GEOS 24705/ ENST 25500

U. Chicago

Apr 2015

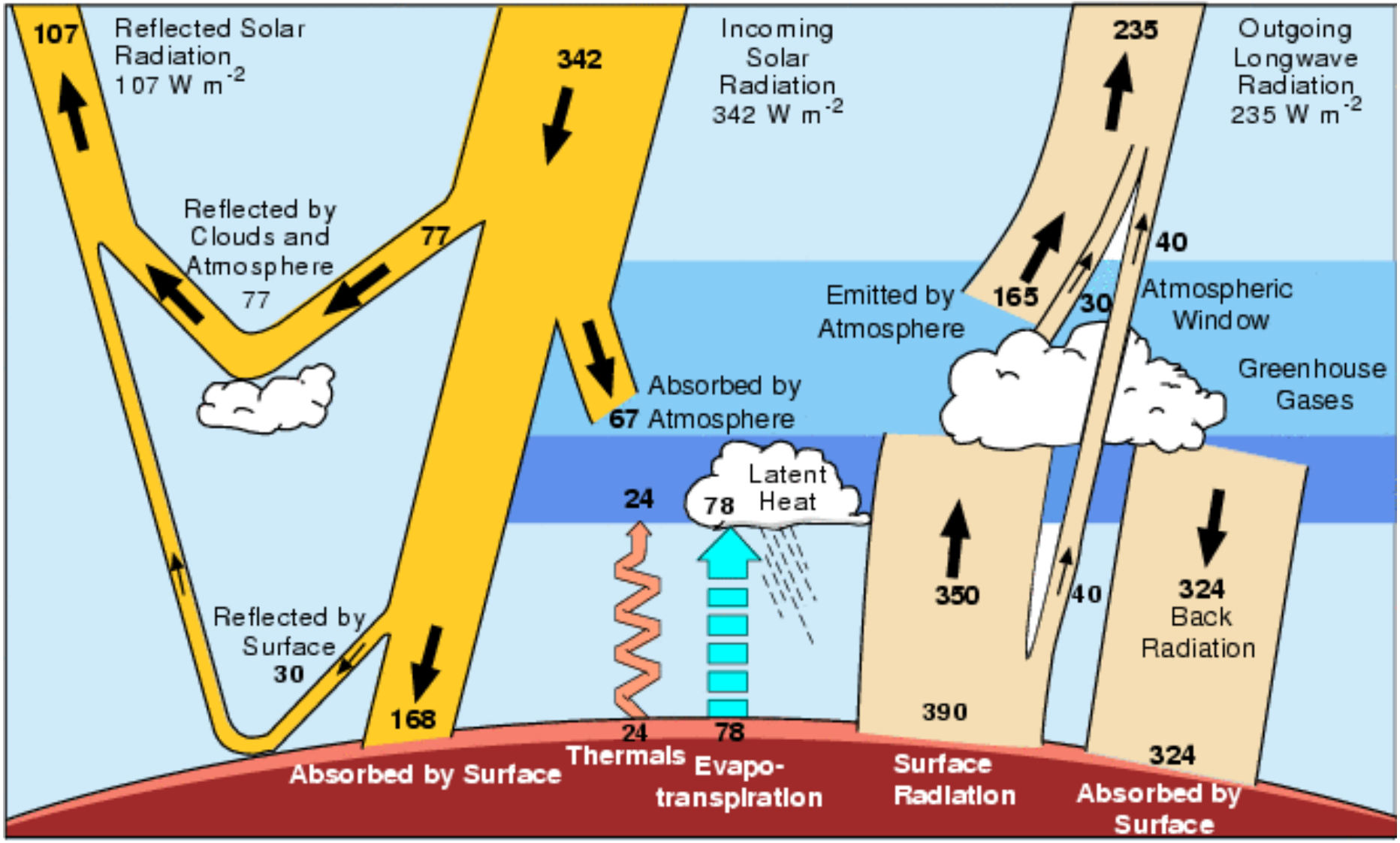
Lecture 2

Earth's energy flows II

Agenda for this lecture

- Earth's energy flows
- Estimation principles – lessons from quiz
- Definition of efficiency
- How big is the Earth?
- How much land does a person have?
- Agriculture and photosynthetic efficiency
- How much energy does human society need?

