

GEOS 24705/ ENST 25500

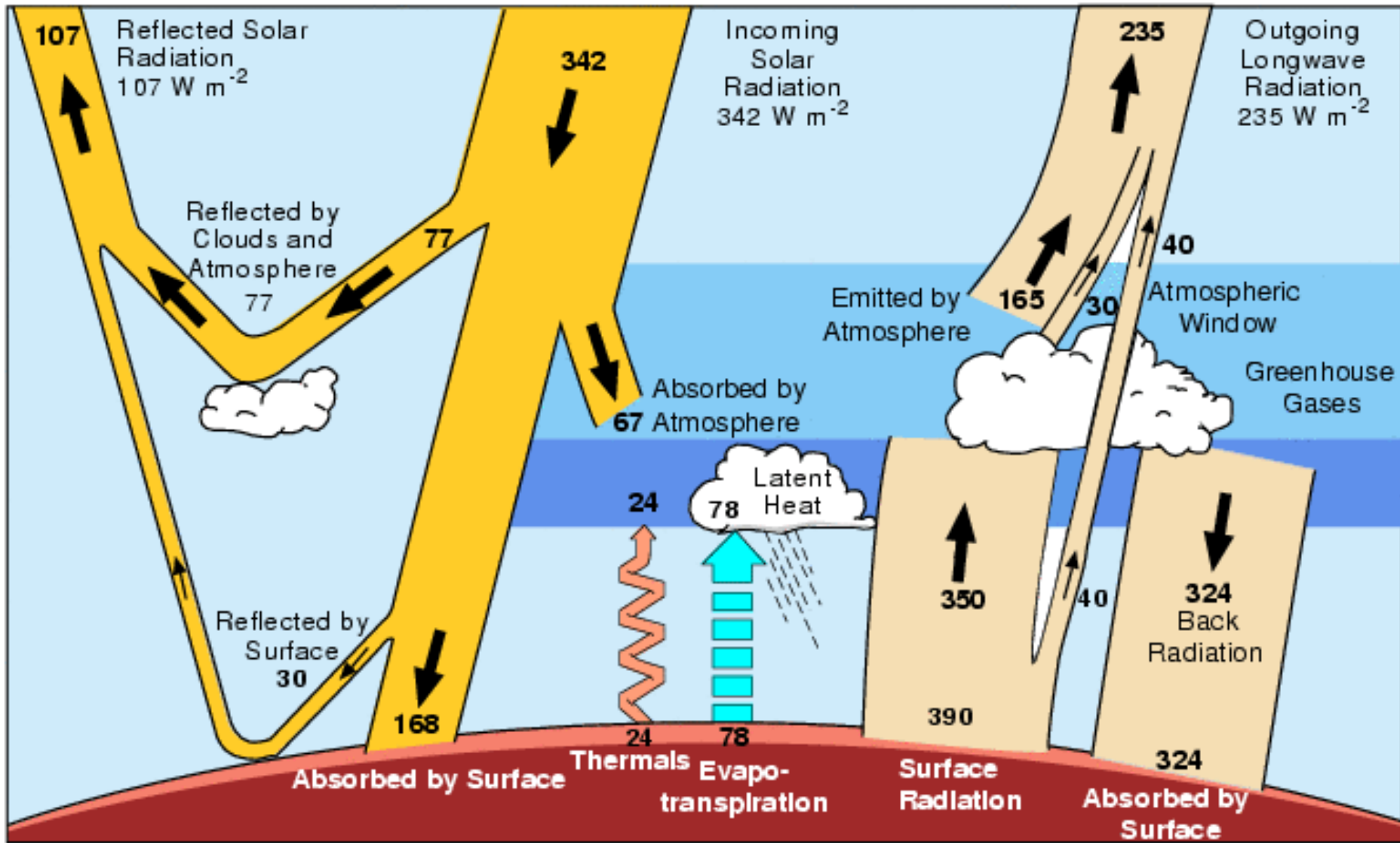
U. Chicago

Apr 2014

Lecture 3

**Earth's energy flows III**

# Global Heat Flows



# Photosynthetic efficiencies and energy flows

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photosynthetic	$\epsilon_{\text{photo}}$	W/m <sup>2</sup>
Rainforest	1%	2
Good farmland, fert. corn	1%	2
Good farmland, ave.	0.5%	1
Land mean	~0.2%	0.4
World mean $\epsilon_{\text{photo}}$	~0.1%	0.2

