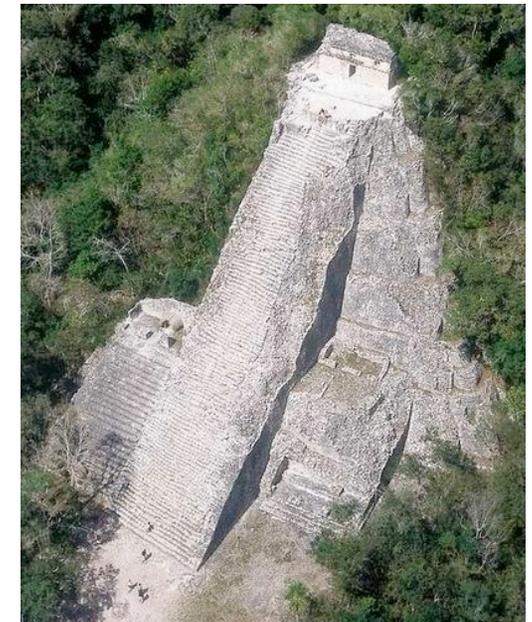


Will Malthus' prediction come true? Is there a global population collapse on the horizon? I will briefly review some basic concepts regarding population growth and collapse and then discuss some of the historical examples from Jared Diamond's book, Collapse, and some predictions concerning the fate of our global population.

