Need quantitative data and analysis:

1) What is Earth's population & what are the trends?
2) What forces cause the population to rise?
3) What is Earth's carrying capacity?
4) What are the social, economic and environmental consequences of high population & rapid population growth?

Concepts:

Growth Rate

Fertility Rate

Replacement level: 2 kids/female = 1 for 1 replacement rate

But population can still grow- "momentum" in system

Momentum is reduced if inc. mother's age @ birth; e.g., prolong female education

Age sex pyramid = Graph of pop levels *vs*. age & gender

Developed nations: columnar or barrel shape

Developing nations: pyramid. Pop will greatly inc. even @ 1:1 replacement leve

Increased life expectancy in USA => Social Security Problem

Demographic transition

Hi B&D rates => Hi B, Low D rate => Low B & D rates

Low growth rate => Hi growth rate => Low growth rate

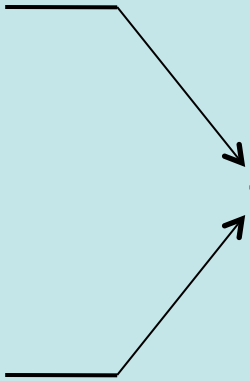
Transition can take >100 y

England 1800-1900AD (London 1750, 3/4 children died before age 5)

Mexico in transition now but has little time!

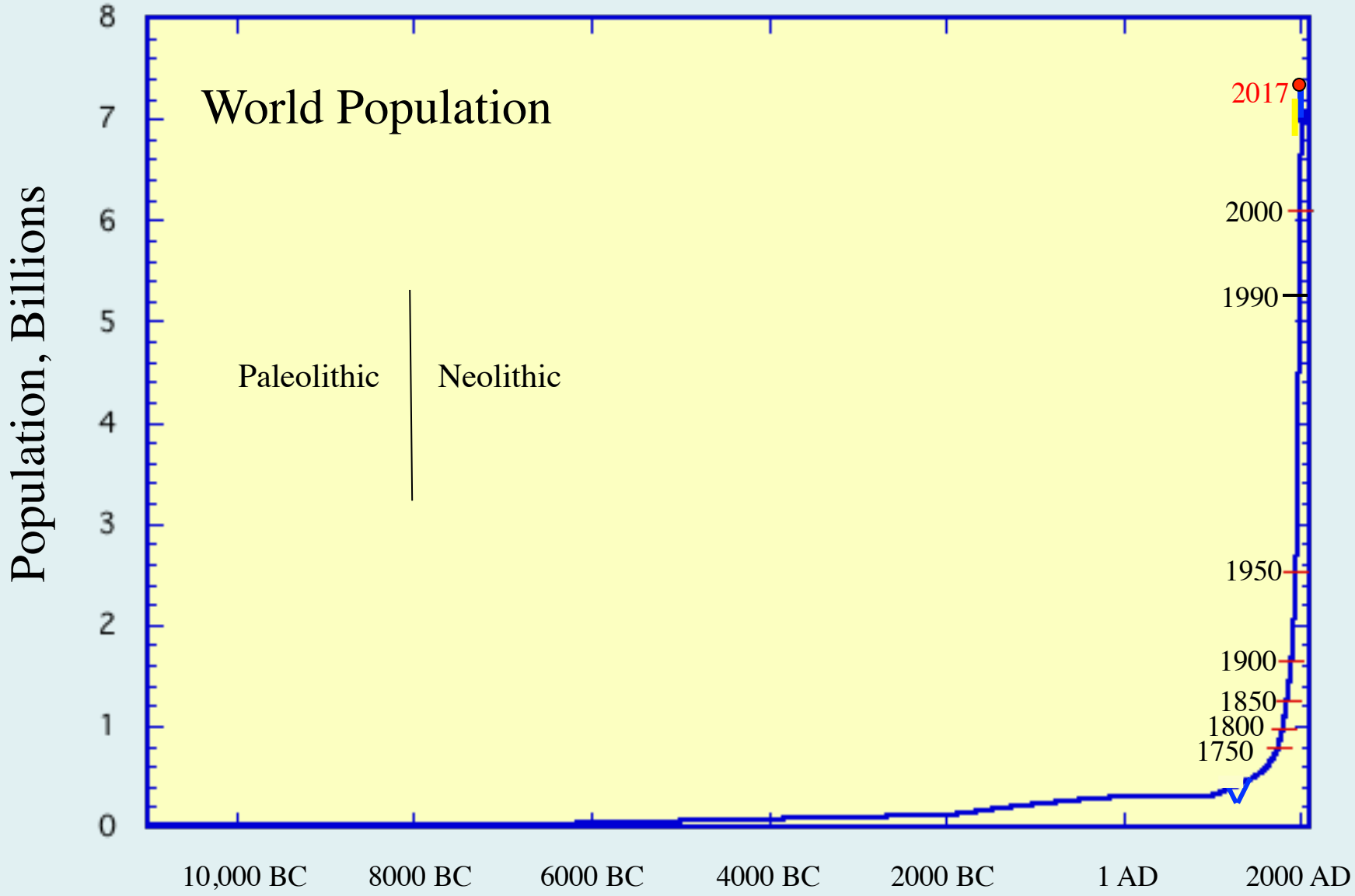
WORLD POPULATION

2/6/17	7,370,090,000
2/3/17	7,369,450,000
2/1/17	7,369,025,000
1/18/17	7,366,049,000
2000	6,096,300,000
1960	3,027,000,000