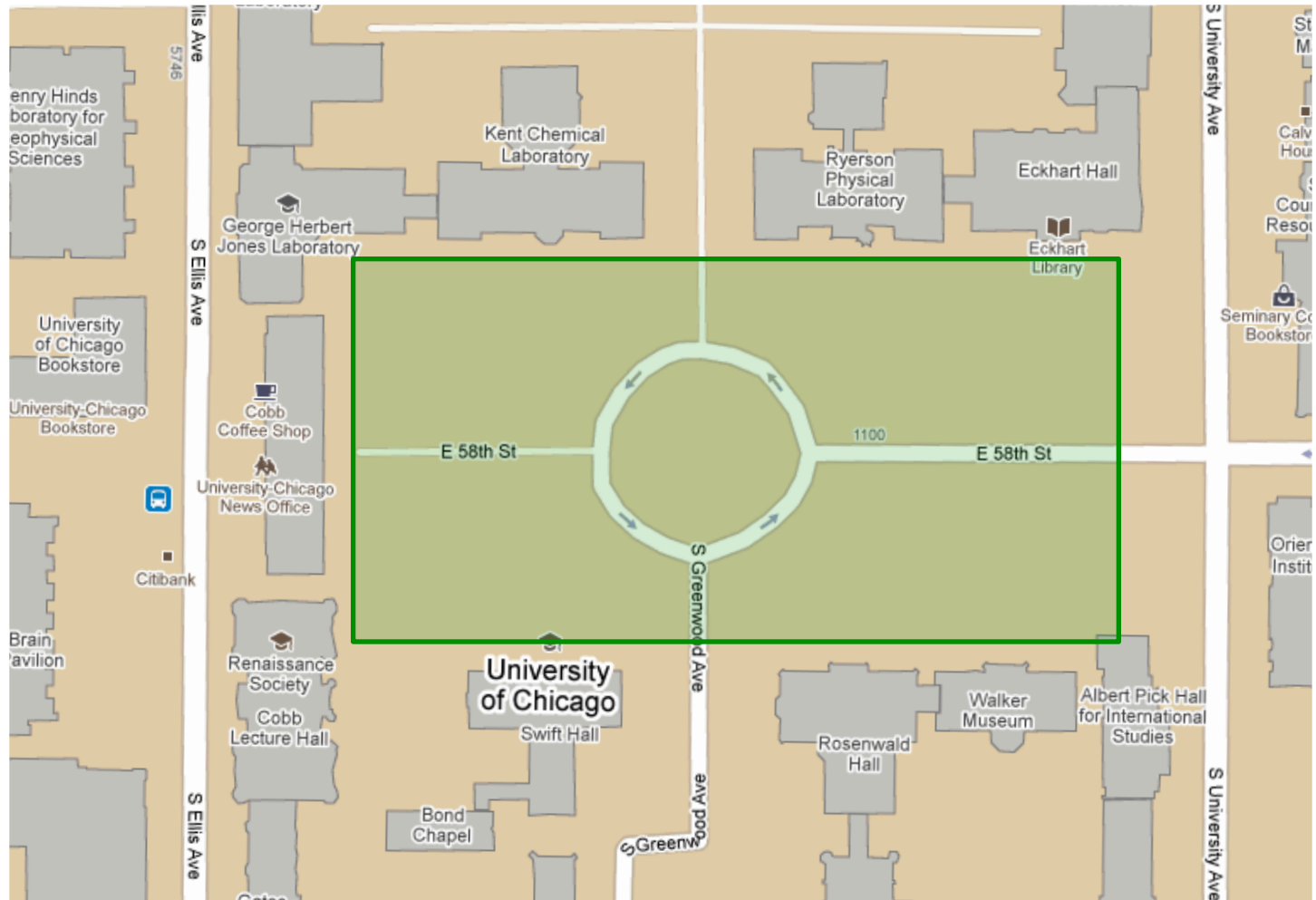
  

food	$\epsilon_{\text{food}}$	W/m <sup>2</sup>
U.S. fertilized corn	~0.5%	1 (1:1 stover:kernels)
World ave., all cereal	~0.15%	0.3
Pre-modern	~0.015%	0.03 (10 times worse)

*Sources: various internet, unverified. Pre-modern efficiency from Grigg, 'Population Growth and Agrarian Change - an Historical Perspective', estimate of ca. 1200 AD British yield of ~700 kg/ha = 125 W/acre. Fertilized efficiency calculated from figures from the Iowa Corn Growers association, 183 bushels/acre -> 10,000 kg/ha or 1700 W/acre. Stover fraction from Iowa State Univ. Extension Fact Sheet BL-112. World average efficiency from USDA estimates from 2010. (Note that wheat is less than corn)*

# Average land/person on Earth is 20,000 m<sup>2</sup>

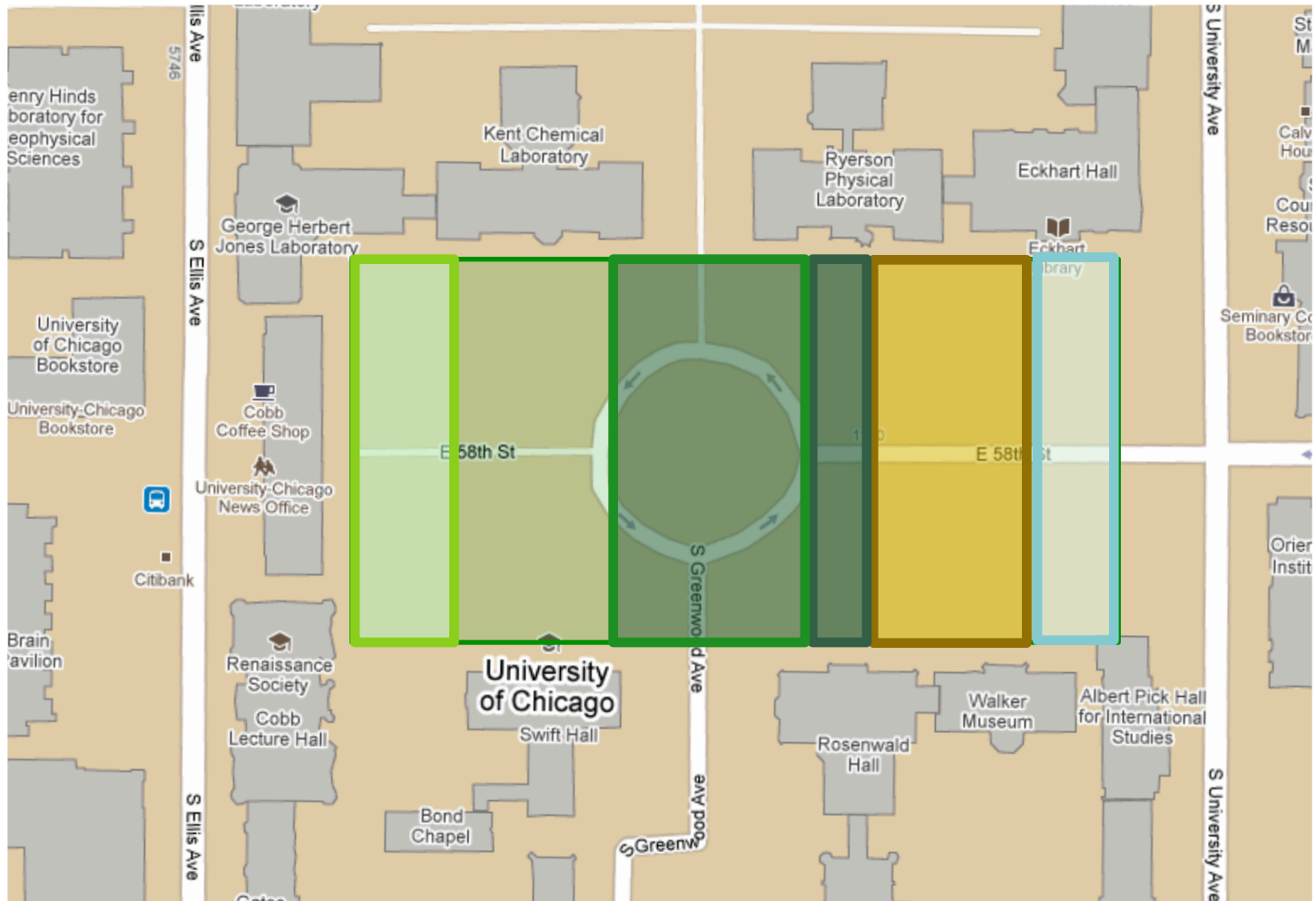
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Equivalent to University of Chicago Quadrangle

