U.S. Maize Production, 1880 and 2007

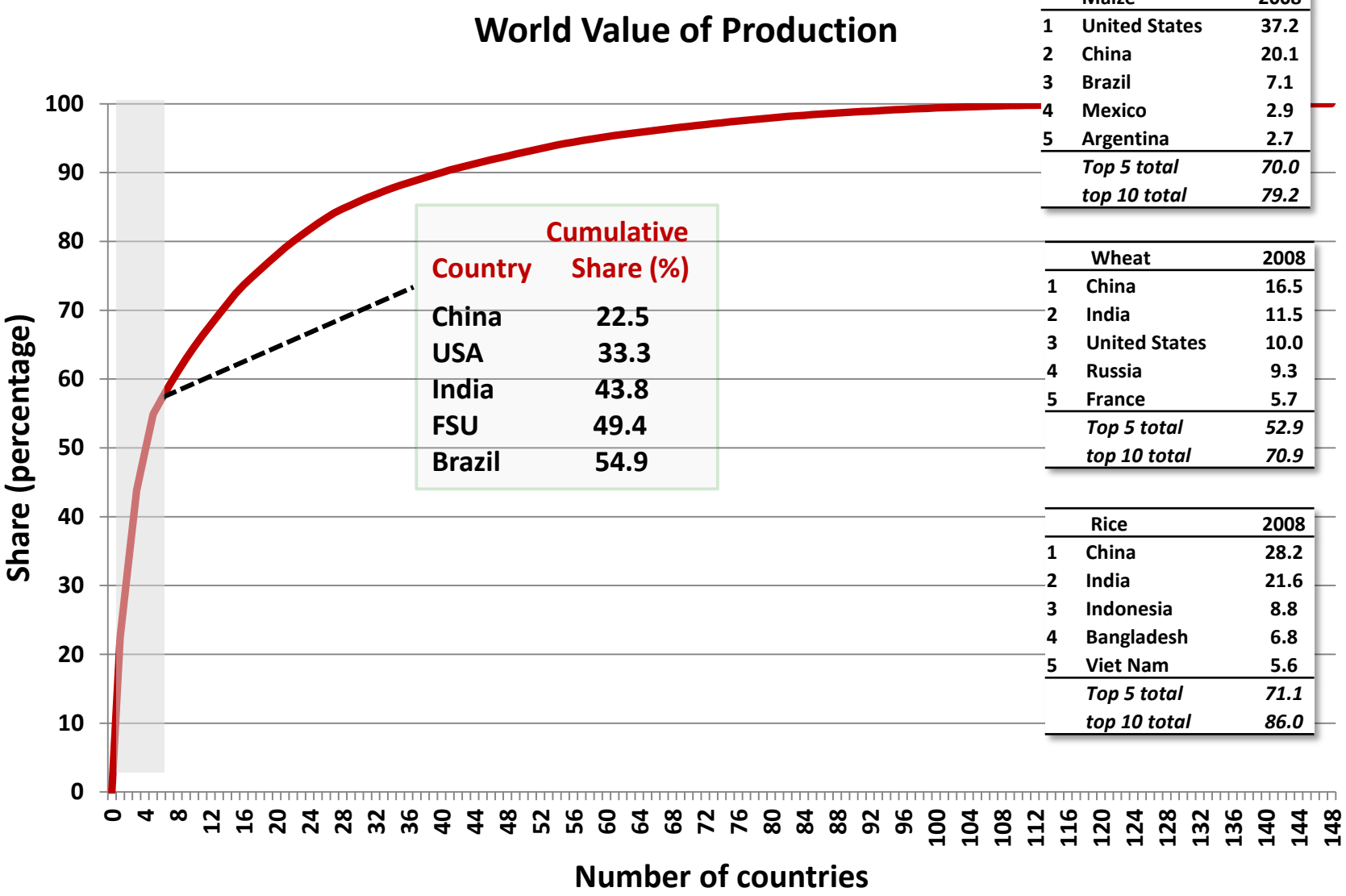






Source: Beddow (2011 forthcoming)