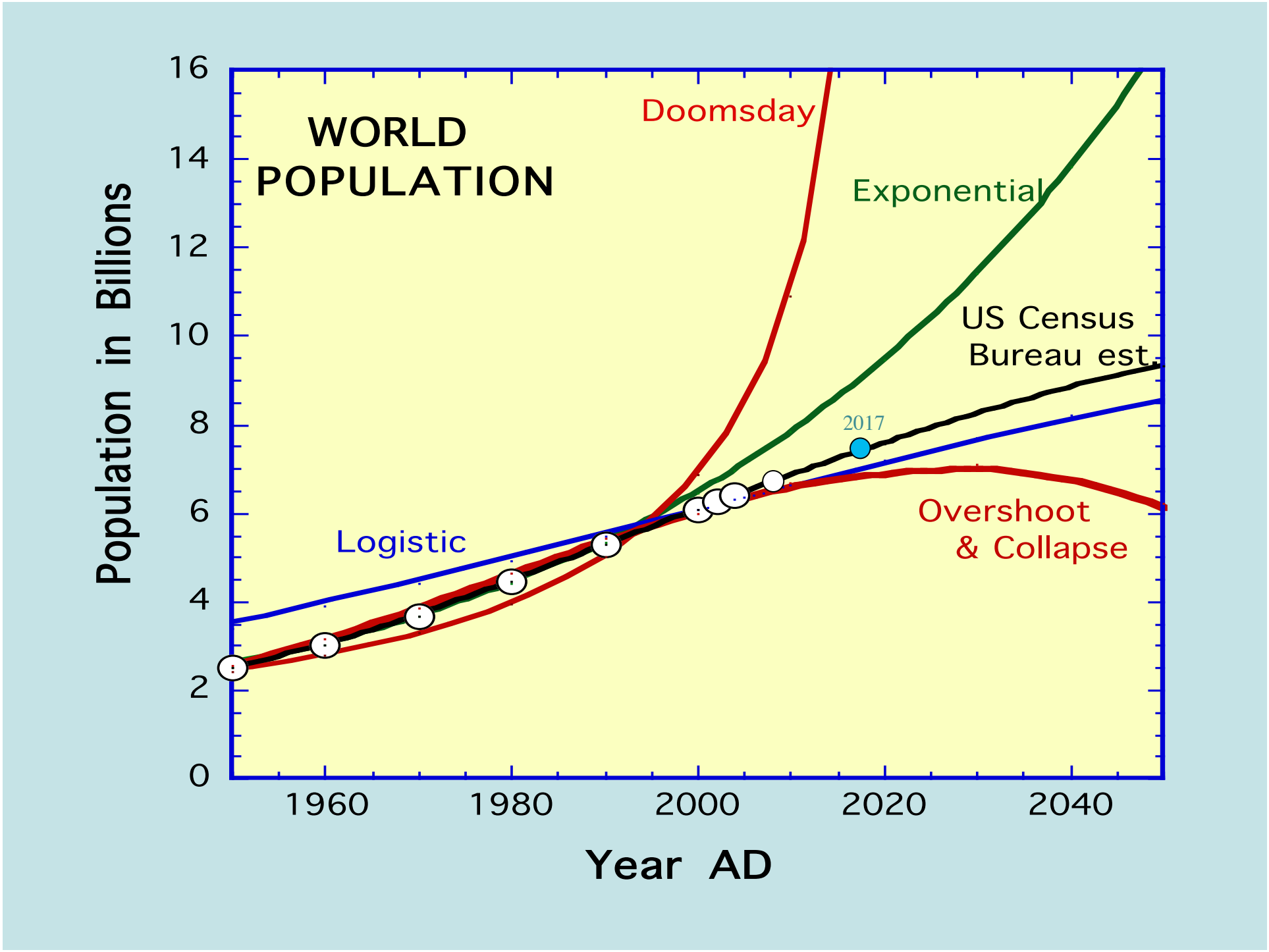


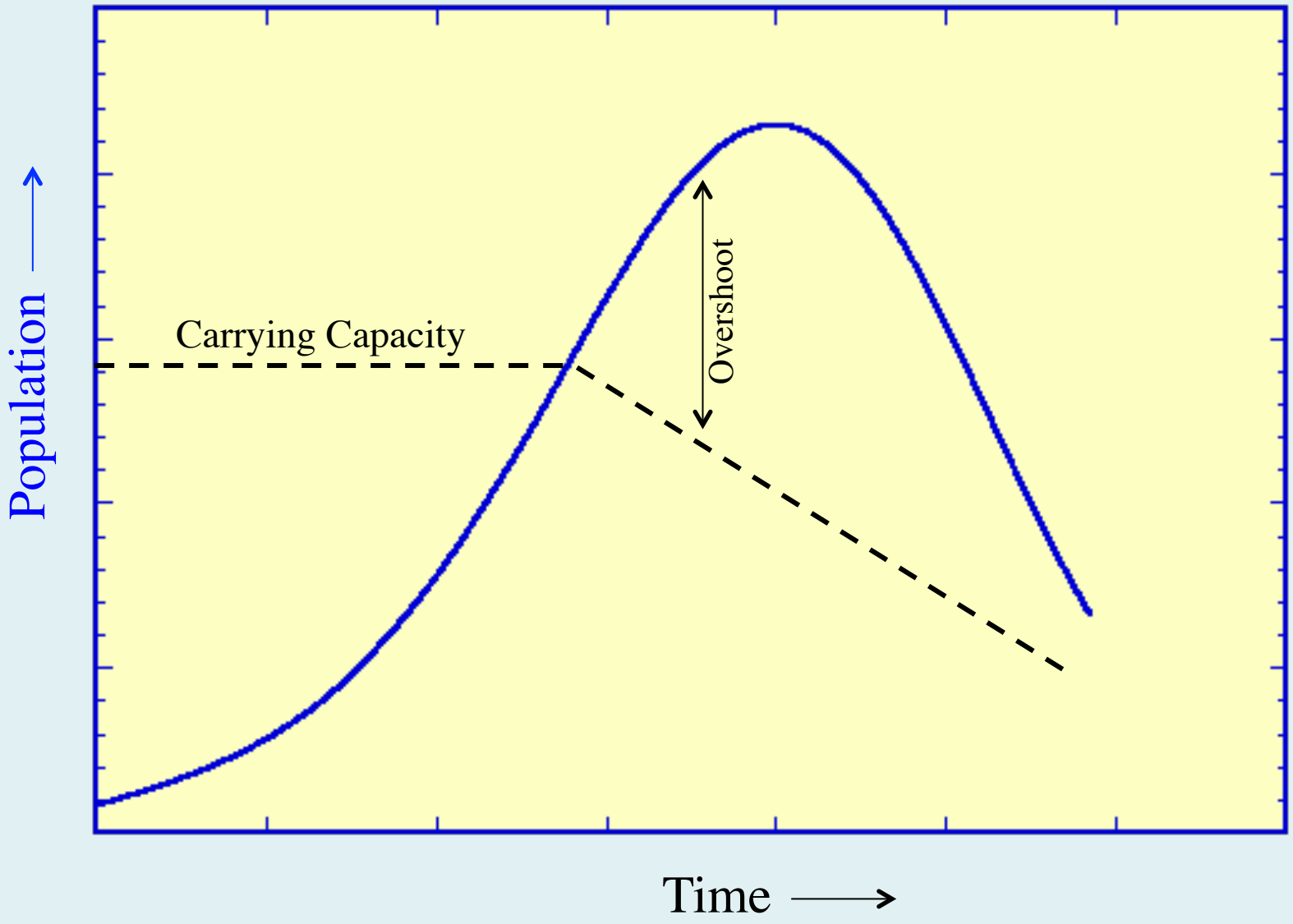
+1,488,000/wk

US Census



Data: UN and US Census


WORLD
POPULATION
Doomsday
Exponential
US Census
Bureau est.
2017
Logistic
Overshoot
& Collapse
Population in Billions
Year AD
0
2
4
6
8
10
12
14
16
1960
1980
2000
2020
2040


Population
Carrying Capacity
Overshoot
Time

World Population ?

Stabilize @ 12 billion @ 2150?