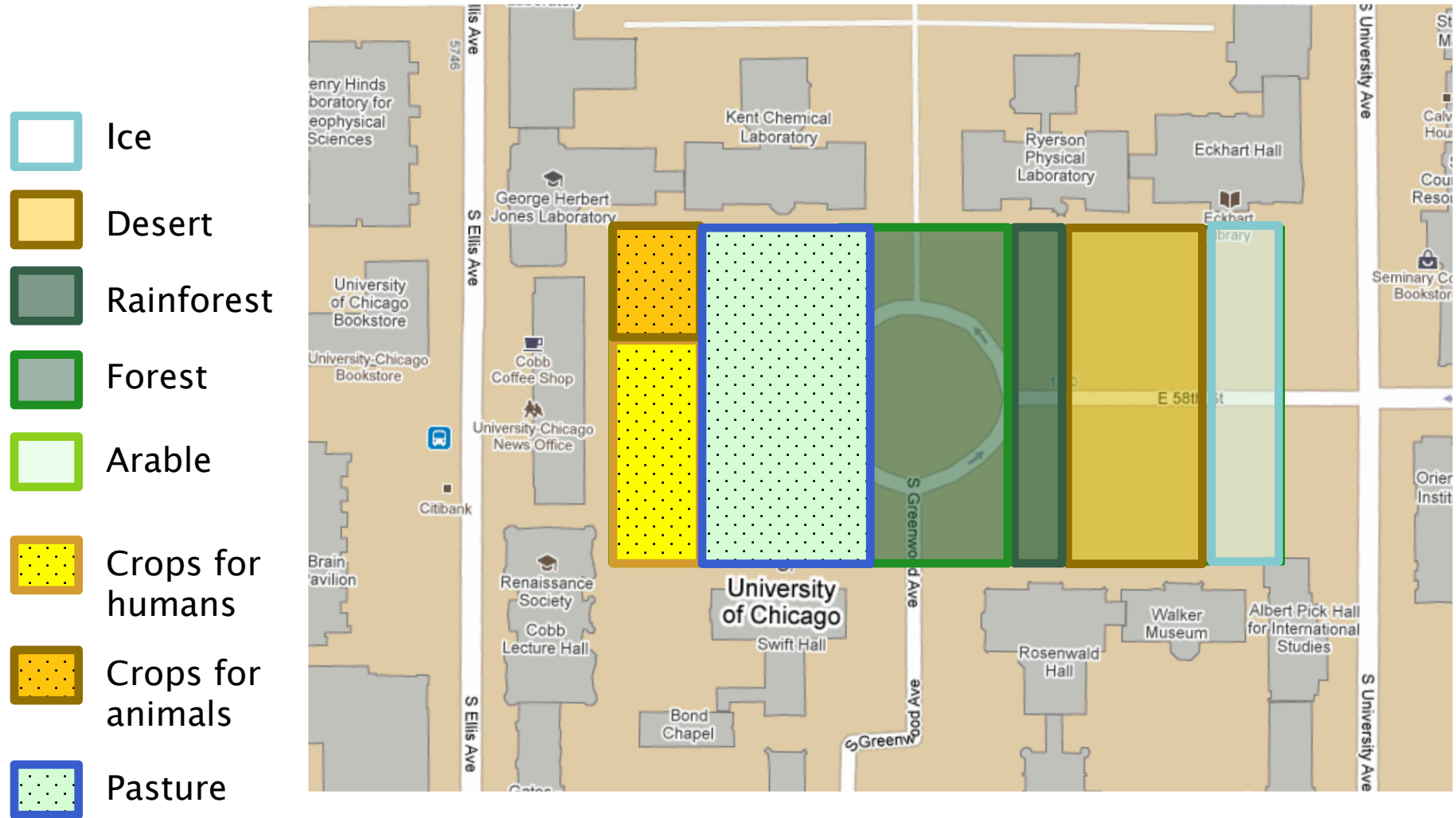
# Average land/person on Earth is 20,000 m<sup>2</sup>

- Ice
- Desert
- Rainforest
- Forest
- Arable



Equivalent to University of Chicago Quadrangle

# Appropriation of land for humans



38% of all land is used for agriculture (excluding forestry)

*Source: World Bank*

# Humans dominate the Earth's surface

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*Fractional use of:*

Earth's land surface  
area used for food     ~ 38%  
(*farm + pasture*)

Land NPP appropriated     ~ 30%



Farmland, Longsheng, China (*Flickr*)

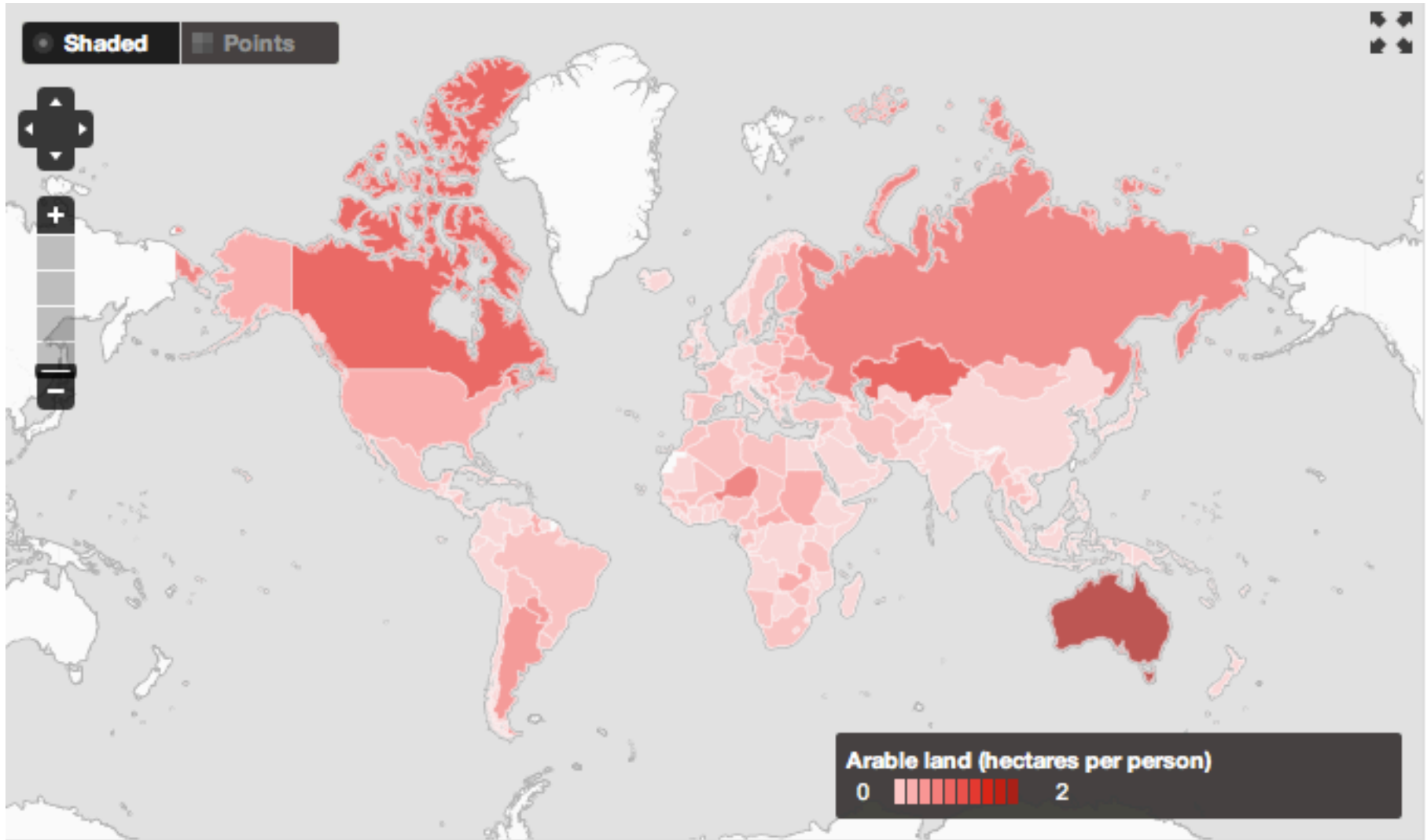


Farmland, Oklahoma (*OK Farm Report*)



Farmland, Washington (*Google*)