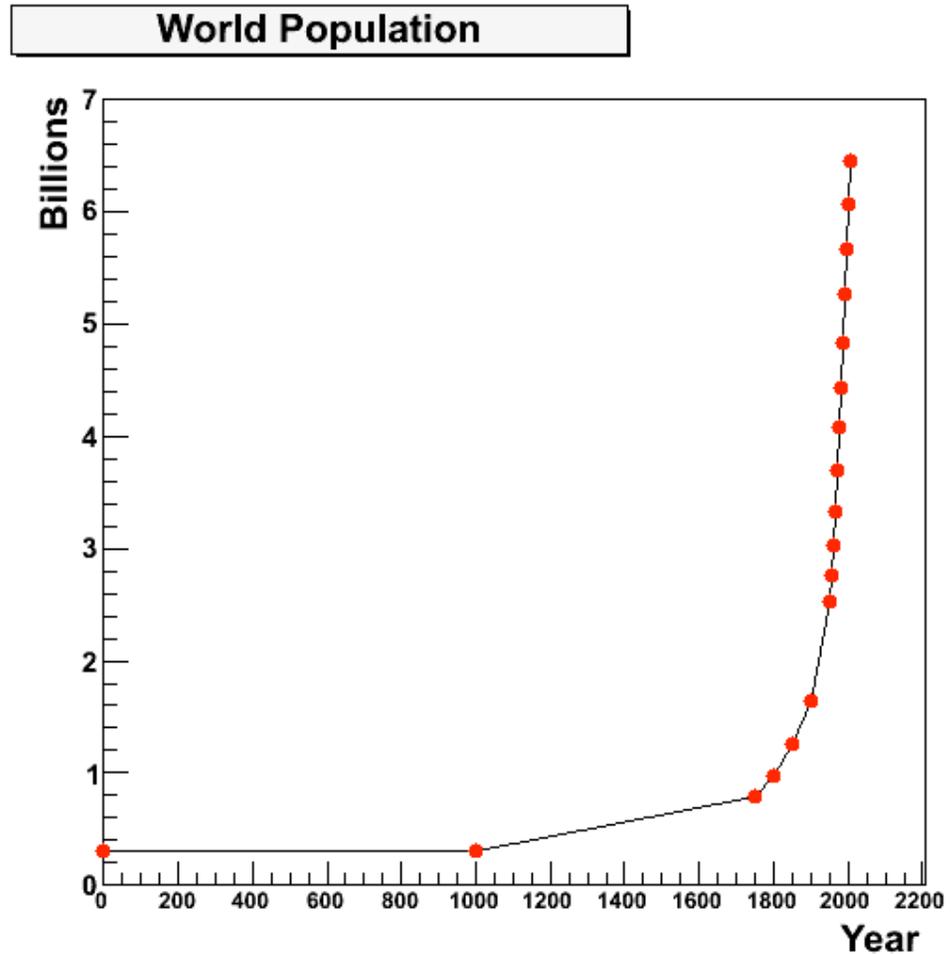


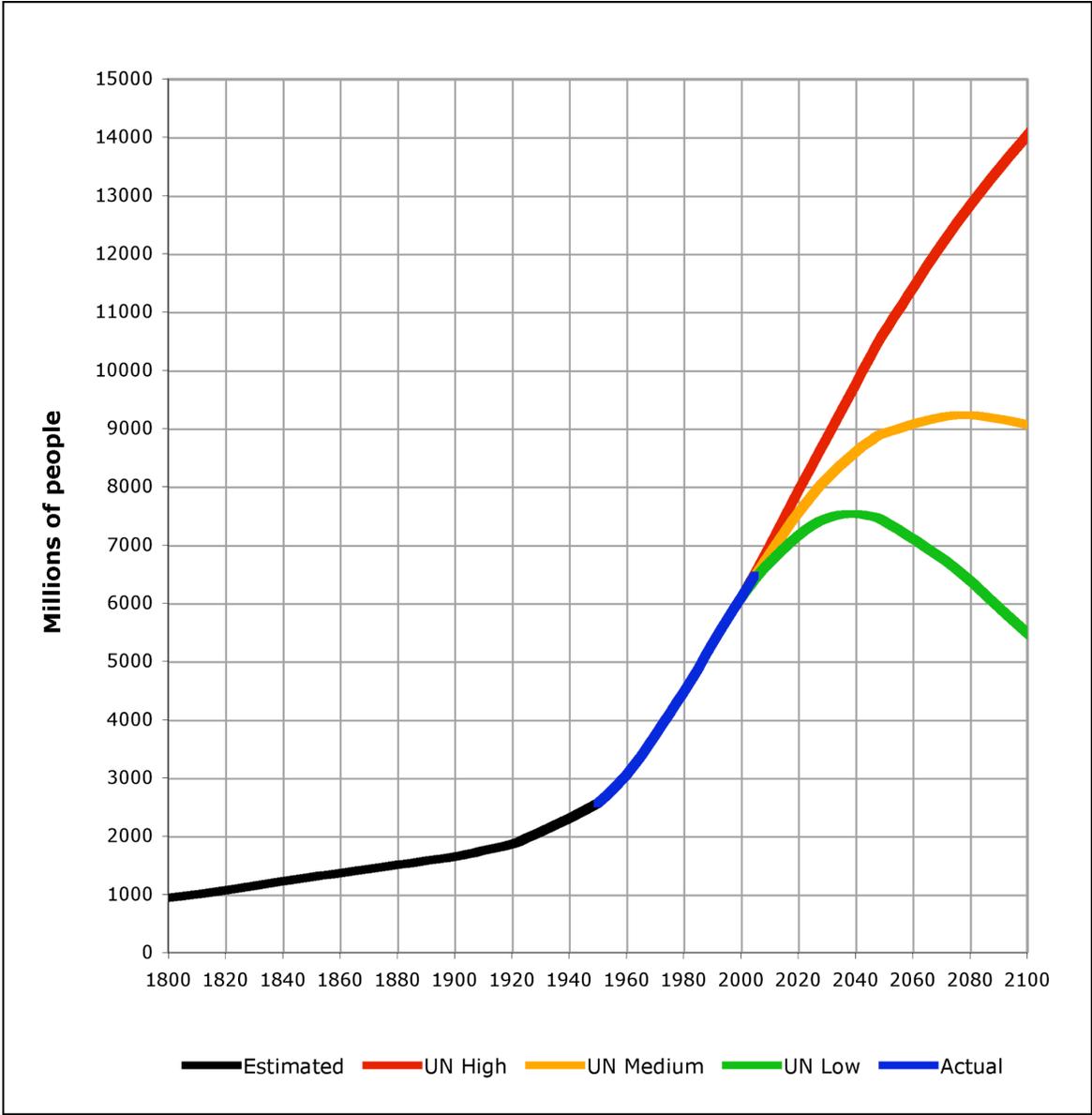
# Malthusian Catastrophe



*“Assuming then my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man. Population, when unchecked, increases in a geometrical ratio.”*

Thomas Malthus  
An Essay on the Principle of Population (1798)