Stabilize @ 30 billion FAO, 1982; Mann 1993 p. 39

Stabilize much before?

Crash?

What is Earth's *carrying capacity ?*
What are *"sustainable"* limits ?

Biological Carrying Capacity: The maximum number of animals an area can support without degrading the habitat.

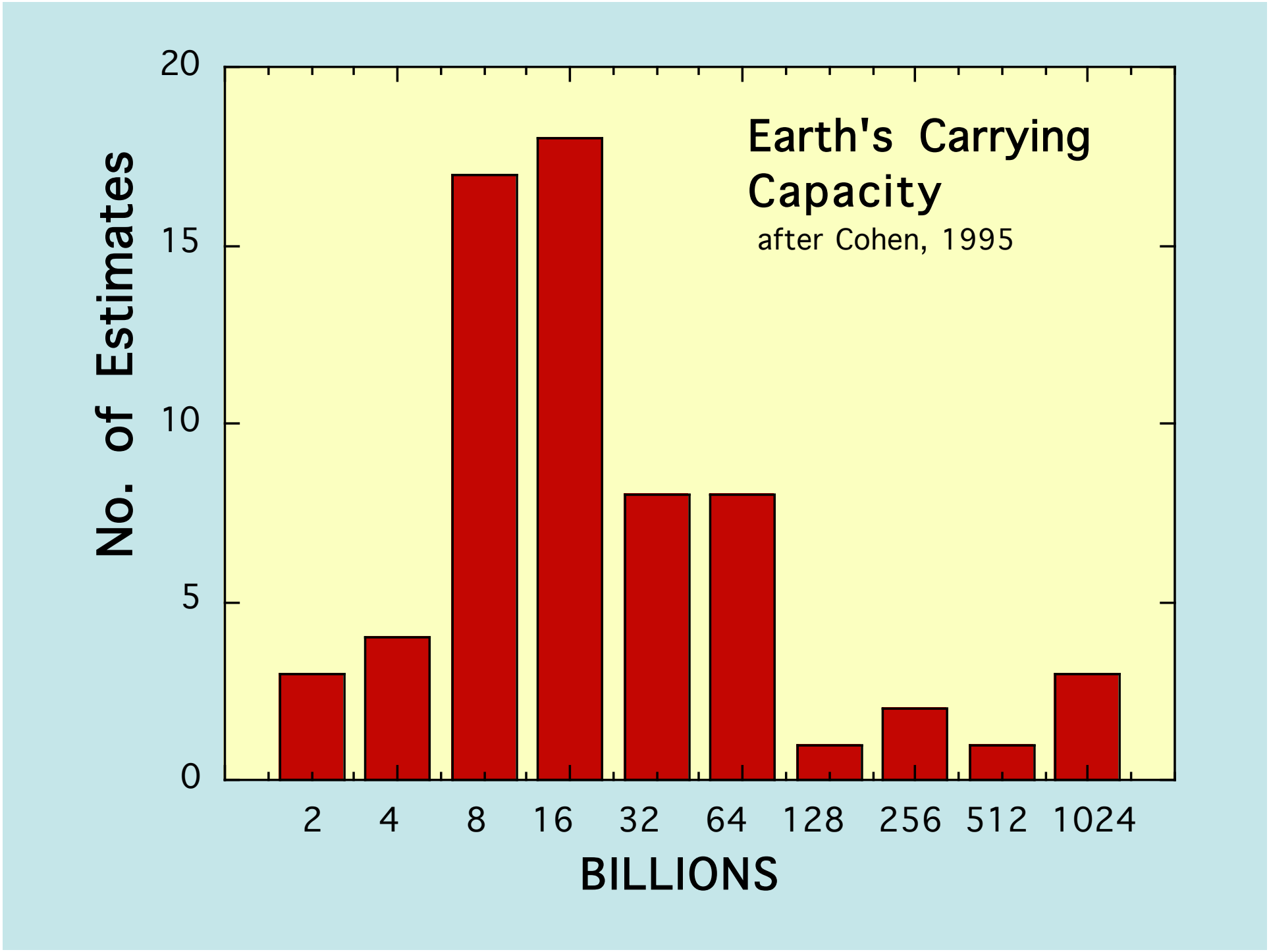
Carrying Capacity: Size of population that can be indefinitely sustained by the environment. Not necessarily fixed.