# Arable land /person is not equally distributed



**Data: actually cultivated land/ person.**

*Source: World Bank, for 2009–2013*



# Arable land /person is not equally distributed

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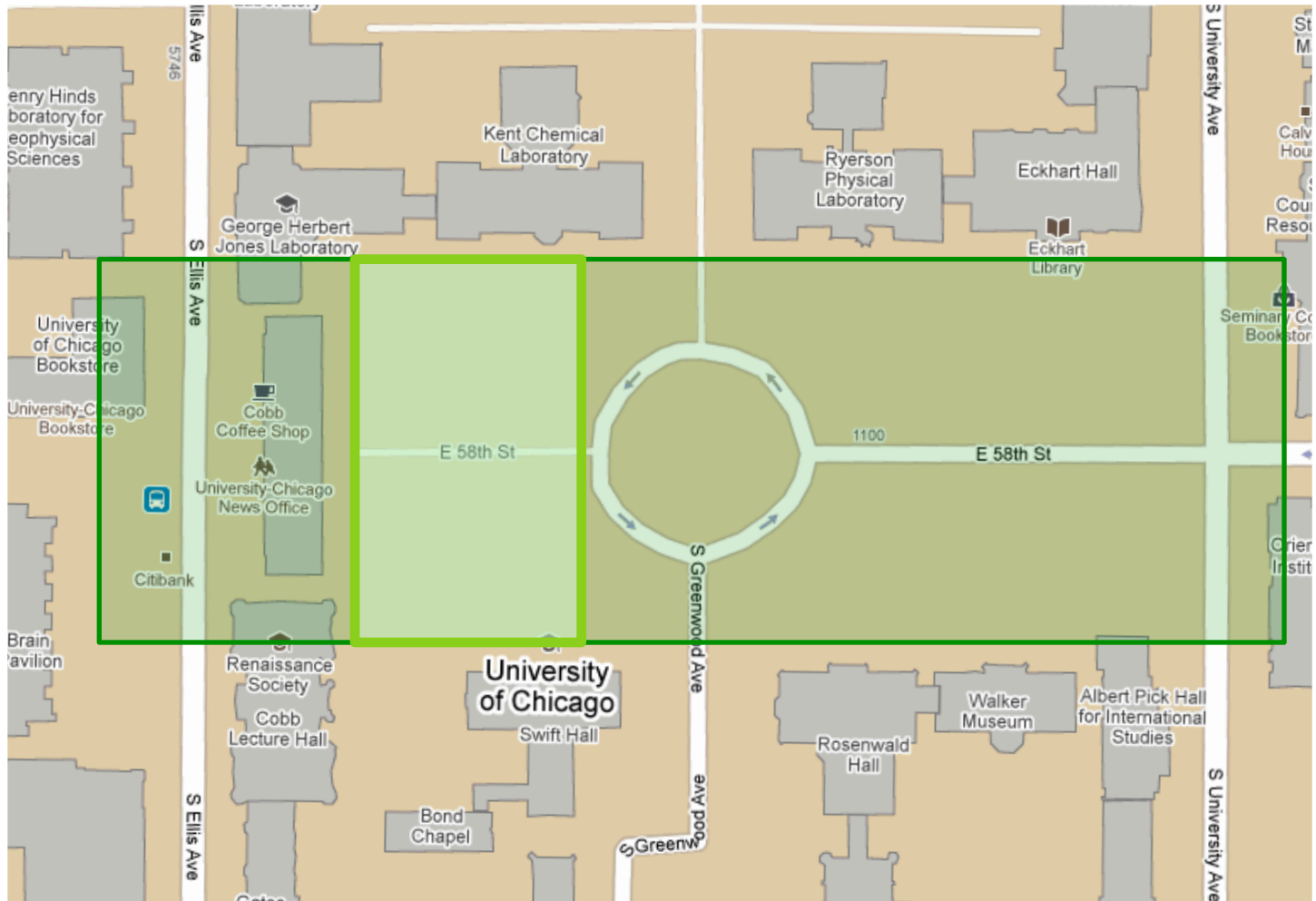
Arable/cap (m<sup>2</sup>) % of land

DRC	43,000	> 50
<i>used</i>	<i>2500</i>	<i>03</i>
Canada	15,000	05 (?)
Russia	8500	07
<b>U.S.</b>	<b>6000</b>	<b>19</b>
<i>World av.</i>	<i>2600</i>	<i>13</i>
Saudi Ar.	1400	02
India	1400	49
Rwanda	1200	46
China	1100	15
Bang.	500	55

unused land in poor DRC and low arable land/person in rich China produces “neo-colonial” pressure – foreign ownership or lease of land

Sources: various internet, unverified. Note that some sources consider “arable” to mean “potentially cultivated” and others to mean “actually cultivated”