Spatial Concentration of Global Agricultural Production, 2006-08 average



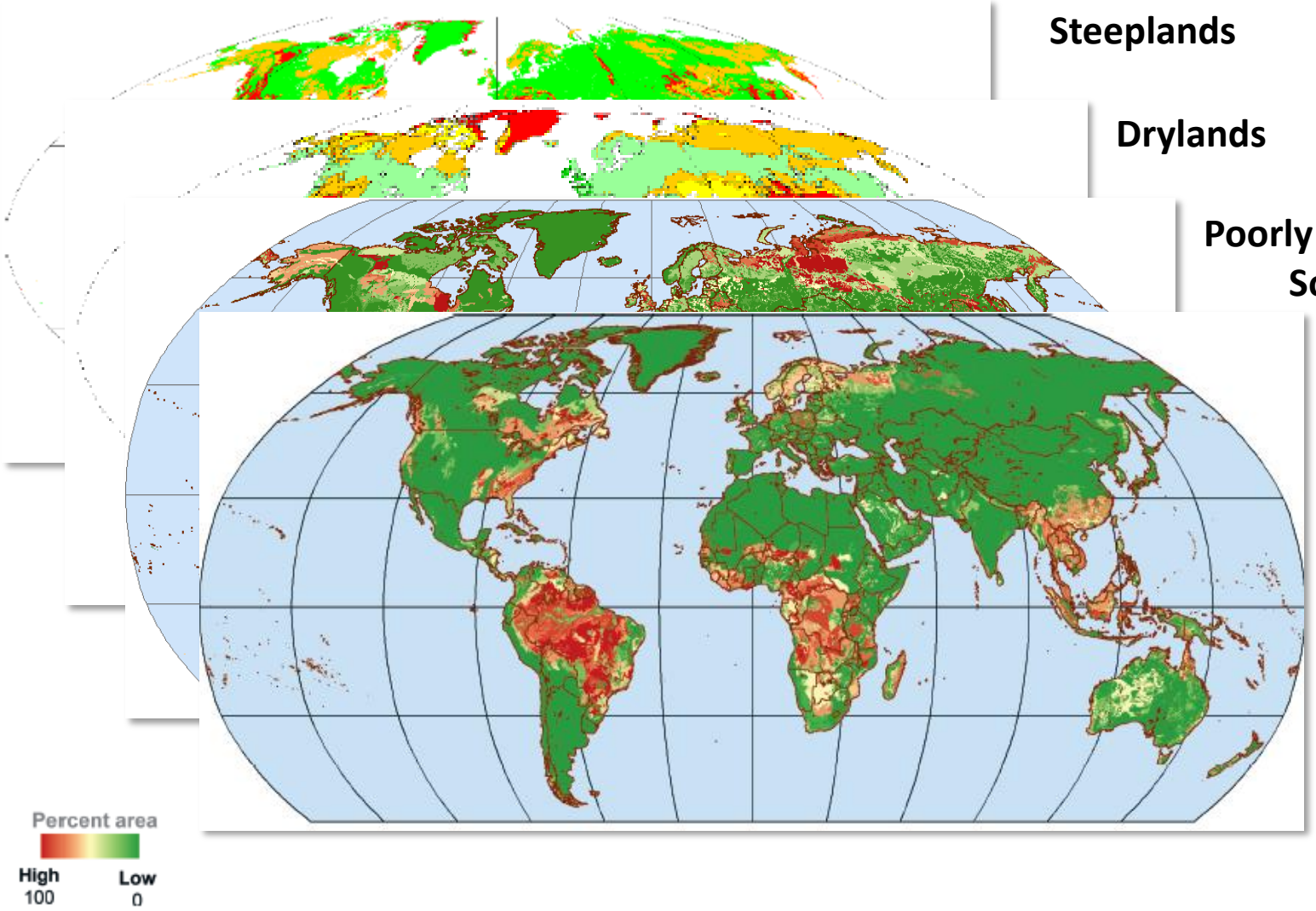
	Maize	2008
1	United States	37.2
2	China	20.1
3	Brazil	7.1
4	Mexico	2.9
5	Argentina	2.7
	Top 5 total	*70.0*
	top 10 total	*79.2*

	Wheat	2008
1	China	16.5
2	India	11.5
3	United States	10.0
4	Russia	9.3
5	France	5.7
	Top 5 total	*52.9*
	top 10 total	*70.9*