Catholic Church estimate = 40 billion (Cohen, p.188)

Estimates based on 3.2 billion ha of Arable land

Population = Amount Available / individual requirement

Constrained by the necessity that is in *least* supply


Earth's Carrying Capacity
after Cohen, 1995
No. of Estimates
20
15
10
5
0
2
4
8
16
32
64
128
256
512
1024
BILLIONS

How much land is needed to sustain a decent existence?

HOMESTEAD ACT (1862) 160 acres = 1/4 sec. = 1/2 mi x 1/2 mi

Defined requirements of

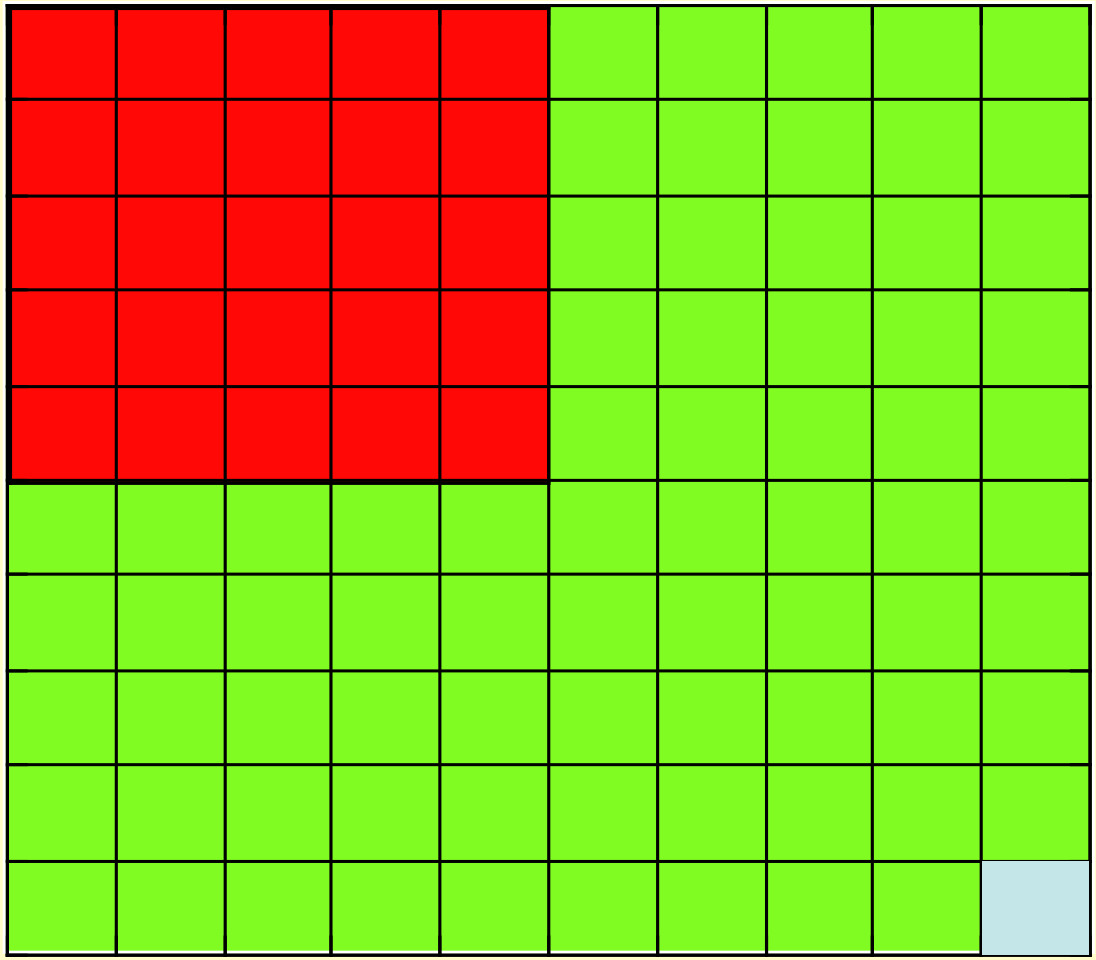
Residence-Improvements-Land Use => Title

Set up small "utopian" farms- excluded plantations, slaves

Favored by abolitionists

<-----------1 Mile----------->

160 acre Homestead



528’ x528’
6.4 acres

How much land is needed to sustain a decent existence?