Global Heat Flows



Kiehl and Trenberth 1997

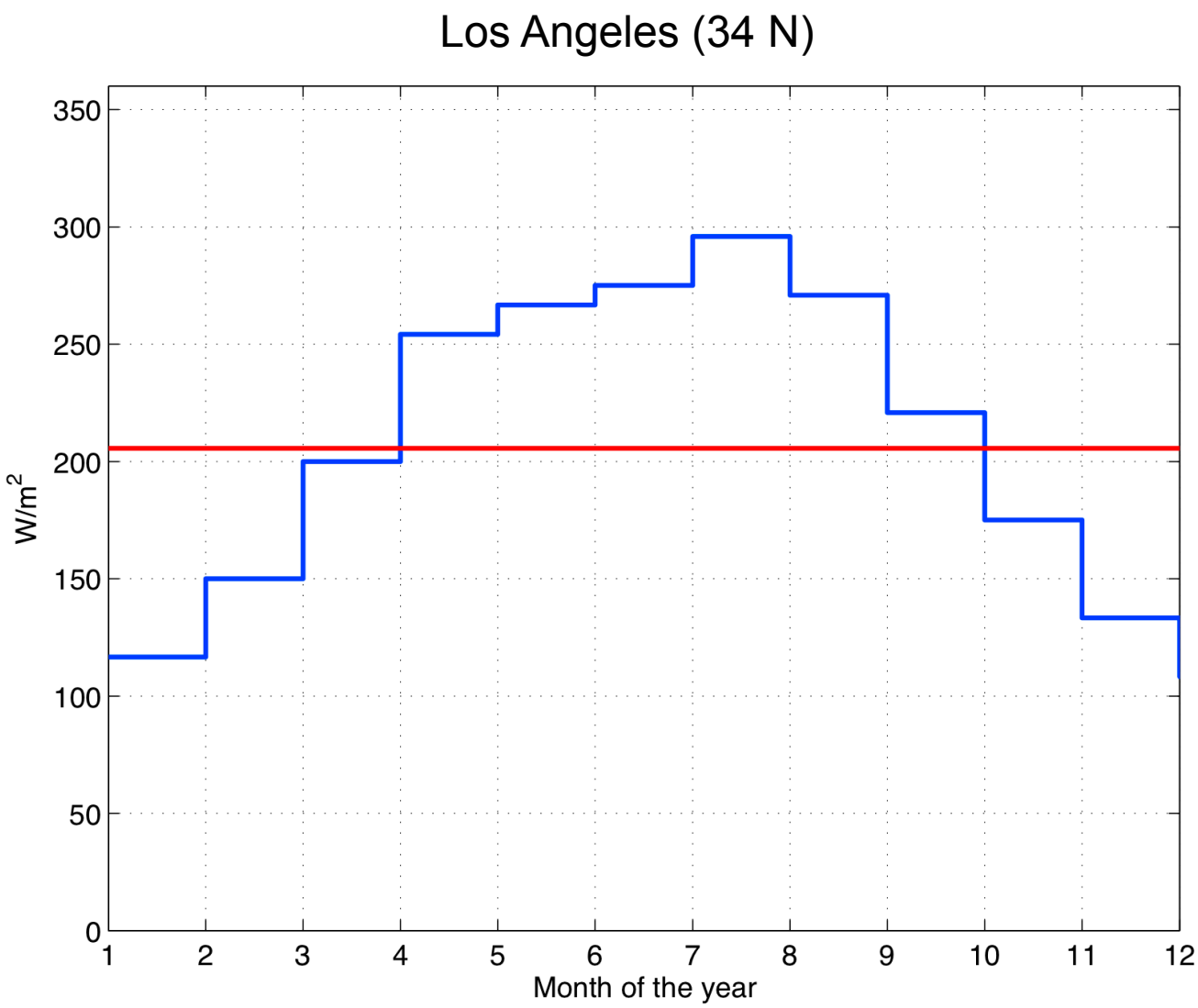


Figure 6: Average monthly solar irradiance in Los Angeles, latitude N33.93. Source: http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/-sum2/state.html, 30-year average of monthly solar radiation, 1961-1990.

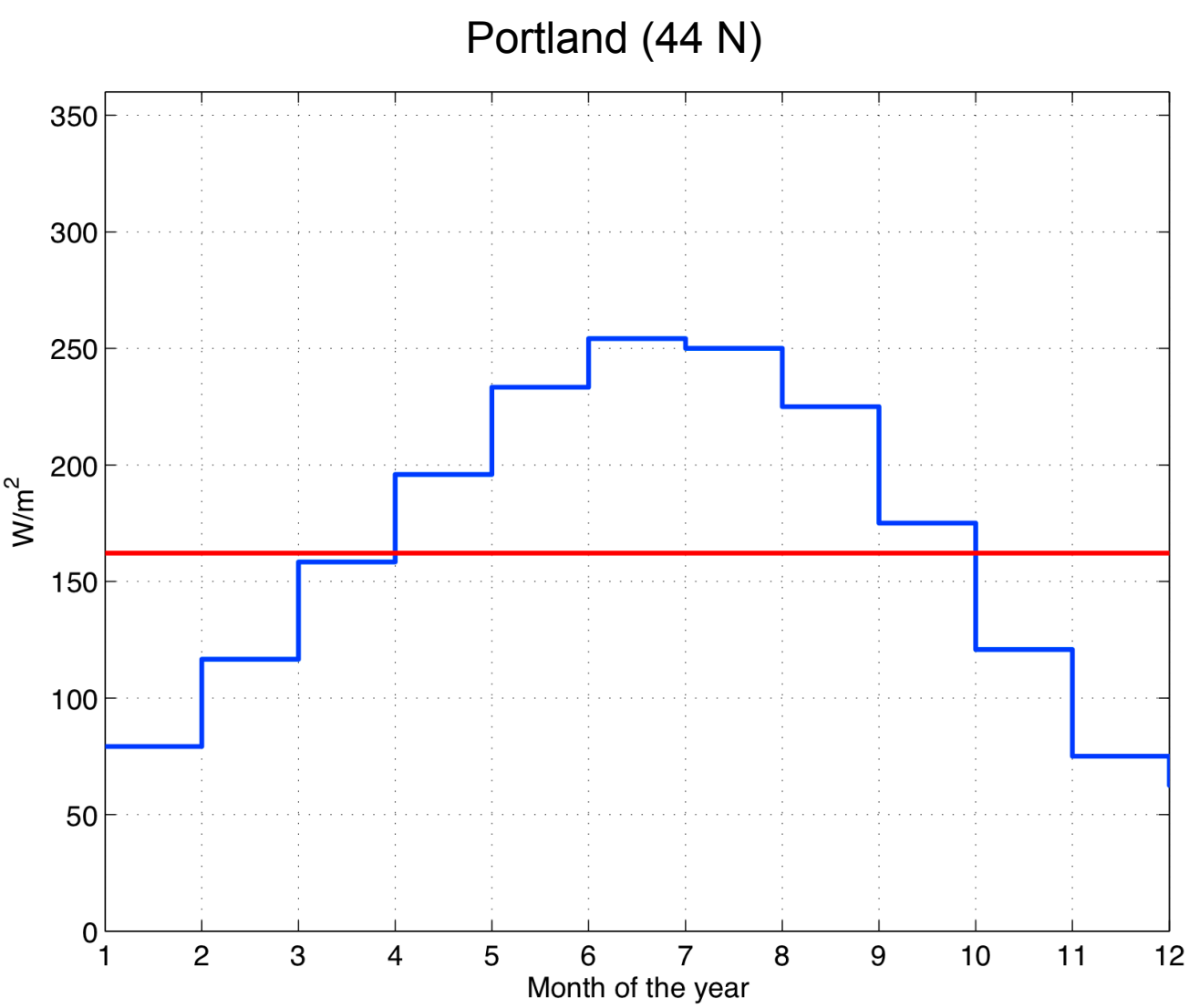


Figure 7: Average monthly solar irradiance in Portland, Maine, latitude N43.65. Source: http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/-sum2/state.html, 30-year average of monthly solar radiation, 1961-1990.