	Rice	2008
1	China	28.2
2	India	21.6
3	Indonesia	8.8
4	Bangladesh	6.8
5	Viet Nam	5.6
	Top 5 total	*71.1*
	top 10 total	*86.0*

Source: Pardey (forthcoming)

Spatial Variation in Abiotic Productivity Constraints



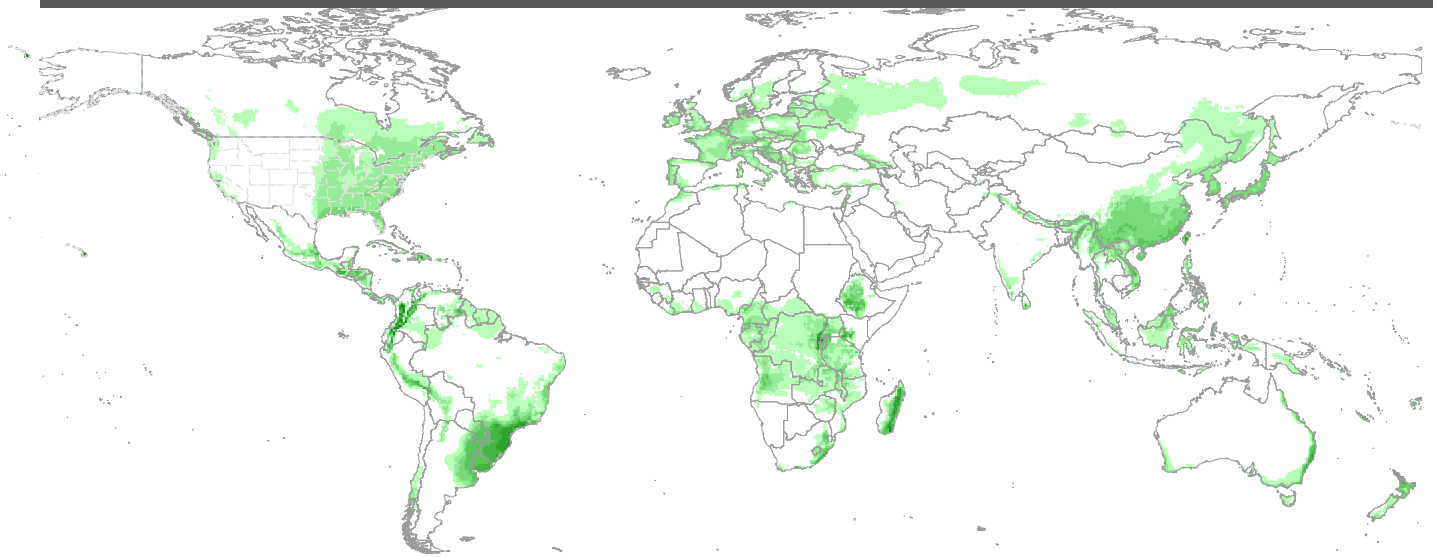
Explore more at http://labs.harvestchoice.org/2010/12/updating-soil-functional-capacity-classification-system/

Global Probability of Occurrence of Wheat Rust (pre-release version)

Puccinia striiformis (Stripe Rust)

Puccinia triticina (Leaf Rust)

Puccinia graminis (Stem Rust)



Growth Index

- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- > 90

Source: Pardey et al. (2011 forthcoming)