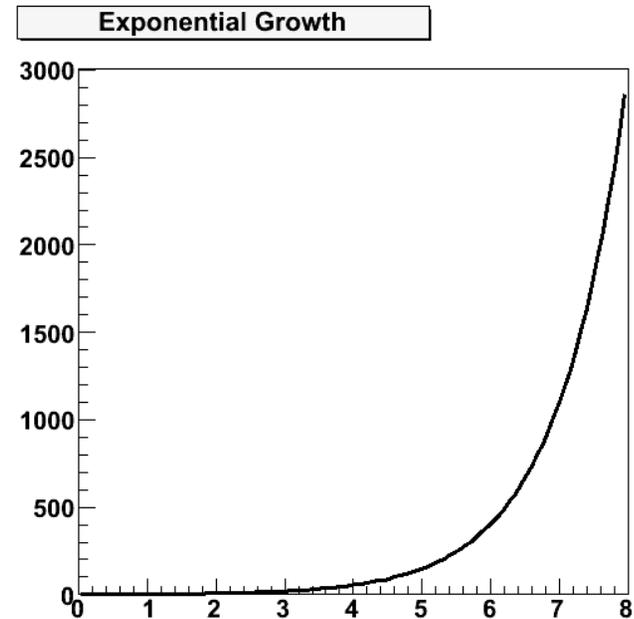




# Models of Population Growth

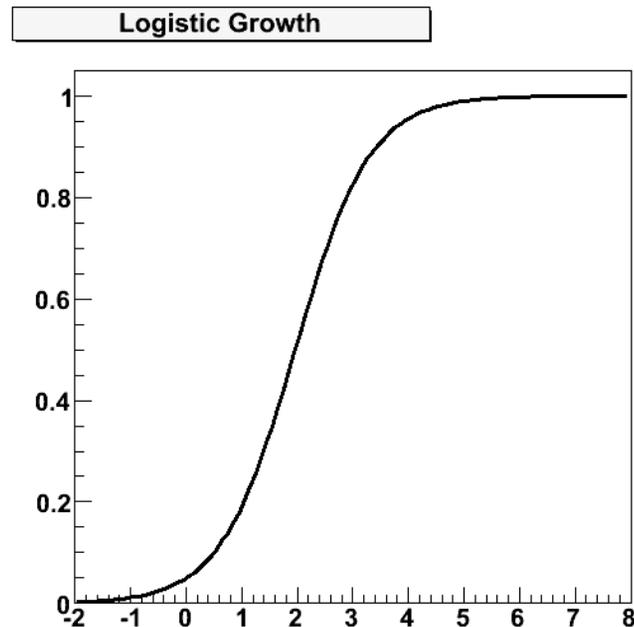
## 1. Simple Exponential Growth

$$\frac{dN}{dt} = rN$$



## 2. Logistic Growth (Verhulst Model)

$$\frac{dN}{dt} = r \frac{N(N_{max} - N)}{N_{max}}$$



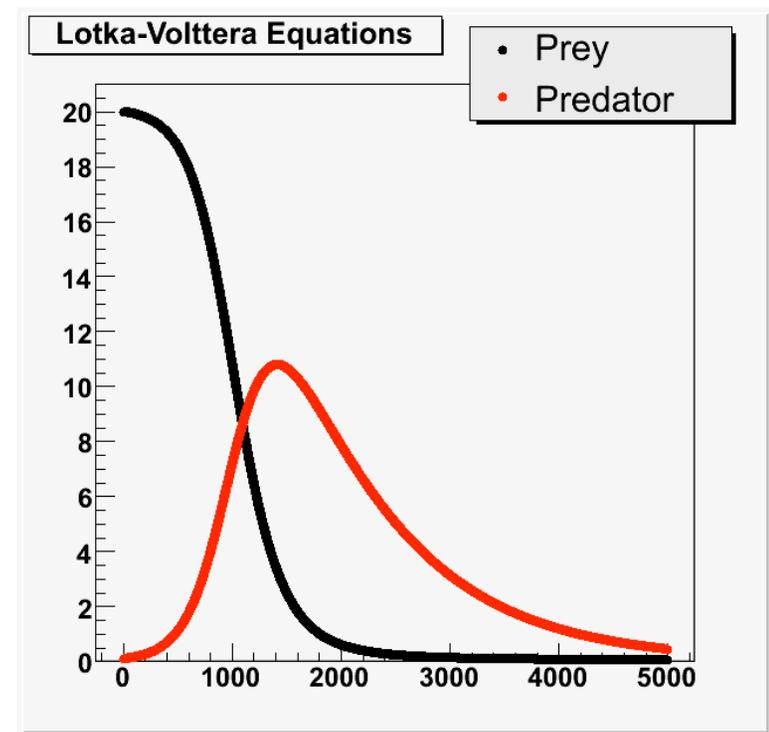
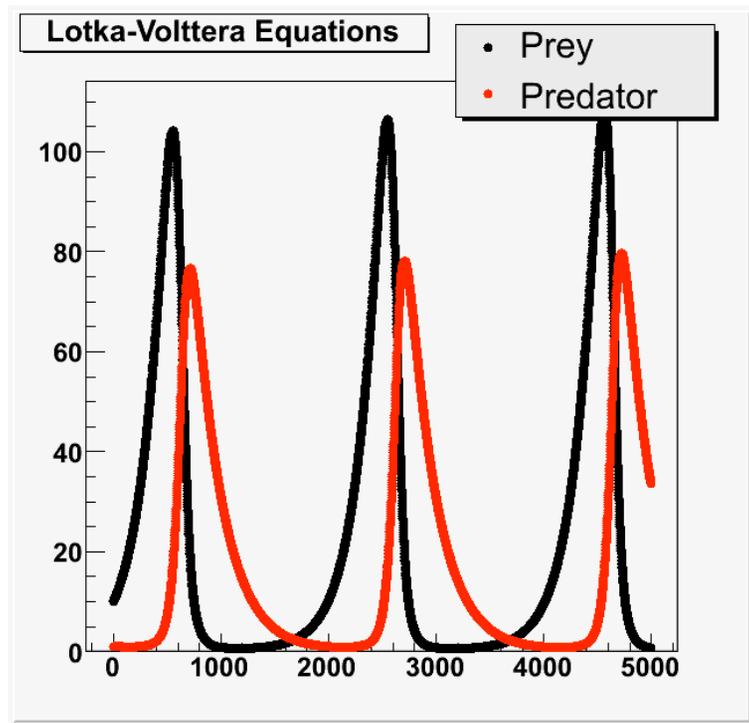
### 3. Predator - Prey (Lotka - Volterra Equations)

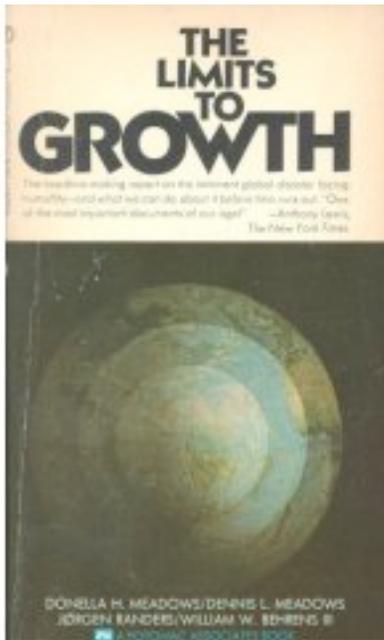
Prey  $\frac{dP}{dt} = \alpha P - \beta PN$