# Average land/person in U.S. is 30,000 m<sup>2</sup>



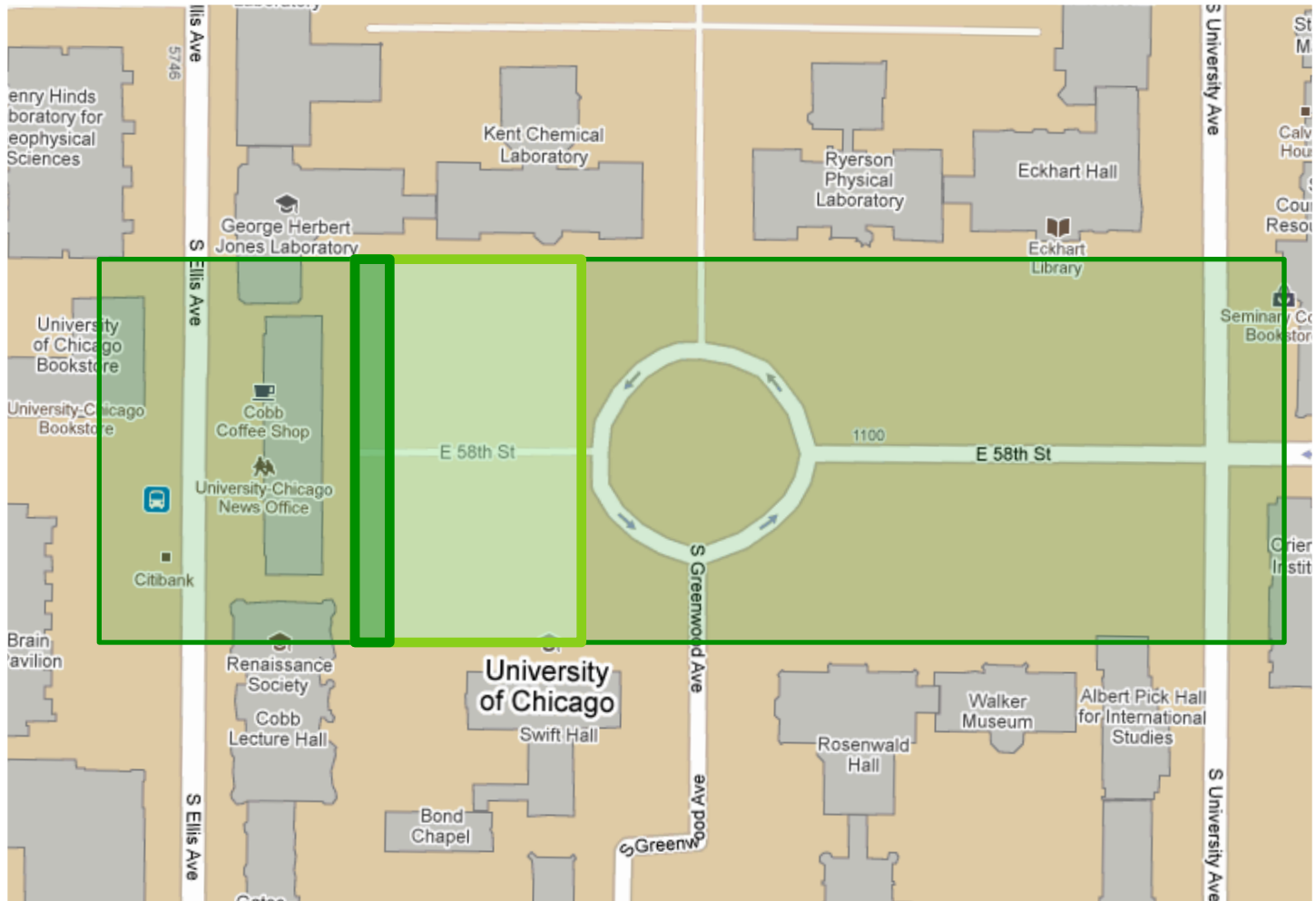
 U.S. arable

U.S. land/person is larger than world average,  
and higher fraction of that land is arable

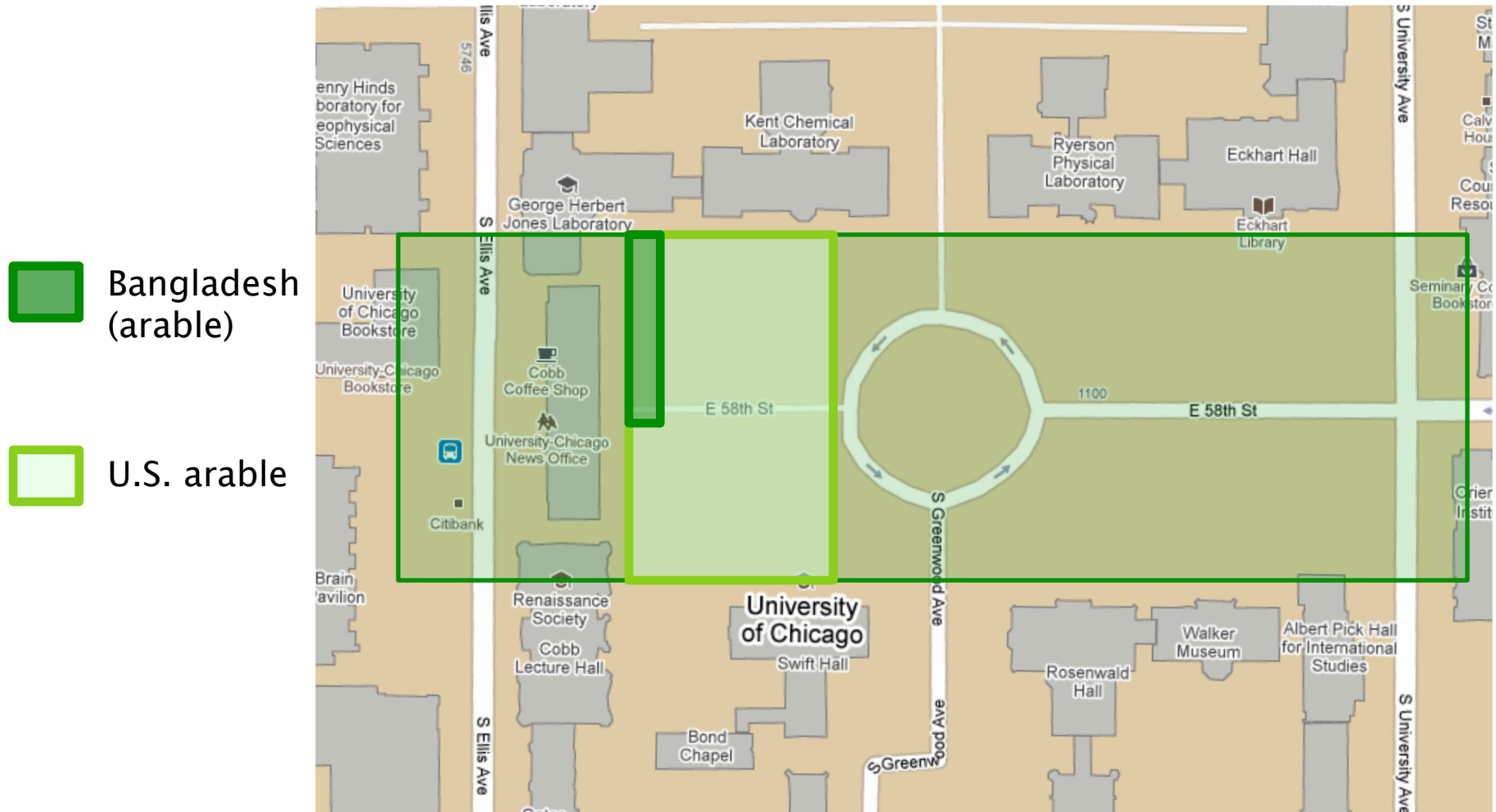
# Bangladesh land/person is 1/30<sup>th</sup> that of U.S.

 Bangladesh (total)