HOMESTEAD ACT (1862) 160 acres = 1/4 sec. = 1/2 mi x 1/2 mi

Residence-Improvements-Land Use => Title

Set up small "utopian" farms- excluded plantations, slaves

Favored by abolitionists

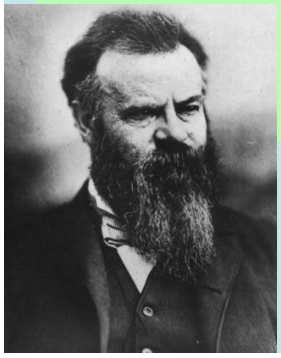
John Wesley Powell (1876) argued that: (Marc Reisner 1986, *Cadillac Desert* p. 47)

a. 2/5 of US area cannot support farming

b. Only 1 to 3% of western land can be reclaimed by irrigation with surface water, even if all that is available is used

c. Dryland ranching requires **4 sections** (2560 acres)

cf. Bill Hatch: 100 acres/cow in Nevada
Ranch ~ 15 sections, $10,000/y



John Wesley Powell
1834-1902
USGS

EARTH: SURFACE AREA = $4 \pi r^2 = 4 \pi (3960 \text{ miles})^2$
= **197×10^6** square miles

LAND AREA = 29% of total = **57.47×10^6** square miles
149×10^6 km^2

USA POPULATION = 324 Million

1.6 Americans/ sq. mile, everywhere => 388 acres each

5.6 Americans/ square mile land = **113 acres** land each

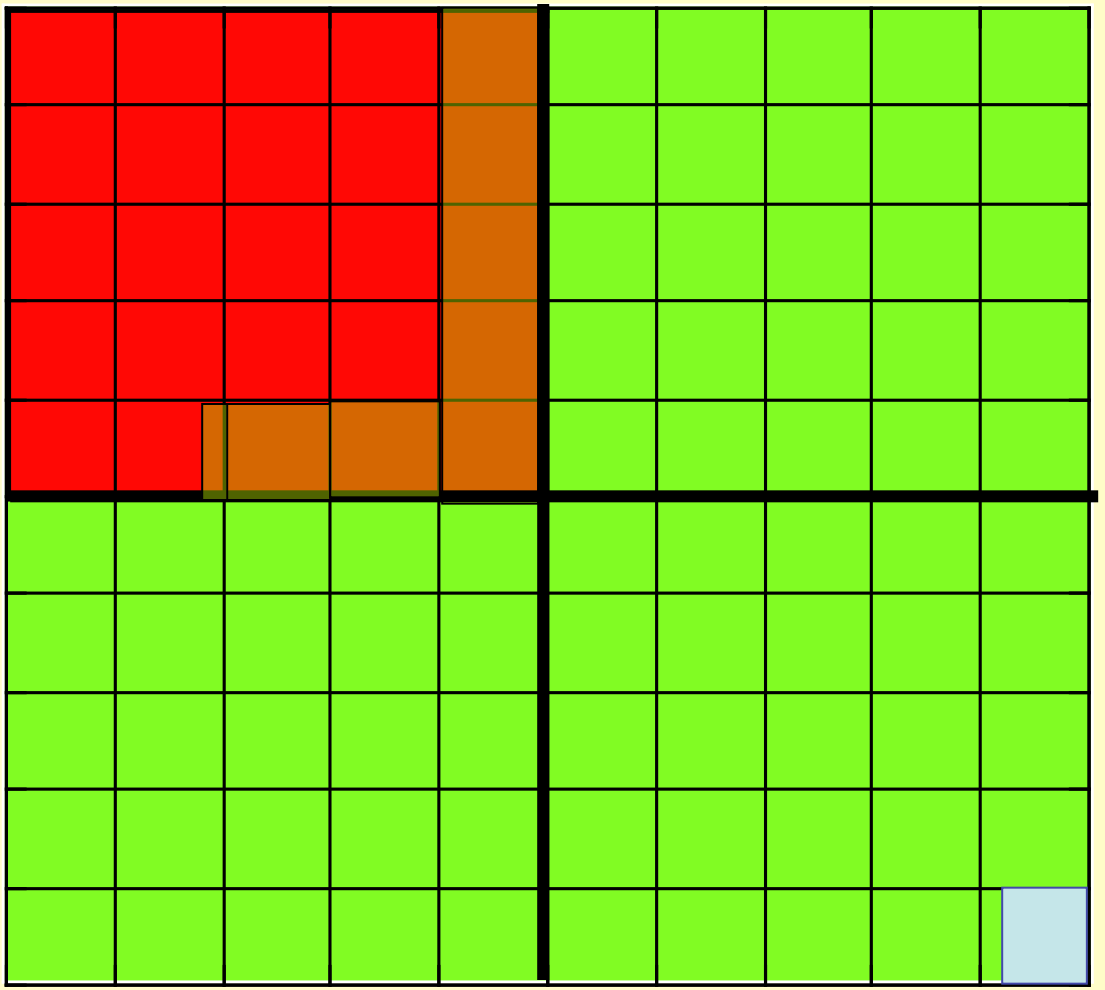
WORLD POPULATION = 7.37 Billion

37.4 humans/ sq mile everywhere 17 acres each

128 humans/ sq mile of land **4.99 acres each**

<----------1 Mile---------->

113 acre "Homestead"