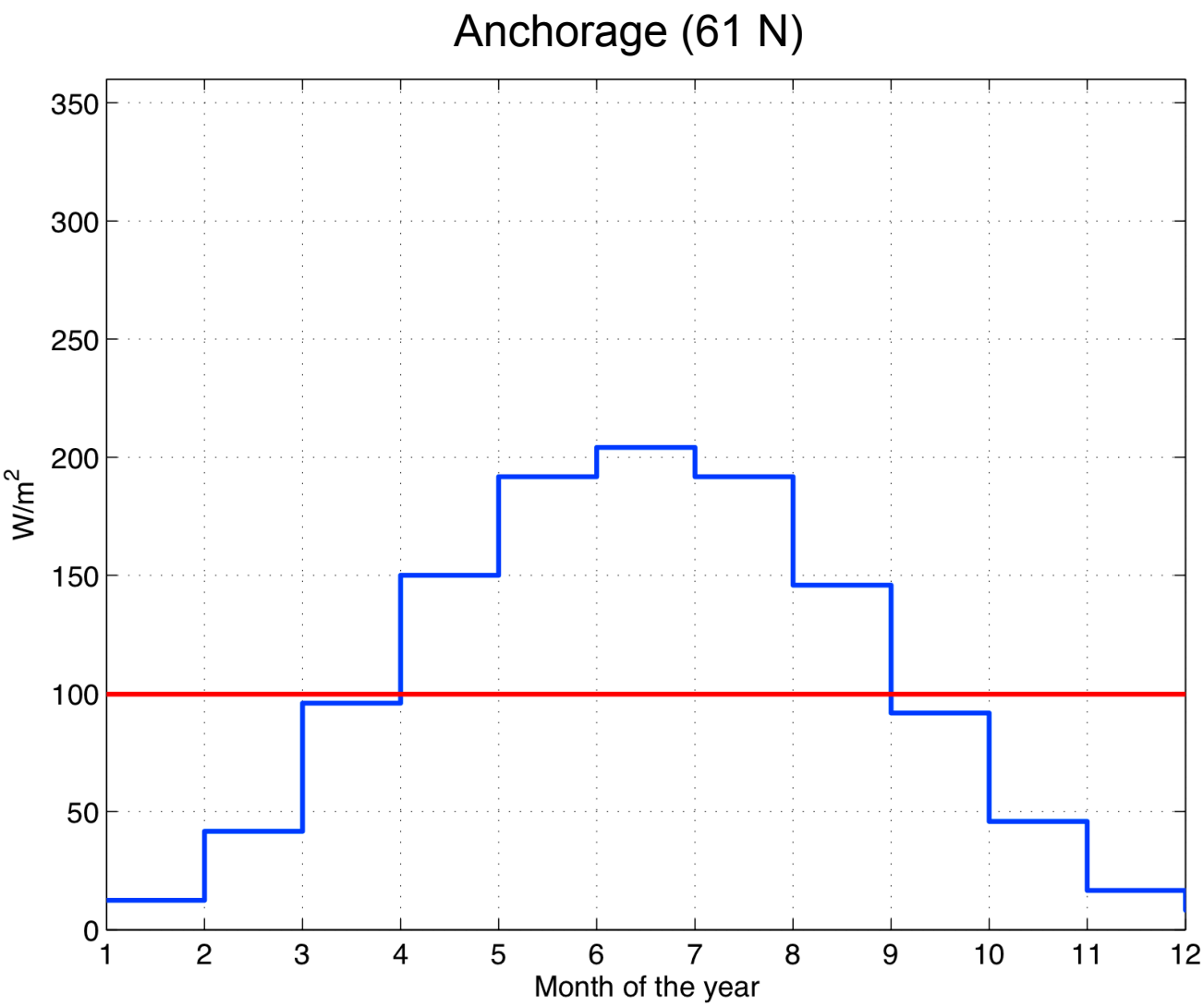


Figure 8: Average monthly solar irradiance in Anchorage, Alaska, latitude N61.17. Source: http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/-sum2/state.html, 30-year average of monthly solar radiation, 1961-1990. Note the change of scale relative to Los Angeles and Portland.

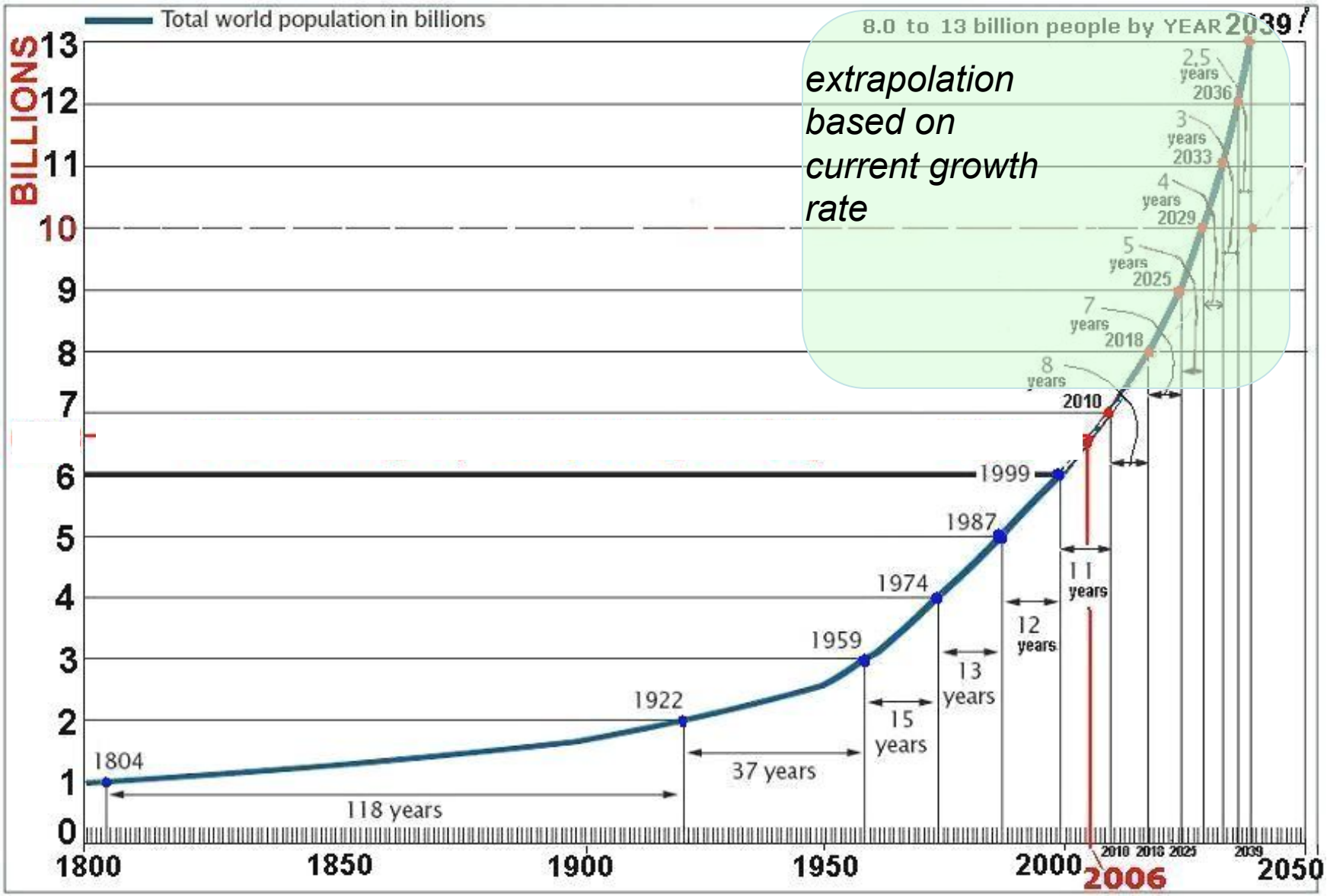
Photosynthetic efficiencies and energy flows

photosynthetic	ε_{photo}	W/m^2	
Rainforest	1%	2	
Good farmland, fert. corn	1%	2	
Good farmland, ave.	0.5%	1	
Land mean	~0.2%	0.4	
World mean ε_{photo}	~0.1%	0.2	
food	ε_{food}	W/m^2	
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)

Why do you care about photosynthetic efficiency?