 U.S. arable



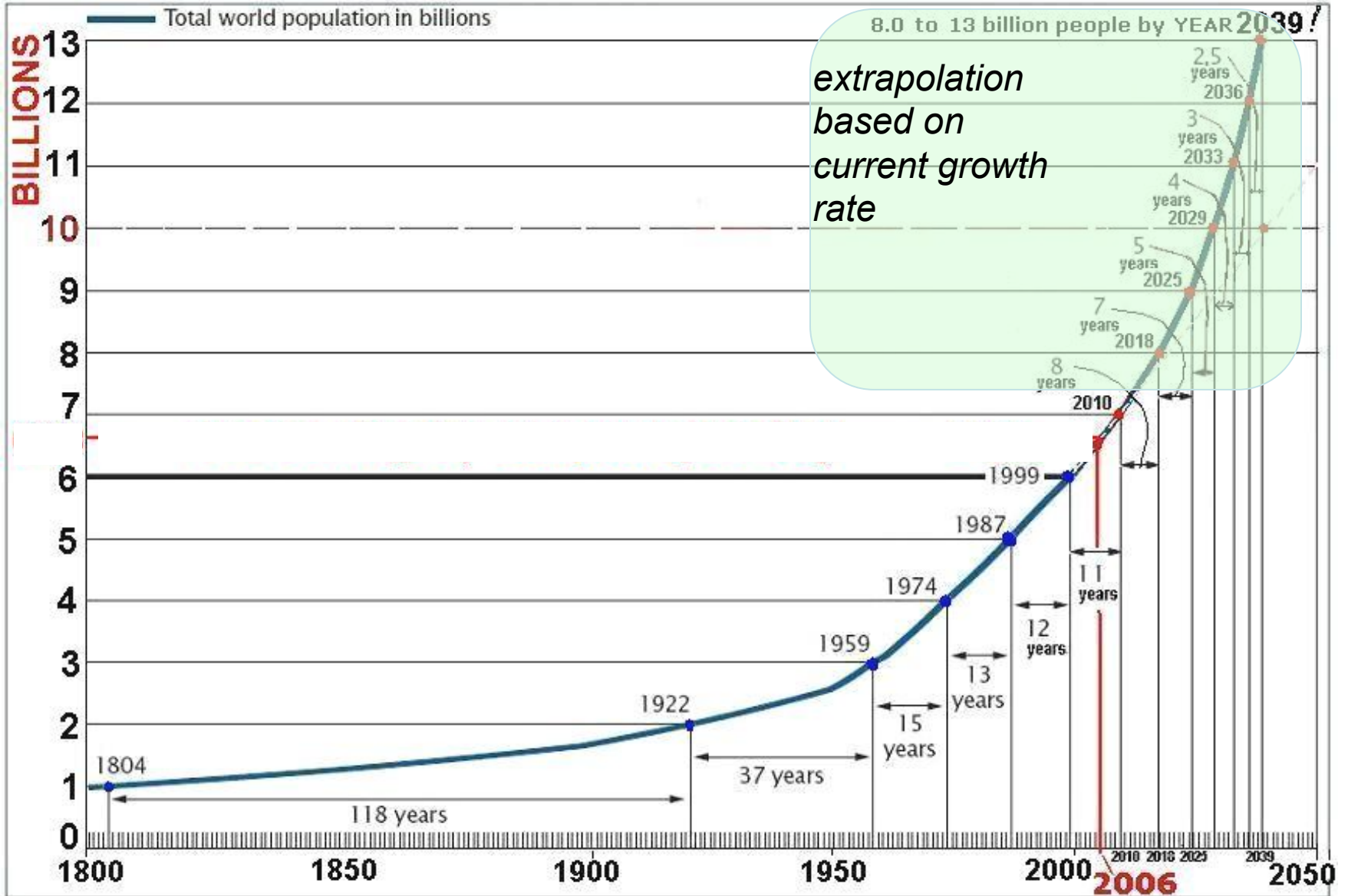
# Arable land/cap. in Bangladesh too low to feed people



.. fraction of arable land in Bangladesh is high, but area/person is so small that country must import food

# World population growth rate now 1.1%/year

*doubling time is ~ 60 years, x3 growth 1950-present*



# Agricultural dilemma

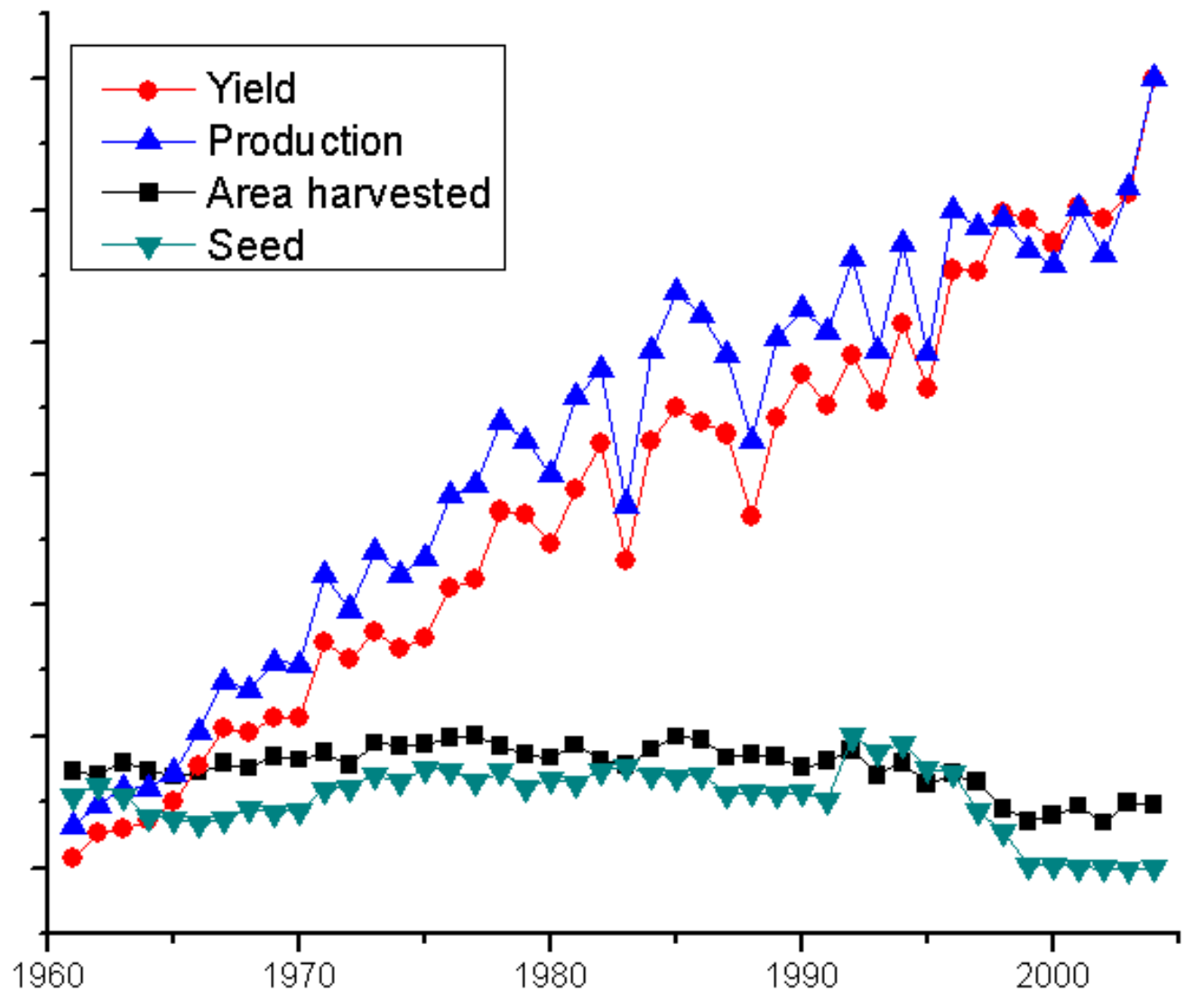
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How is it that we seem to be at present magically at the maximum number of people that can be reasonably supported?