5 ac each

Land Character

Arid and Hyperarid land = 19% (an additional 15% is semiarid)

Currently Glaciated = 10.2 % (inc. Antarctica = 5.1 x10^6 sq mi)

Permafrost = 10% (inc. 45% of USSR & 50% Canada)

>39 % unusable

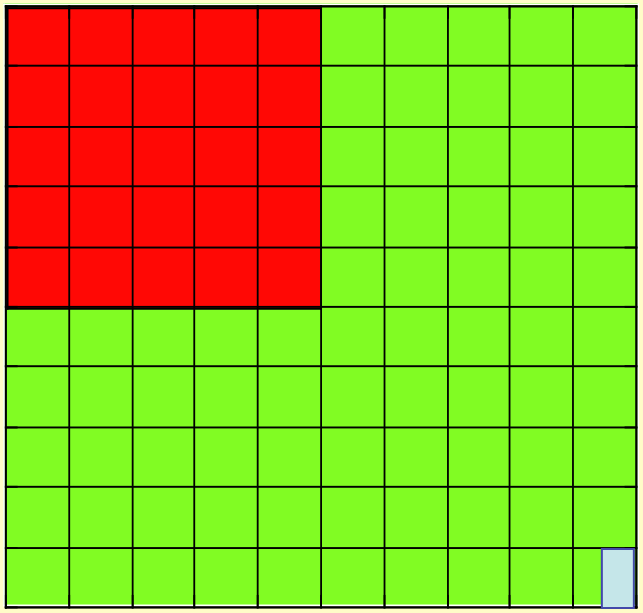
WORLD POPULATION = 7.37 Billion

=> 3.0 acres of habitable land each

Conclusion:

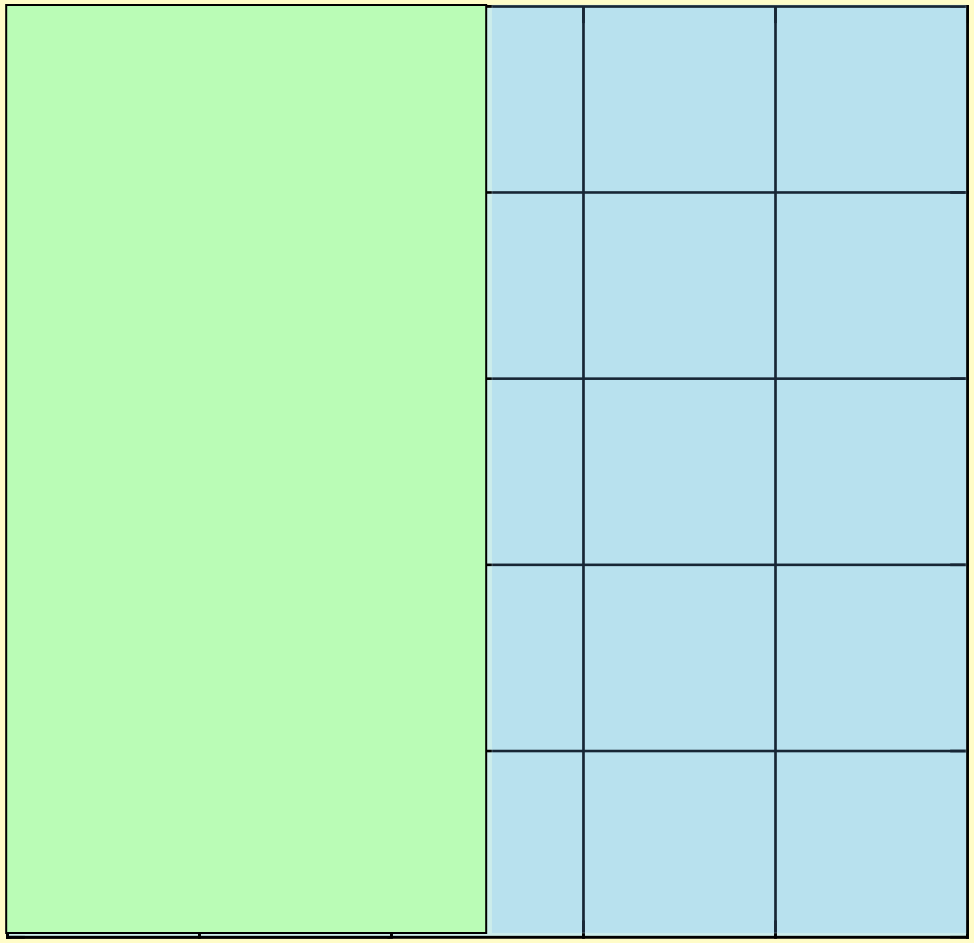
There's enough people now, that the world is small.