Pred  $\frac{dN}{dt} = -\delta N + \epsilon PN$

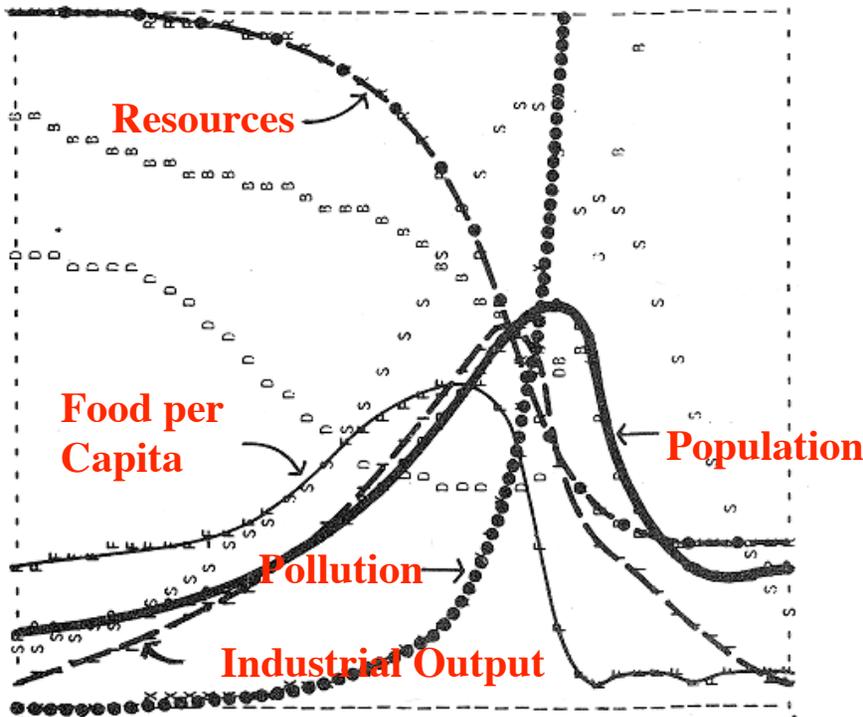
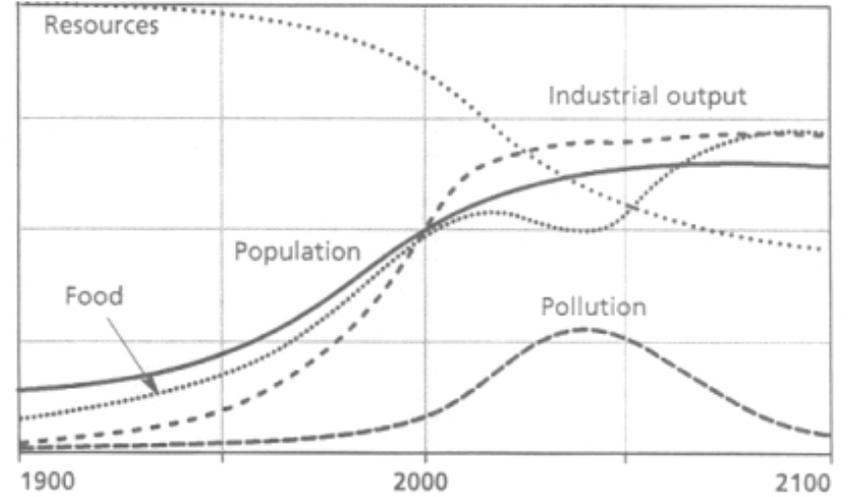
Fixed Point  
 $(P, N) = \left(\frac{\delta}{\epsilon}, \frac{\alpha}{\beta}\right)$

At  $t=0$  Prey  $\gg$  Pred, but no prey growth

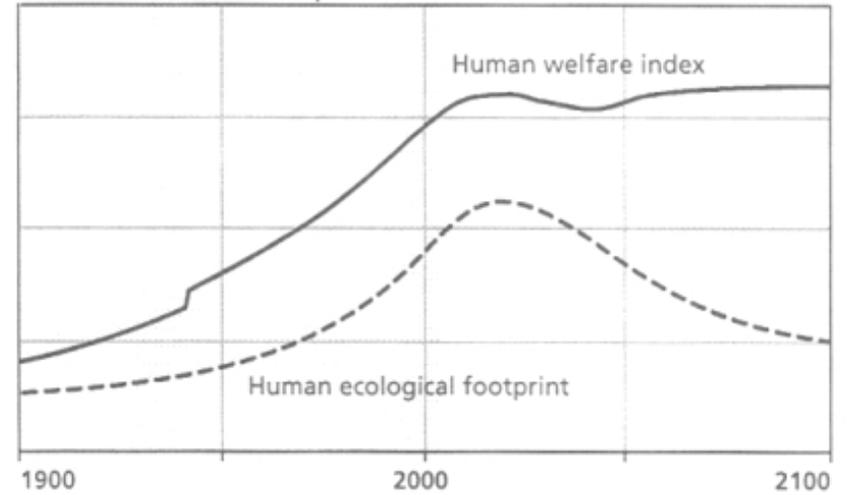




State of the World



Human Welfare and Footprint



# 5 Point Framework

*For attempting to understand  
why a society collapsed*

1. **Environmental Damage** - Deforestation, soil erosion and nutrient loss, water
2. **Climate Change** - Droughts, floods, periods of cold weather
3. **Hostile Neighbors** - Wars and competition for resources
4. **Friendly Trade Partners** - Imports and exports
5. **Societal Response** - Identifying problems, changes of behavior and values

# Societies: Past and Present

- Easter Island \*
- Pitcairn and Henderson
- Anasazi \*
- Maya \*
- Viking
- Greenland Norse \*
- Bottom Up (New Guinea, Tikopia, Japan)
- Rwanda \*
- Dominican Republic, Haiti
- China \*
- Australia

\* Societies I will discuss

# Easter Island

## Diamond's Account

- 900 AD : Small colonization group arrives.
- 1000 AD : Construction of Moai begins.
- 1200 AD : Growing population begins clearing forests.
- 1400 AD : Rate of deforestation peaks, population as high as 15 - 20 k.
- 1680 AD: Deforestation nearly complete, loss of bird species, triggering clan warfare, famine, and population collapse.