*seems statistically unlikely...*

# Green Revolution: steep rise in yields since 1950

Total world production of coarse grain, 1961-2004



Source: FAO

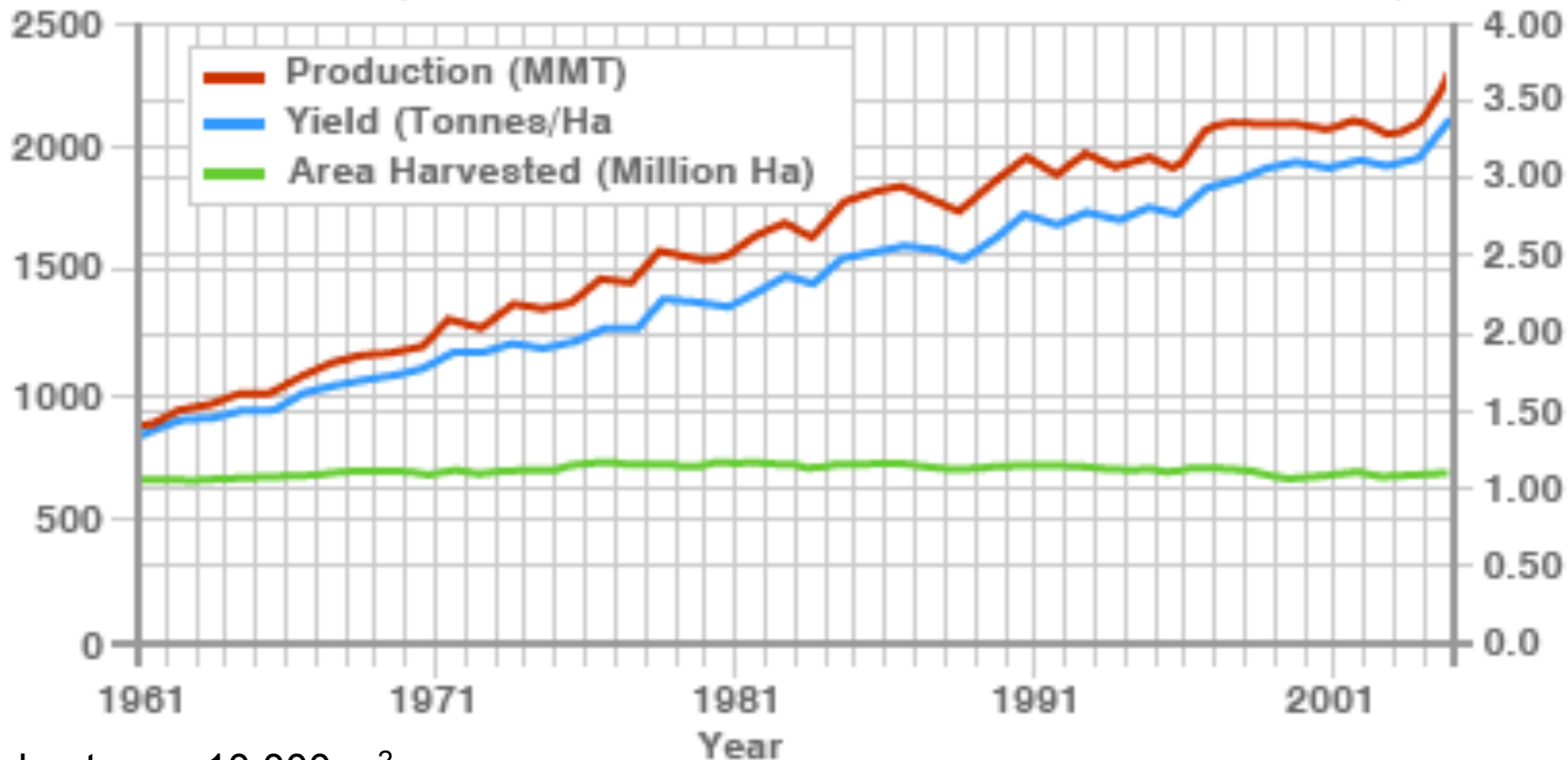
# Green Revolution: 3 x rise in global ave. yield compensated for 3 x rise in population

*Without that yield increase people would likely be hungry now  
Note that land usage is nearly flat - gains are from yield*

## WORLD CEREALS PRODUCTION AND YIELDS

Million metric tonnes / million hectares

Tonnes / hectare



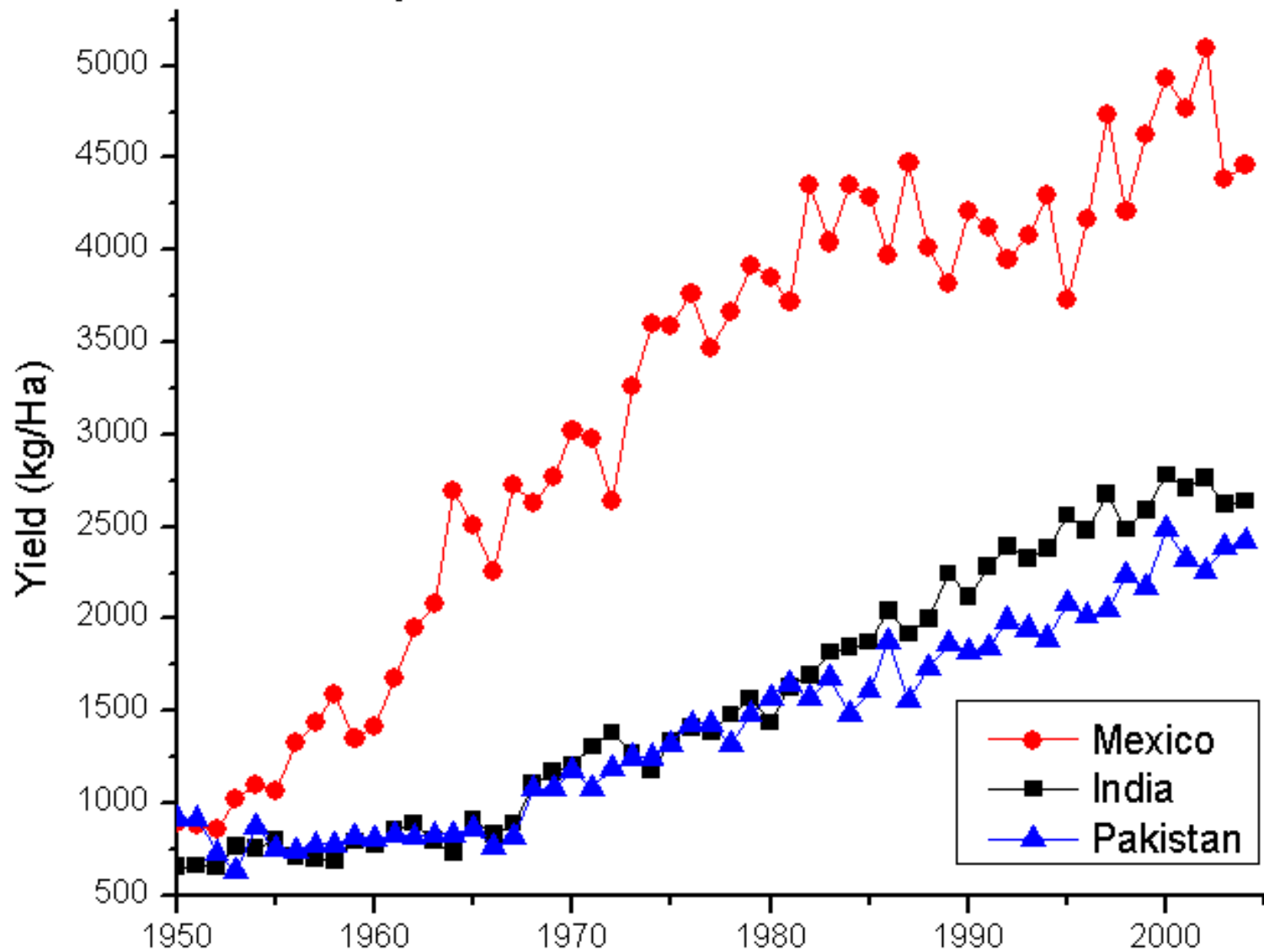
1 hectare = 10,000 m<sup>2</sup>

SOURCE: UN Food and Agriculture Organization



# Yield rises vary by country

Wheat yields in selected countries, 1950-2004



Source: FAO

# Green Revolution: 3x yield increase

Prevented hunger, but at cost in \$ and energy

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Norman Borlaug, 1914-2009  
born Iowa, college U. Minn.  
Nobel Peace Prize 1970