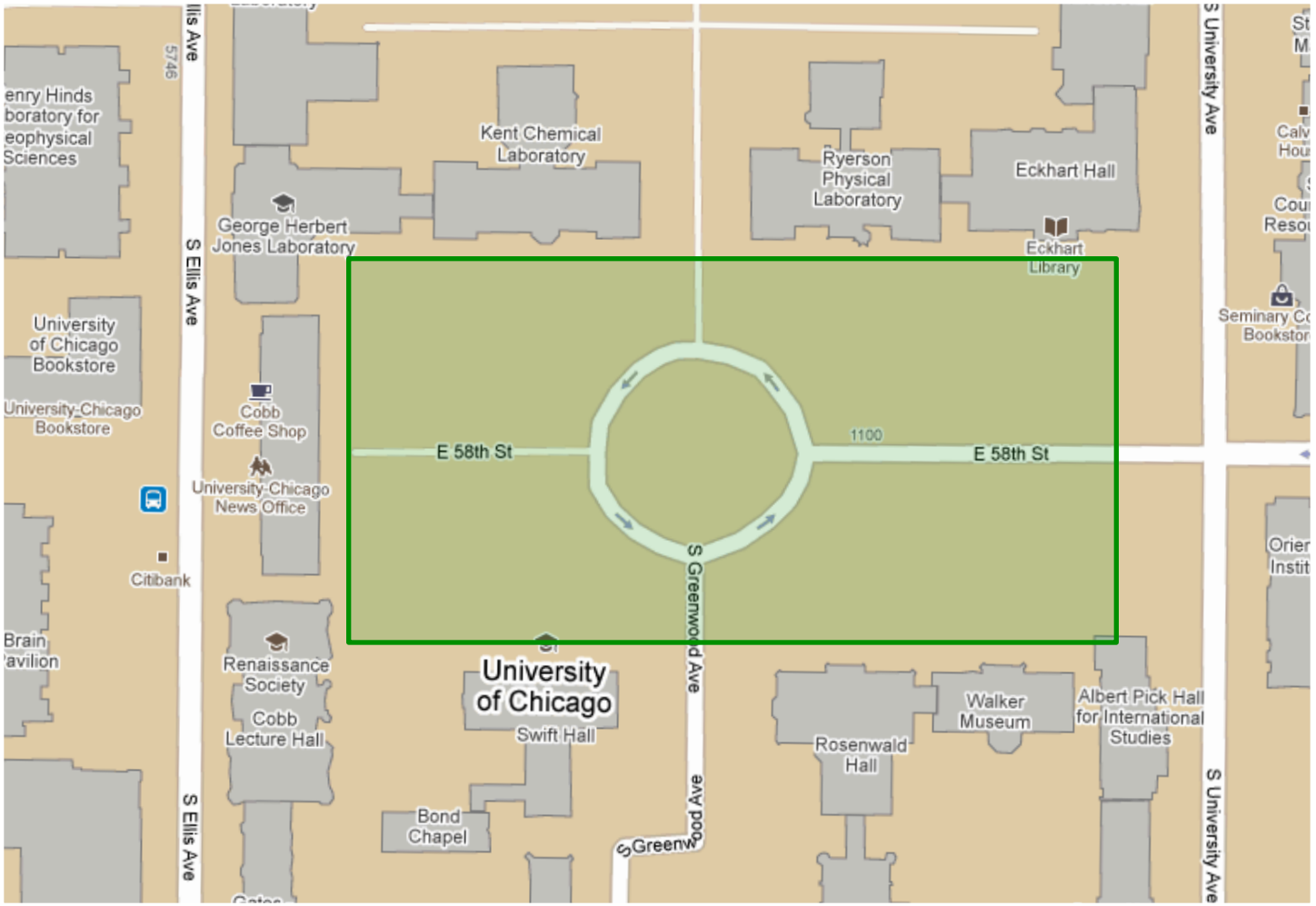
Because there are so many people on Earth that land is limiting



At present, ave. land/person on Earth ~ 20,000 m^2

What can you visualize that corresponds to that area?