**Moai**

Food Sources : sweet potatoes, yams, taro, banana, sugarcane, chickens, wild birds, and rats.

The island had been forested for tens of thousands of years before the trees disappeared, a process that took place between 800 and 1500 A.D (Flenley).

Between 1300 and 1650 A.D., inhabitants burned wood from trees, but they used grass, ferns and other similar plants for fuel after that point (Orliac).

**Deforestation lead to soil erosion, desiccation, and nutrient leaching.**

Hunt's Account <http://www.americanscientist.org/template/AssetDetail/assetid/53200?fulltext=true&print=yes>

- 1200 AD : Small colonization group arrives with rats, population grows quickly, Moai building begins.
- 1250 AD : Population growth leads to deforestation peaks - rat palm seed eating prevents regrowth.
- 1350 AD: Population plateaus at 3k, deforestation complete

# Anasazi, Chaco Canyon

- 700 AD : Small one story buildings erected in canyon.
- 900 AD : Population growing, communities become larger but more compact. Turquoise trade.
- 1030 AD : Construction of multi - storied buildings, and urban centers.
- 1115 AD : Extended Anasazi community also has experienced population boom - serve as agricultural and trading outposts to political/religious center.
- 1140 AD: Cohesive system starts to break down after severe drought, people disperse.



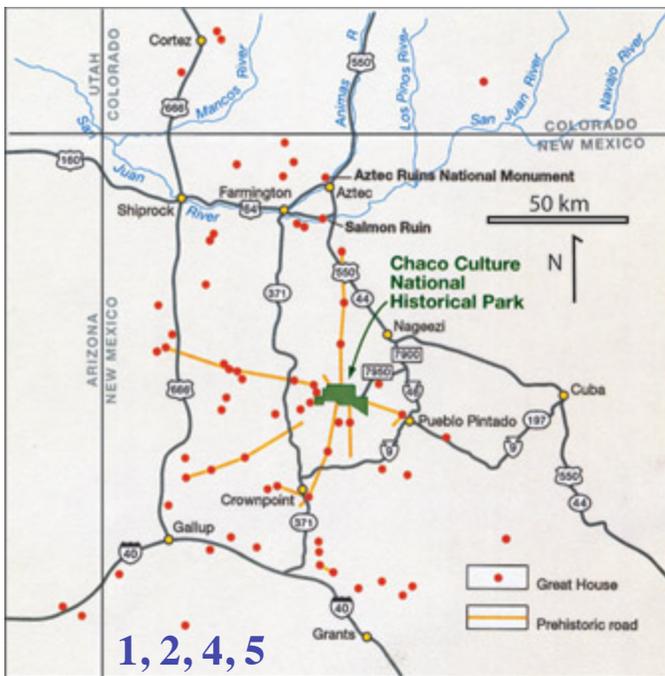
**Pueblo Bonito, Chaco Canyon**

Food Sources:  
Corn, squash, beans,  
and turkey.

**Advantages of Chaco Canyon :** narrow canyon caught rain run-off resulting in high alluvial ground-water levels and soil renewal. Low elevation allowed for long growing season. Pinyon and juniper woodlands.

↳ Canyon could support a large population. But this large population eventually exhausted it's resources by **deforestation** and relied on **imports** of food and material.

**Drought was likely final blow that caused the collapse, as the outlying settlements were no longer willing to support center.**



# Maya

- 250 - 900 AD : Classic Period
- Widespread construction of urban/agricultural centers.
- Growth of a city centered empire (city-states).
- Kings and dynasties erect pyramids, palaces, and monuments.
- Developed writing, art, architecture, and a calendar
- Wars between city-states
- Drought and famine
- Decline of institution of kingship by 9<sup>th</sup> century.

Food Sources : Corn, beans.

**Challenges on the Yucatan** : karst terrain, and unpredictably fluctuating rainfall.

**Mayan society advanced and environment not too fragile.**

## **The case of Copan:**

- Population rose steeply from 5<sup>th</sup> to 8<sup>th</sup> century.
- Construction of monuments between A. D. 650 - 750.
- By A. D. 650 people start occupying steep hill slopes (41%).
- Erosion from the hill slopes damage valley agriculture.
- Skeletons reveal poor health from A. D. 650 - 850.
- Kings downfall by A. D. 950, valley abandoned by 1250.

**“Too many farmer grew too many crops on too much of the landscape”**

**1, 2, 3, 5**



**Pyramid in central plaza, Tikal**





## Norse Greenland

- 800 - 1300 AD : Medieval Warm Period, fjords were lush.
- 980 AD : Icelandic settlers arrive on the southwest tip.
- 1000 AD : All land suitable for farms occupied (pop ~ 5k).
- 1363 AD : End of Western Settlement
- 1420 AD : End of Eastern Settlement
- 1420 AD : Little Ice Age begins.