160 acre
Homestead



3.0 ac each

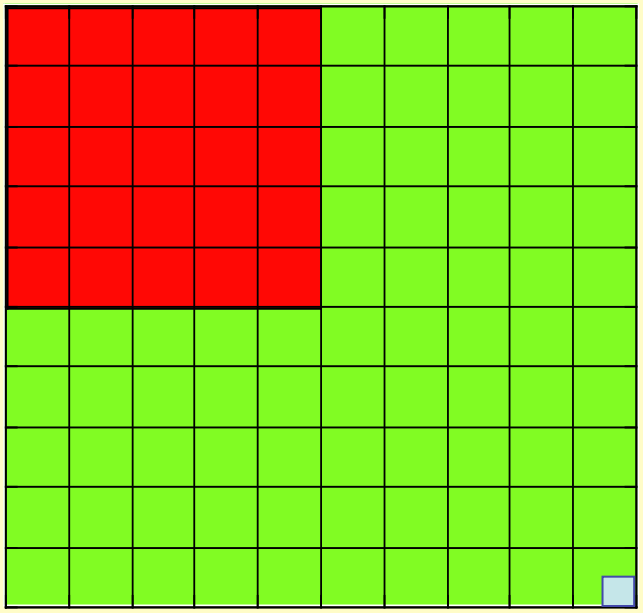
<-------1 Mile------->



<---------- 528’ ---------->

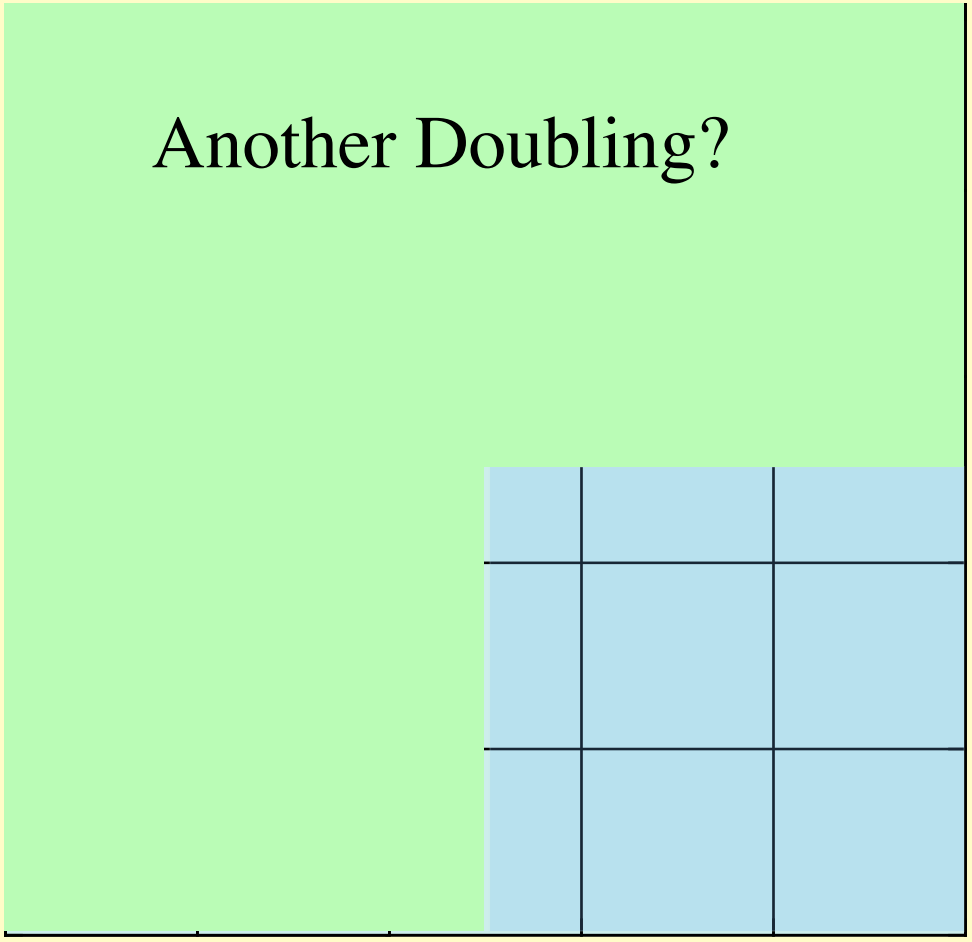
Available habitable land ea
@ 7.22 B

160 acre
Homestead



1.5 ac each

<--------1 Mile-------->



<---------- 528’ ---------->

Available habitable land
@ 14 B

Agricultural basis

Carrying Capacity = Food supply / individual dietary requirement

Currently only 6 x 10^6 mi^2 (= 11%) of Earth's land is food producing

=> **~0.5 acres each currently (~ 0.2 ha)** Cohen p. 186, 220

Arable land 32 x 10^6 km^2 = 3.2 billion ha (21%) Meadows 1972 p 48

=> **1.1 acres each currently (< 0.45 ha)**

Need 2.2 acres (**0.9 ha**) Agland / Person for USA standards

With best farming practices
need ~ 0.67 ac (**0.27 ha**) to feed a person

~ 5 g cereal required to make 1 g of pork or chicken

Carrying Capacity Estimates based on Arable Land
= 3.5 to 12 billion (16B unsustainable)