Crop Disease – Stem Rust Example

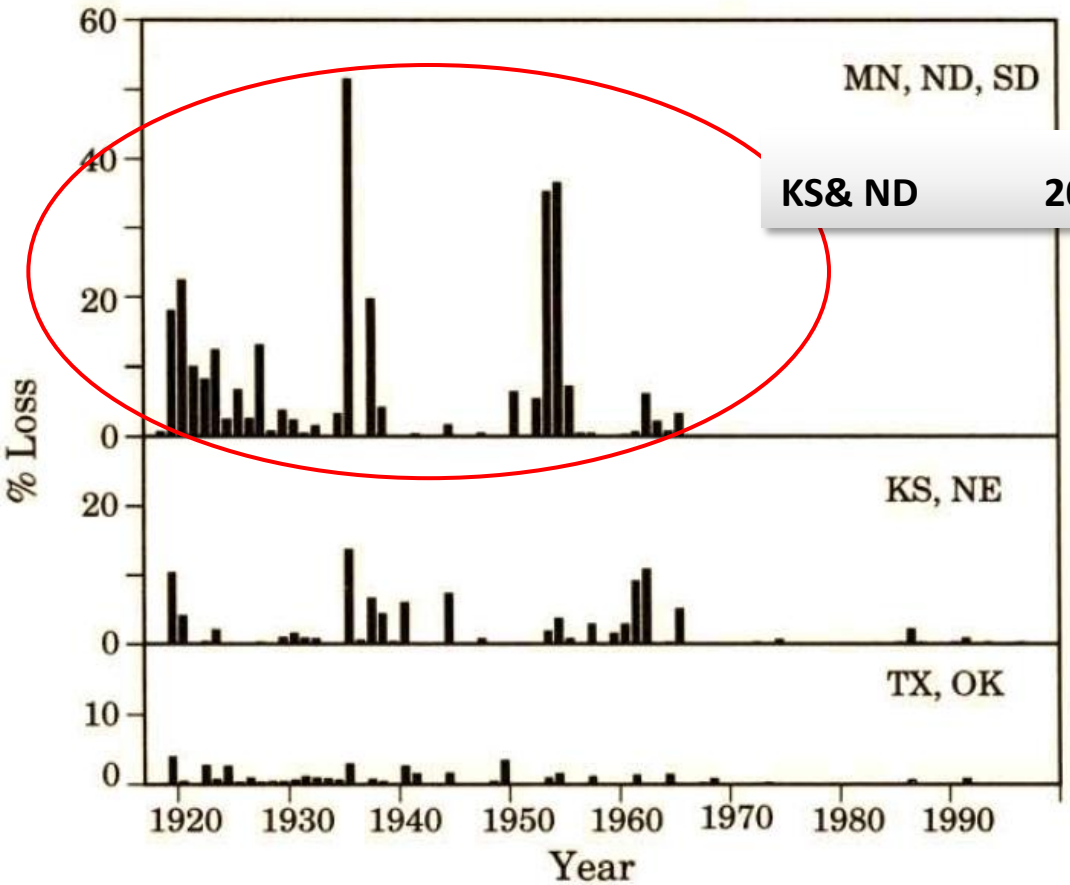
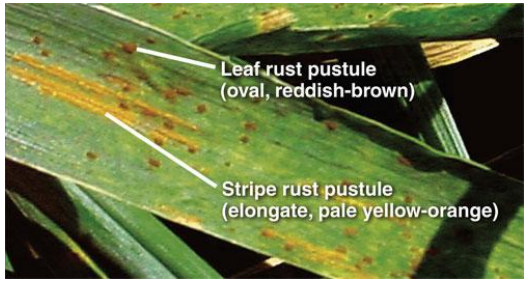


Fig. 4.1. Percentage loss in wheat yield caused by stem rust from 1918 to 1997 in northern, central, and southern regions of the Great Plains of the United States (2,10).

KS& ND 20.4 MMT ~ 100% Oz output



Final Thoughts

"Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth in the United States."

Abramovitz (AER 1956, pp. 5-23)

In an idea he attributed to Zvi Griliches, Schultz argued that the economically ideal output-to-input ratio would stay at or close to one, the notion being that "… the closer we come to a one-to-one relationship in our formulation, the more complete would be our (economic) explanation [of the sources of output growth]."

Schultz (1956, p.758)

Final Thoughts

Agricultural economists and other social scientists tend to take data as facts. The problem is the data are not facts. Facts are what is really there. Data are quantitative representation of facts, which statistical workers and economists concoct.

I call the study of how primary statistical information is made into economic data "factology." The neglect of factology risks scientific ruin.

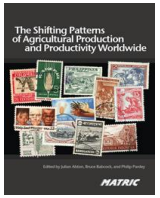
The bottom line is, for data producers, that full disclosure of procedures and labeling of data series are essential; and, for data users, be careful and investigate the data before using them.

Bruce Gardner (1992, AAEA Waugh Lecture)

Thanks!

Selected Sources

Alston, J.M., M.A. Andersen, J.S. James, and P.G. Pardey. ***Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D*** *Spending.* New York: Springer, 2010.



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