Food Sources: Domestic livestock (cows and pigs struggled, goats and sheep), caribou, seals, hares.

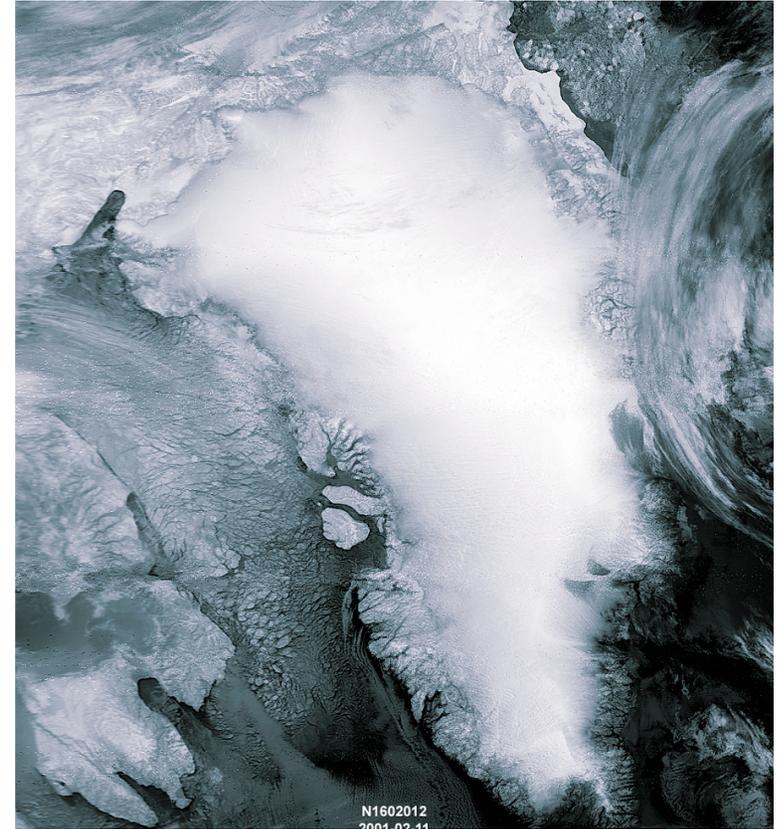
Trading partners (Europe and ivory)

Hostile Neighbors (Inuit)

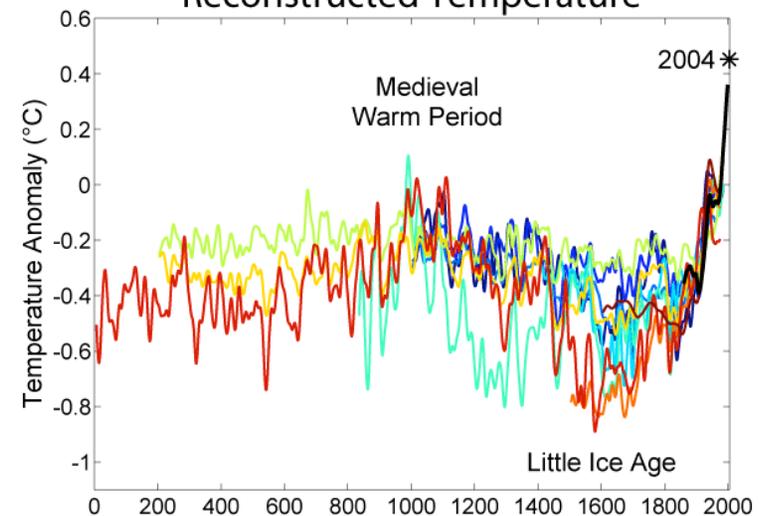
Environmental Damage (deforestation, erosion)

Societal response (maintained European customs)

**1, 2, 3, 4, 5**

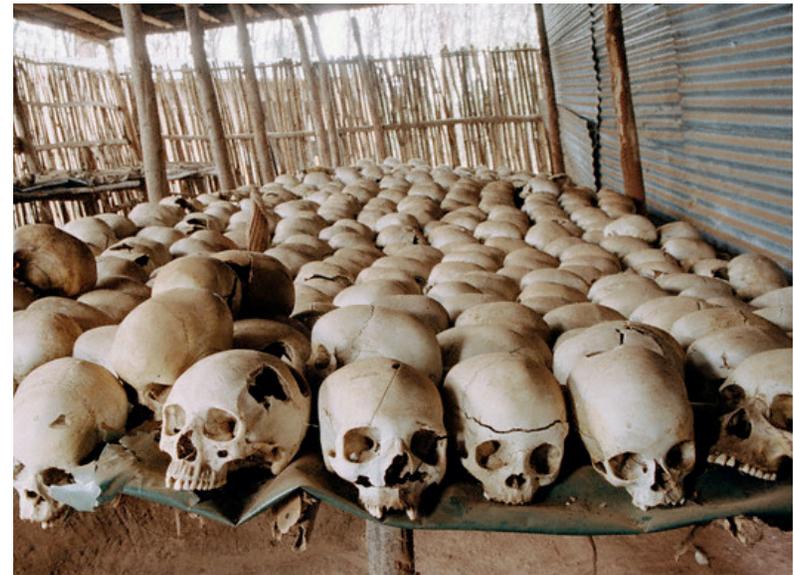


Reconstructed Temperature



# Rwanda

- Highest population density in Africa
- 3% growth (NW crops, medicine)
- Subsistence agriculture (unmechanized)
- Inequity in land distribution
- Hutu ~ 85% and Tutsi ~ 15%, small Twa
- Tutsi historically dominated Hutu
- President Habyarimana (1973-1994), Hutu
- 1990 RPF (Tutsi) invade from Uganda
- 1994 - assassination and genocide