Average land/person on Earth is 20,000 m²



Equivalent to University of Chicago Quadrangle

Average land/person on Earth is 20,000 m²

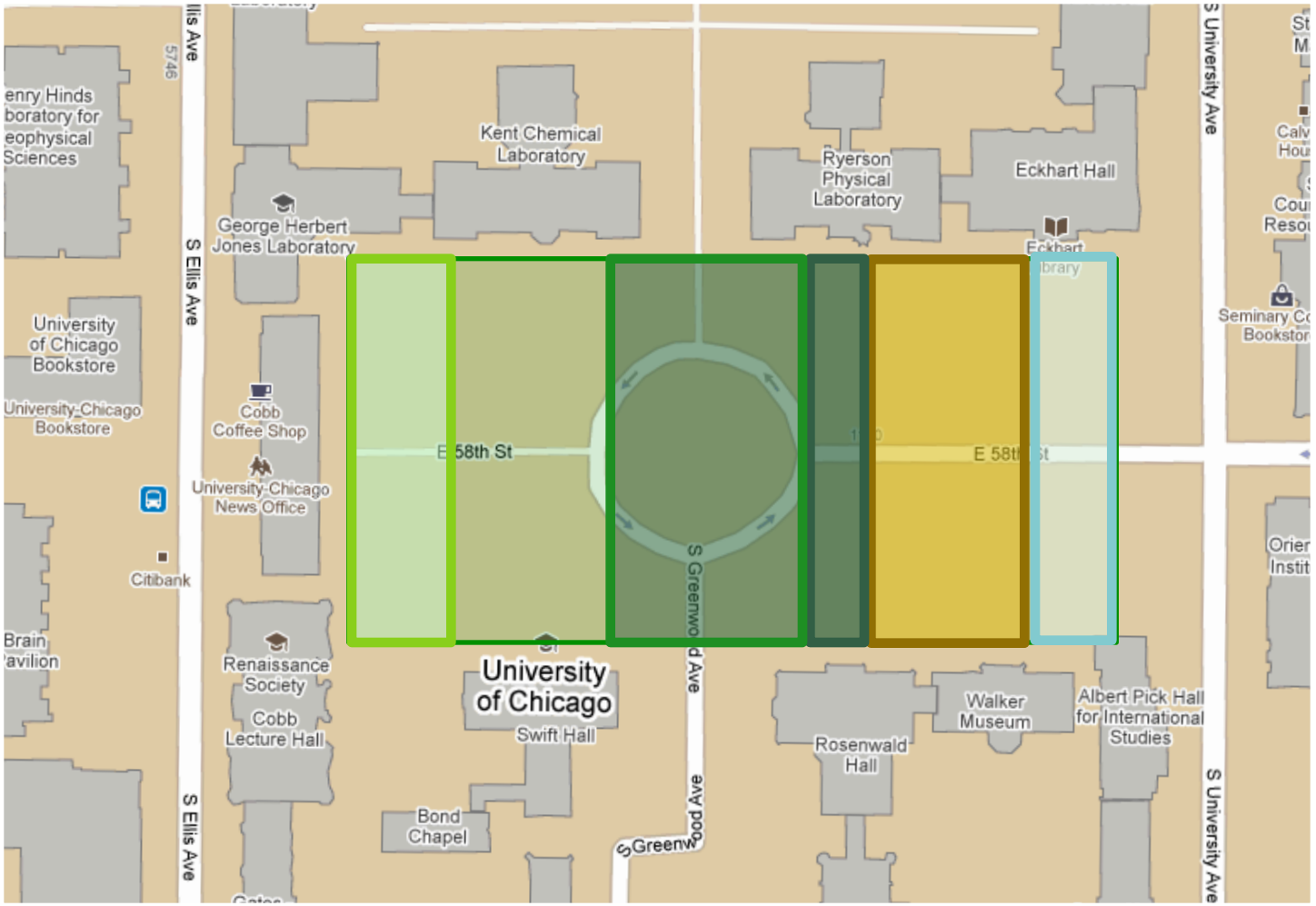
Ice

Desert

Rainforest

Forest

Arable

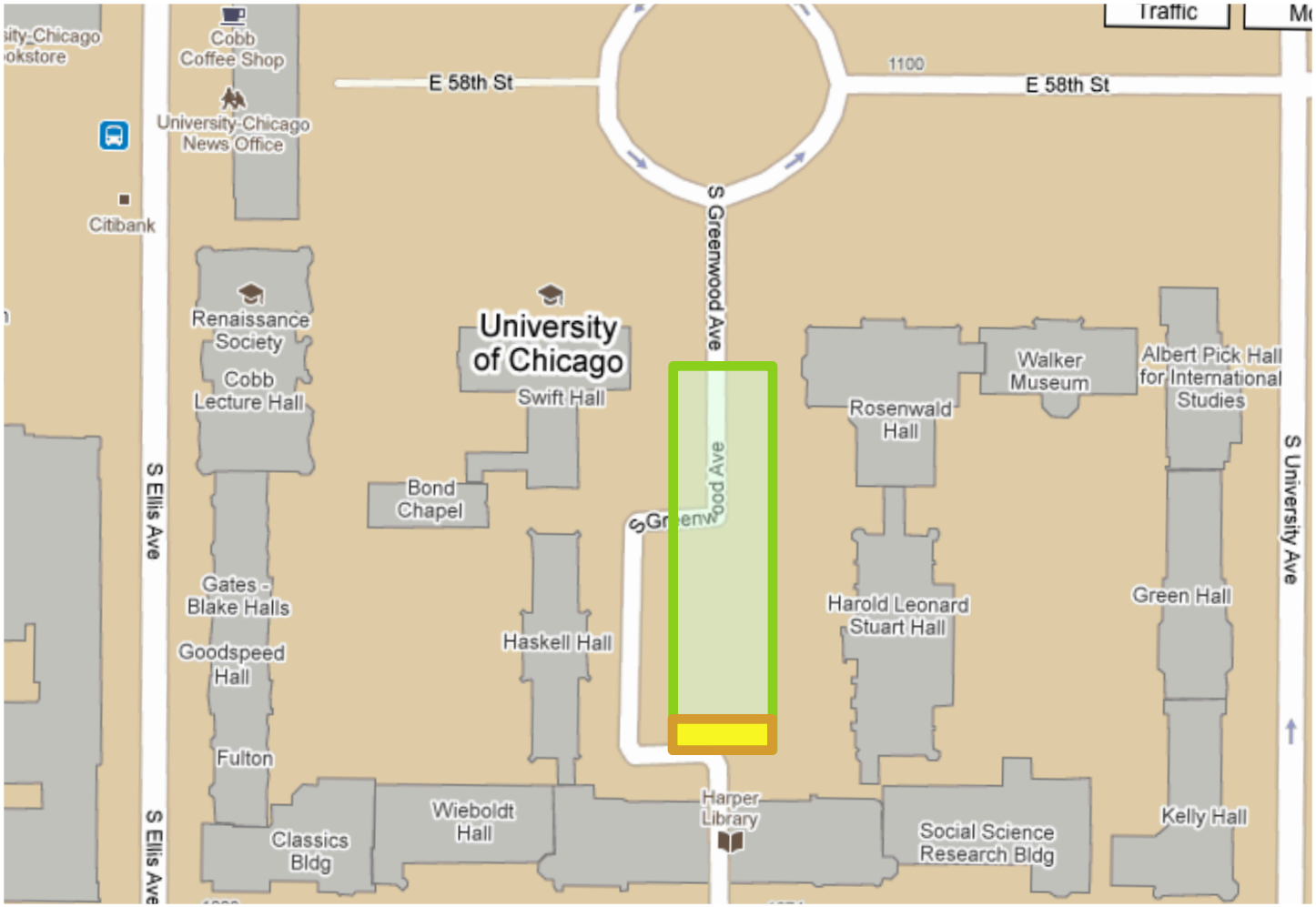


Equivalent to University of Chicago Quadrangle

Average arable land/person on Earth is ~2500 m²

Arable

Needed for food (U.S. corn only)