2017

32. Bbbl/y

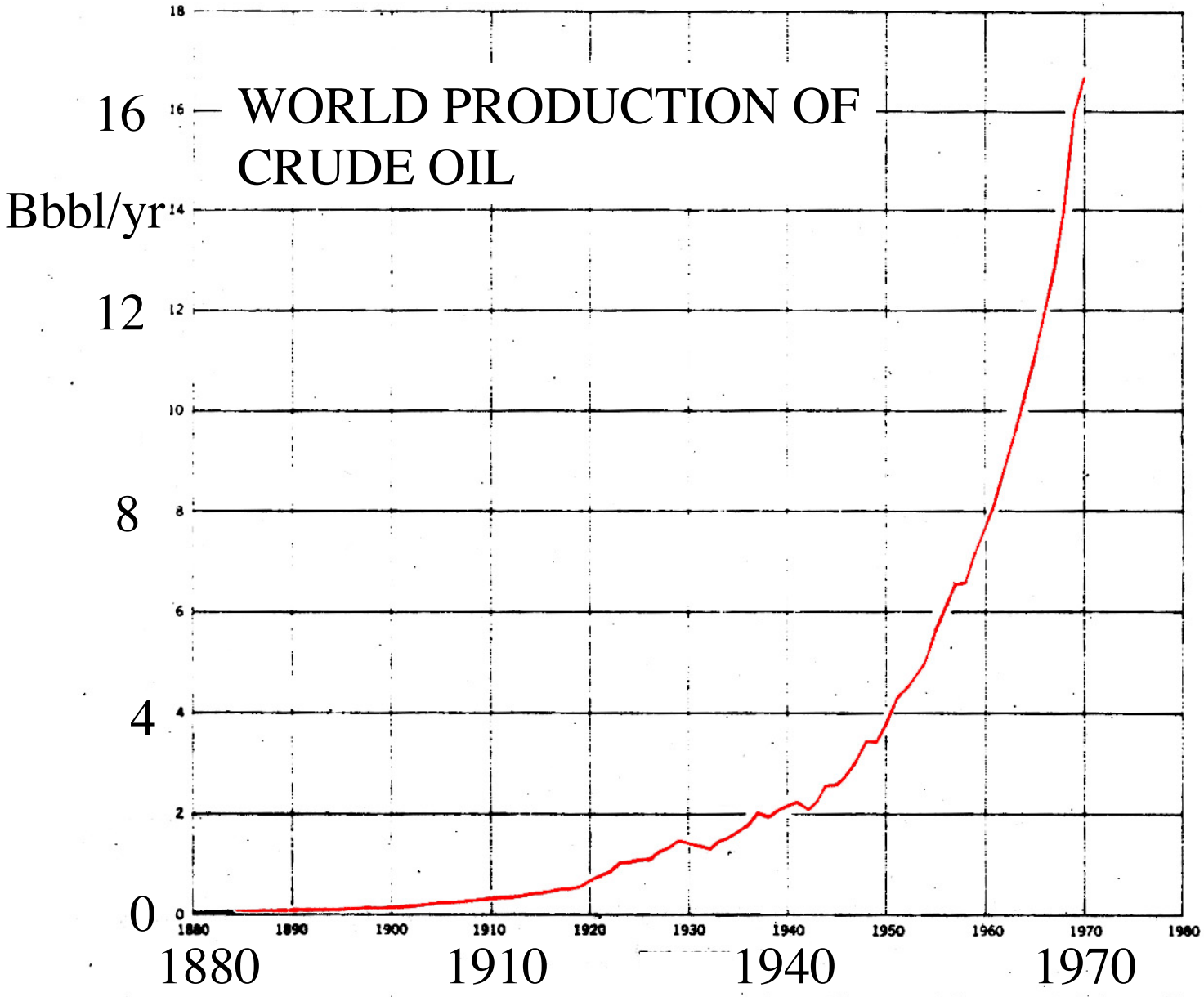


FIGURE 4. World production of crude oil (Hubbert, 1974, fig. 5)

World cannot stay on an exponential growth trend.

Controlled growth is required to maintain balance between population and resources

Economist Thomas Robert Malthus (~1800)

Population growth will outstrip food supply, with disastrous consequences.

Geologist M.K. Hubbert 1976

"Cessation of exponential growth will be .... inevitable...."

ENVIRONMENTAL IMPACT

Over the next 13 years, will add another billion people

Implies continued depletion of resources.

Implies increasing prices of oil, food, wood, water, etc.

World must industrialize to increase agricultural productivity and to support large population

Contemporary economics does not incorporate environmental degradation.

USA tax deductions

USA welfare system

Individual rights *vs.* Community rights

Land Transformation: Need more agricultural land

Forest & Grassland -> Rangeland -> Cropland ->Wasteland

Progressive desertification

Erosion, sedimentation in rivers

GW depletion, Water pollution (fertilizers, pesticides)

Progressive Urbanization & Industrialization

Increasing Extinction Rates (biodiversity "mining")
20,000-50,000/year out of estimated 10M species

after Cohen p. 338

Pollution:

Anthropogenic : Natural Ratios

(EOS 71:52 p. 1884-1886)

Pb	333	x
Cd	20	x
Cu	14	x
As	4	x
S	0.5	x

Other Changes:

Water Quality Degradation

Air Quality Degradation:

SMOG

Acid Rain

CH_4	2	x increase
CO_2	1.4	x increase
Temperature		+0.6°C

Requirements for a sustainable economy:

- The people currently living, future generations, and the environment must be properly considered.
- The regeneration of renewable resources must exceed their rates of use.
- Pollution production rates cannot exceed the environment's absorptive capacity.
- The use of nonrenewable resources must be less than the rate of development of sustainable, renewable substitutes.

after Daly 1991/ Brad Walker

Conclusions

There's enough people now, that the world is small

Living on Capital

Soil, GW, fish, trees; fossil fuels, biodiversity….

Quality of life must go down

Rates of increase must go down.

Good evidence that this is starting to happen

Doomsday: (repent!)

So far, prophesies have always proved wrong!

No historical precedent

Tradeoff: Quality of Life

Do we want to feed poor people more,
or do we want to feed more poor people?

Methuselah's choice:

For a *stationary population* with a birth B, the death rate D must equal B,

so

B = D

and

Average Lifespan = 1/B

Cohen, 1995, p. 157.