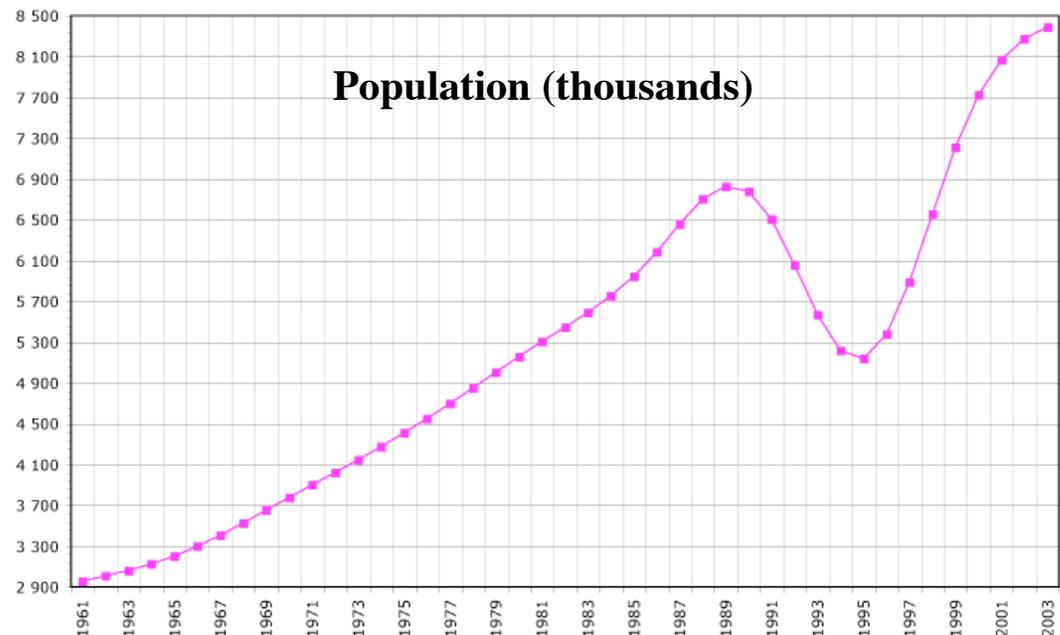
## Environmental Problems:

Deforestation, soil exhaustion, erosion due to hillside farming.

## Diamond's Claim:

Genocide a result of more than just Hutu-Tutsi hatred. Twa killed, and often Hutu killed Hutu.

Overpopulation and shortage of land were the major driving factors.



# China

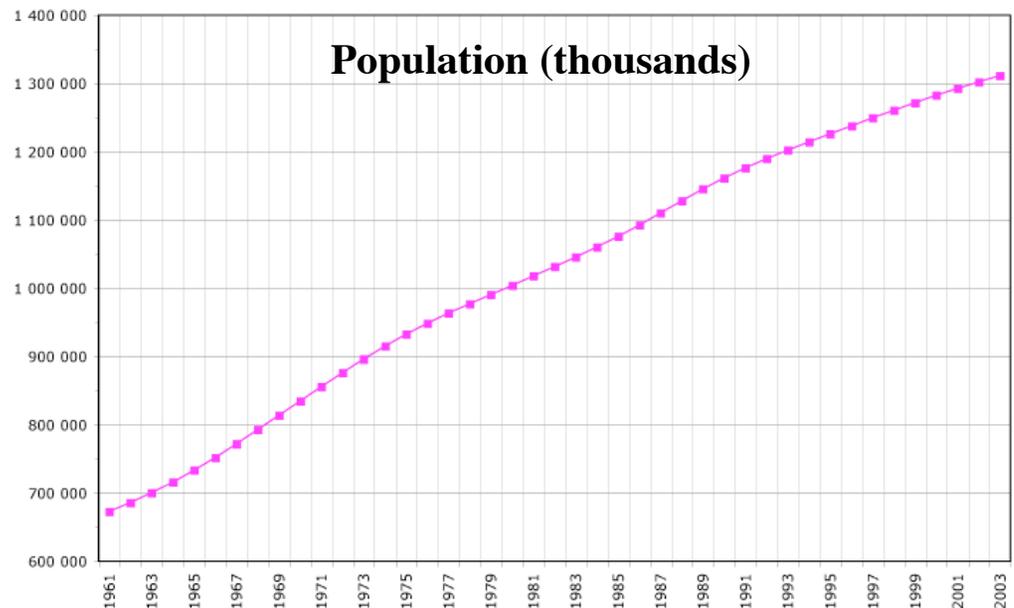
- 1.3 billion people ( ~1/5 world total), 1.3% growth
- Household growth 3.5% in past 15 years
- Household size 4.5 (1985) to 3.5 in (2000)
- Economic growth of 10%/year (> 4 x 1<sup>st</sup> world)
- Highest production of steel, cement
- Highest prod & cons of coal, fertilizers
- Close to highest in prod of electricity and autos
- Close to highest in cons of timber
- Industrial production 1/2 efficient as 1<sup>st</sup> world