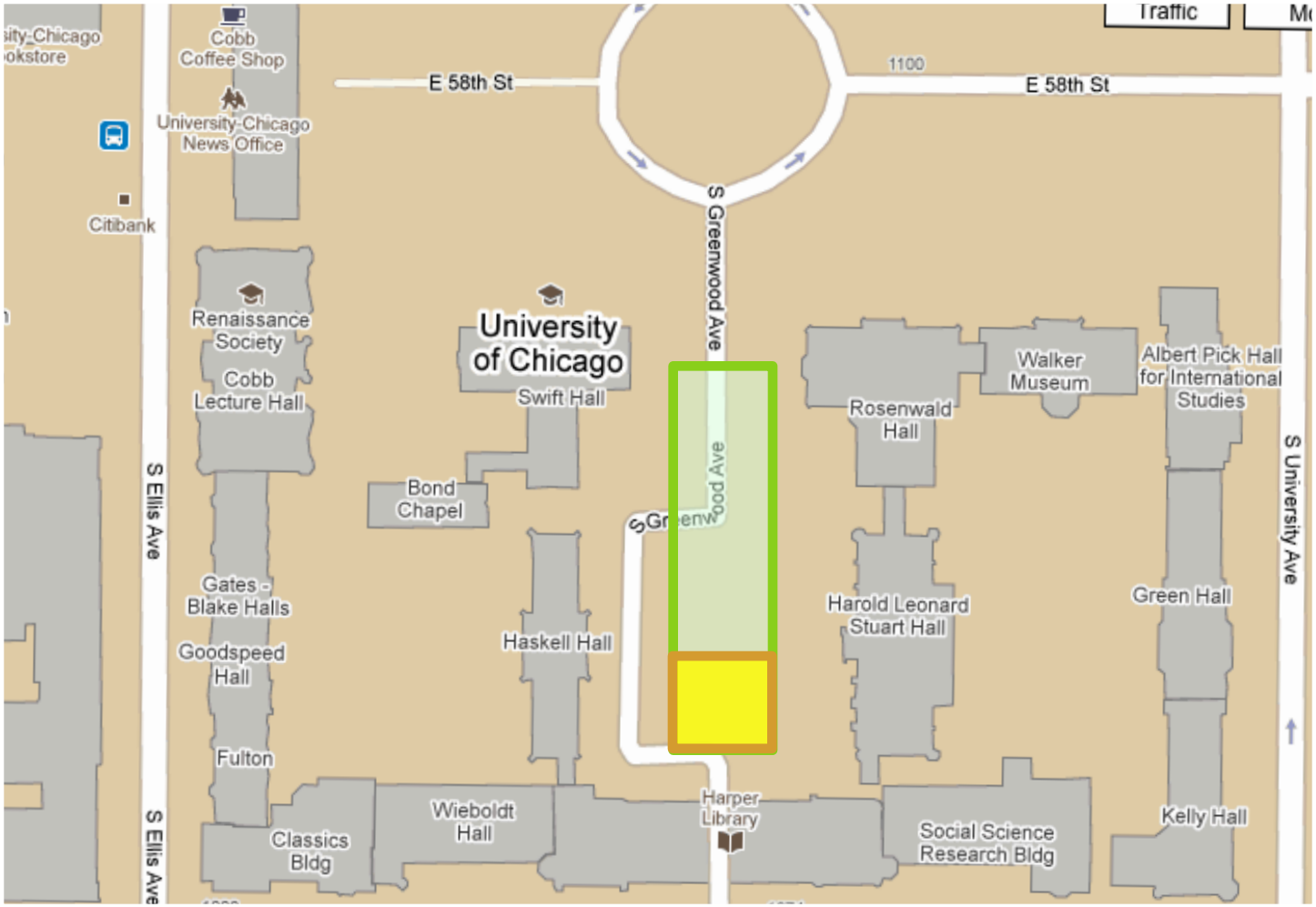


Equivalent to ½ of Harper Library Quadrangle

Average arable land/person on Earth is ~2500 m²

Arable

Needed for food (world av. cereal yield)