*Image: Associated Press, 1970*



Fertilizer plant  
ammonia and urea production

*Image: Hyosung Power & Industrial Systems*

# Green Revolution: 3x yield increase

Prevented hunger, but at cost in \$ and energy

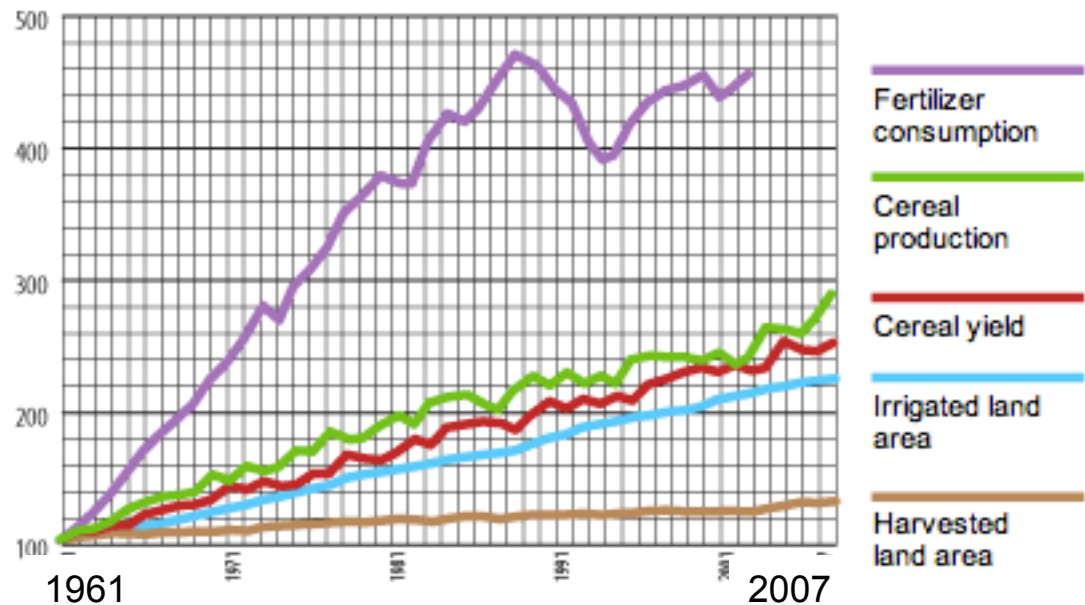
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Norman Borlaug, 1914-2009  
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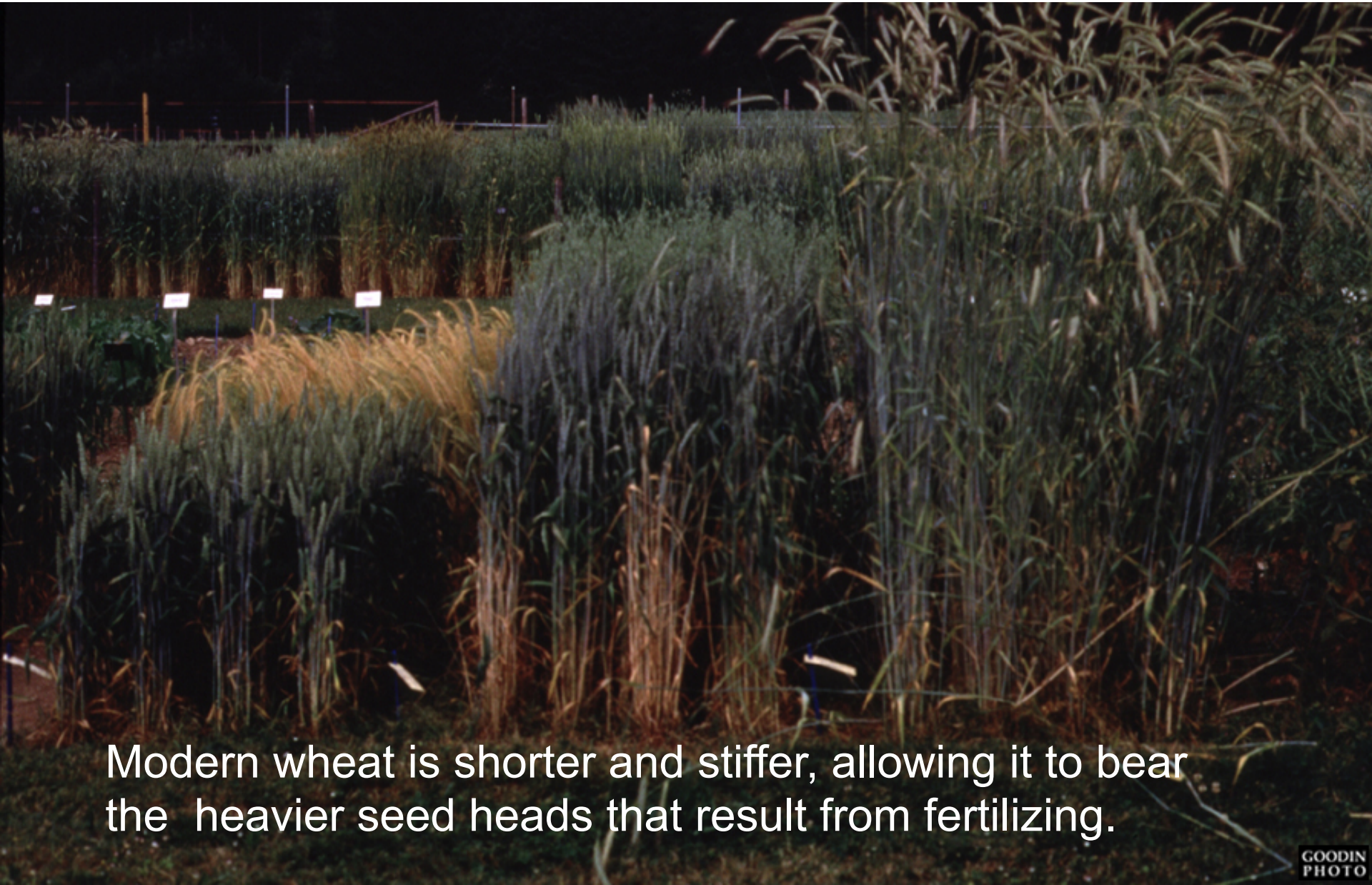
Indicators of global crop production intensification, 1961-2007  
Index (1961=100)



**Yields go with fertilizer use and irrigation**  
world fertilizer use quadruples  
during Green Revolution

Image: U.N. FAO

# Modern vs. ancient wheat



Modern wheat is shorter and stiffer, allowing it to bear the heavier seed heads that result from fertilizing.