**Three Gorges Dam - Yangtze, will be largest hydro-elec dam**

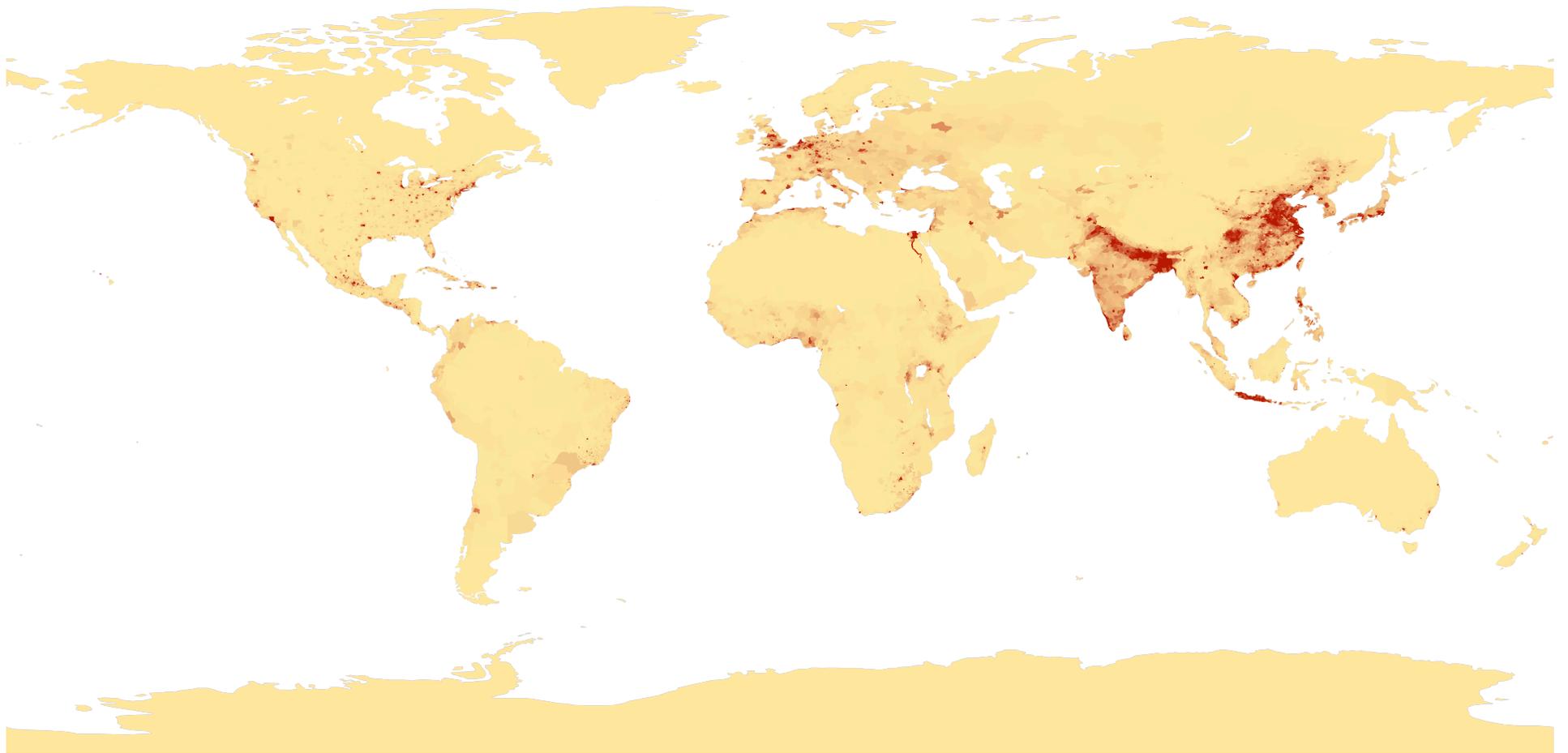
## Environmental Problems

1. Air pollution
2. Water pollution and waste
3. Biodiversity loss (fisheries)
4. Cropland loss
5. Desertification
6. Disappearing wetlands
7. Grassland degradation
8. River flow cessation
9. Soil erosion
10. Trash



# Major Problems Today

1. **Destruction of Natural Habitats** (esp. deforestation, wetlands, reefs)
2. **Loss of Wild Food Sources** (fish, shellfish - protein for free)
3. **Loss of Biodiversity** (loss of free services, disruption of food chains)
4. **Soil Degradation** (erosion, salinization, nutrient loss, acidification/alkalinization)
5. **Energy Sources** (declining reserves of hydrocarbons)
6. **Freshwater Sources** (most rivers/lakes in use, aquifers dwindling)
7. **Photosynthetic Ceiling** (in 1986 world was using ~ 50% of capacity )
8. **Chemicals in Environment** (mercury, DDT, PCBs, plastics, refrig. , deterg.)
9. **Alien Species** (Australia rabbits/foxes, pests/pathogen, Zebra mussels, weeds, lampreys)
10. **Gases** (Global warming and ozone)
11. **Population**
12. **Per Capita Impact** (Third world striving for First World)



# Failures of Group Decision Making

- Failure to Anticipate
- Failure to Perceive
- Perceive, Fail to Try
- Perceive and Try, Fail to Solve