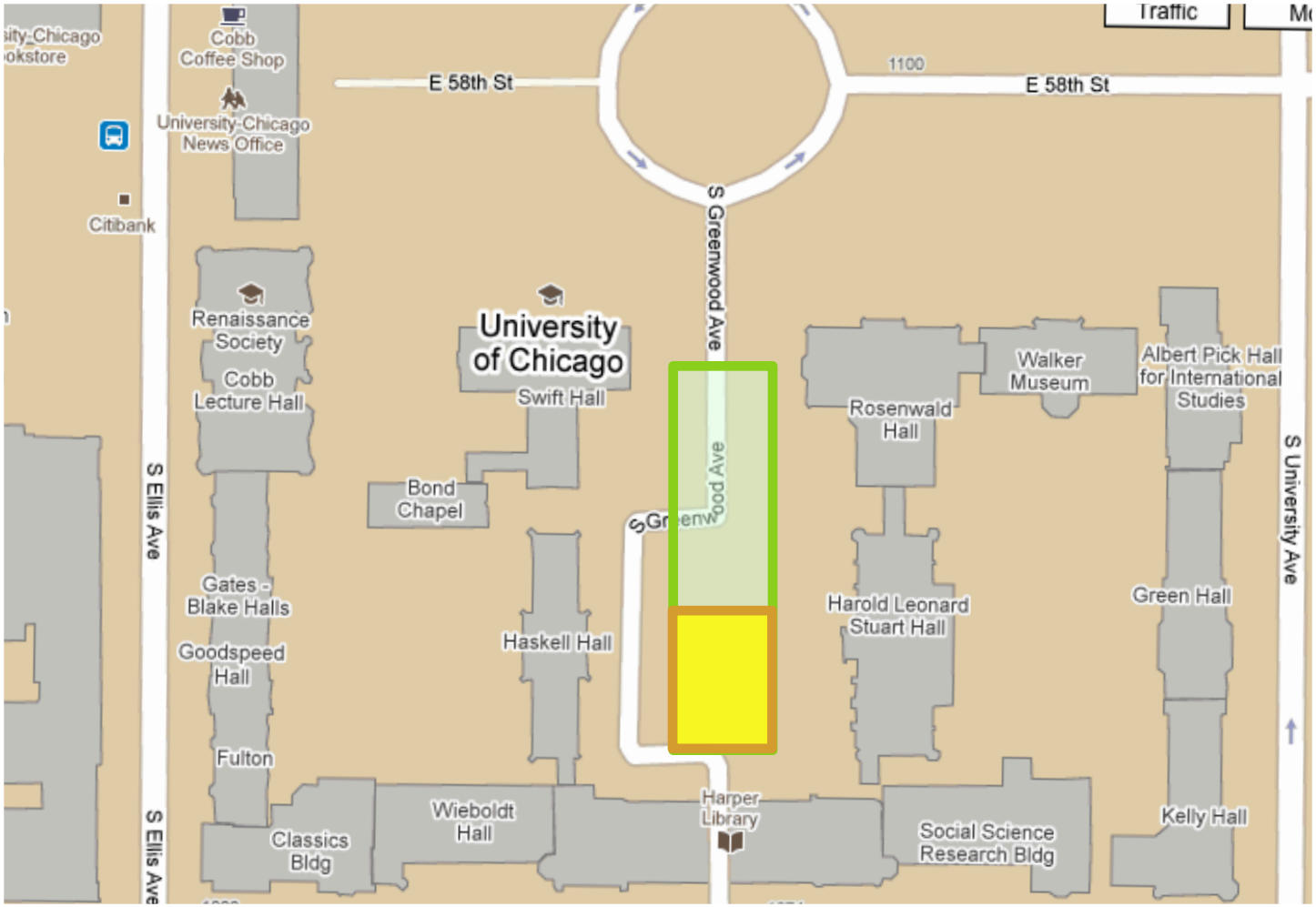


Safety factor of ~ 1/3 if all vegan + no wastage

Average arable land/person on Earth is ~2500 m²

Arable

Needed for food (world av. cereal yield, 1/3 wastage)

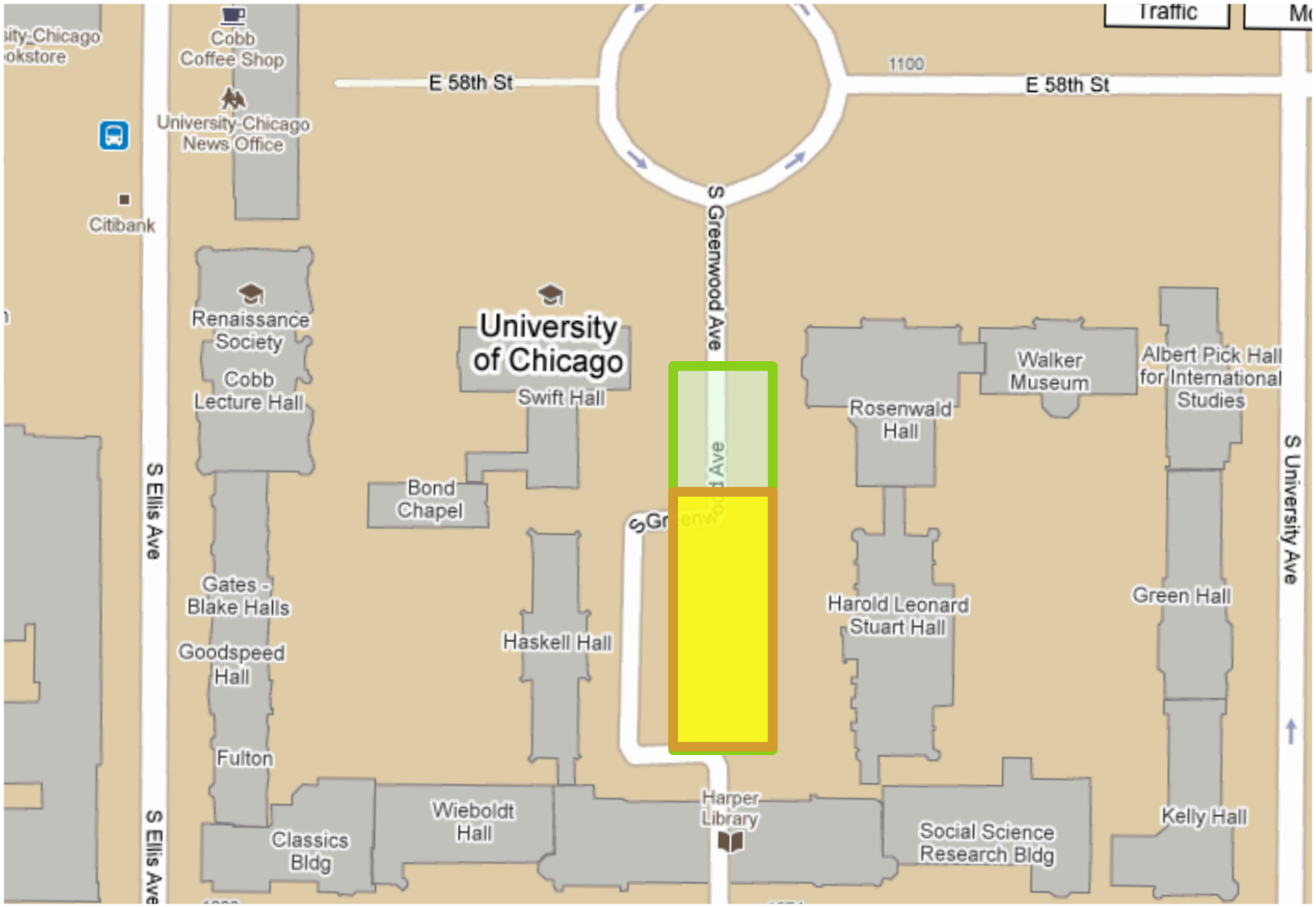


Safety factor < 1/3 given wastage

Average arable land/person on Earth is ~2500 m^2

Arable

Crops for humans



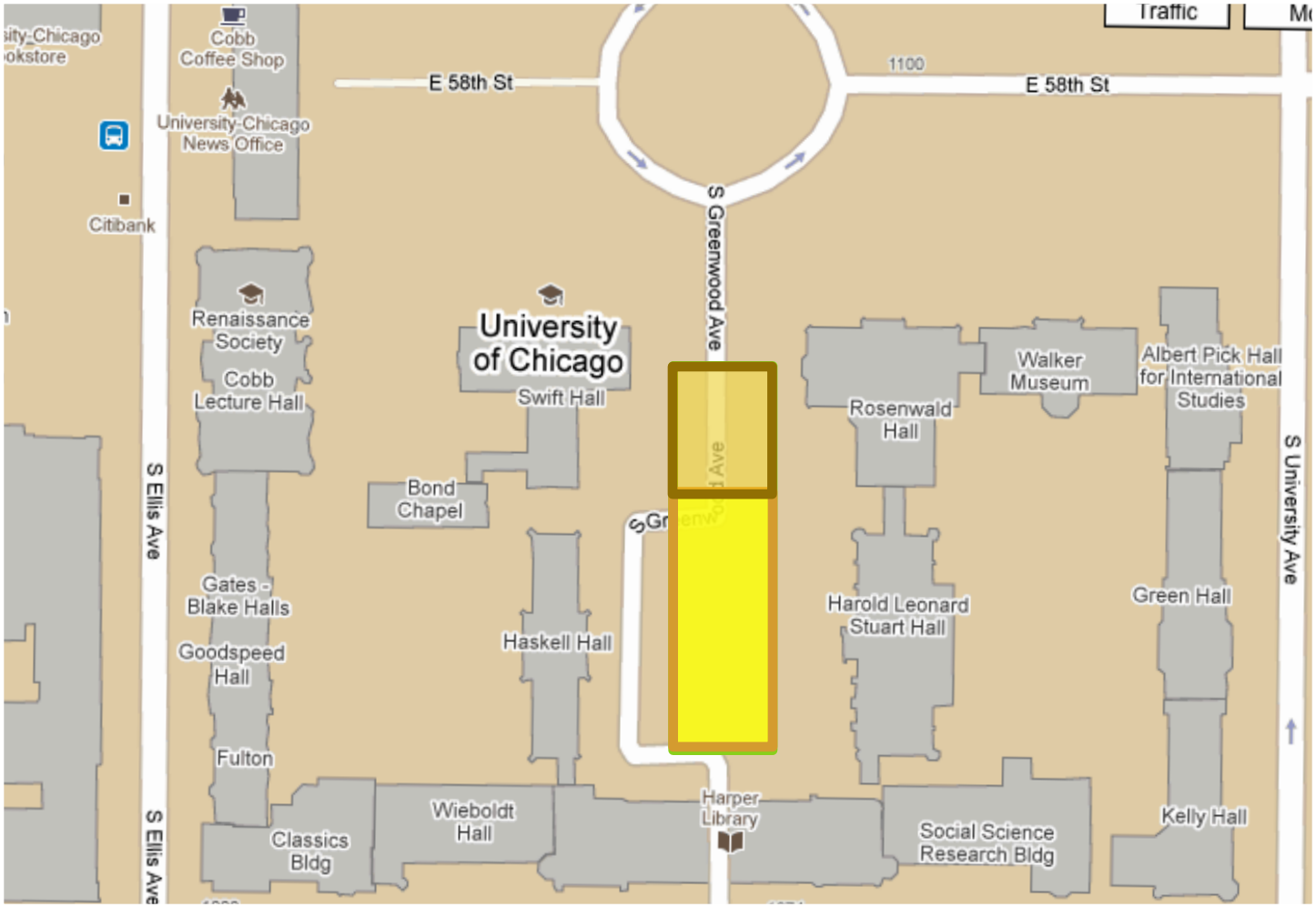
Actual crops for people take up 2x as much land – people eat more than 100 W and vegetable calorie yield is less than grain

Average arable land/person on Earth is ~2500 m²

Arable

Crops for humans

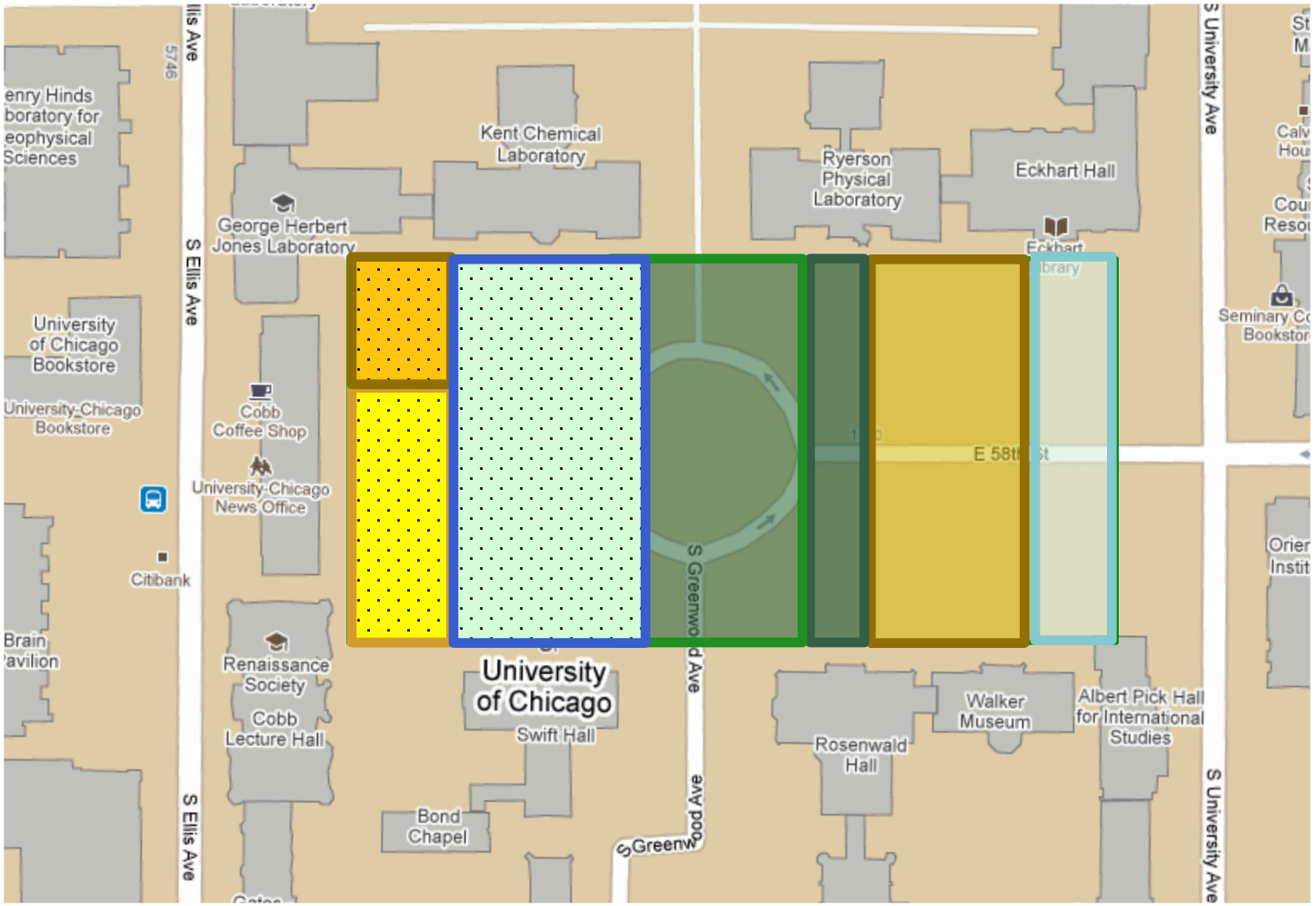
Crops for animals



Feed crops for livestock fill the rest: ~ 12% of Earth surface cultivated

Appropriation of land for humans

- Ice
- Desert
- Rainforest
- Forest
- Arable
- Crops for humans
- Crops for animals
- Pasture



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

Source: World Bank