Population and Climate Change: a Proposal

Based on a talk at the NAS

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Population growth

<table>
<thead>
<tr>
<th>Year (AD)</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1AD</td>
<td>0.3b</td>
</tr>
<tr>
<td>1650</td>
<td>0.5b</td>
</tr>
<tr>
<td>1800</td>
<td>1.0b</td>
</tr>
<tr>
<td>1927</td>
<td>2.0b</td>
</tr>
<tr>
<td>1960</td>
<td>3.0b</td>
</tr>
<tr>
<td>1975</td>
<td>4.0b</td>
</tr>
<tr>
<td>1987</td>
<td>5.0b</td>
</tr>
<tr>
<td>1998</td>
<td>6.0b</td>
</tr>
<tr>
<td>2011</td>
<td>7.0b</td>
</tr>
</tbody>
</table>

World population growth
Optimum Population Trust
Source: United Nations 2008-based Medium Variant Projection

9.1 billion at 2050?
6.8 billion in 2009

Year (AD)
Population and climate: one study at the London School of Economics

Per dollar spent, **family planning** reduces four times as much carbon over the next 40 years as adopting **low-carbon technologies**

Concluded: Family planning is **cost effective** and should be a primary method to reduce emissions

Copenhagen: **no discussion** on population or family planning
Population growth affects every environmental challenge we face:

- Generation of GHG, other pollutants and toxic waste
- **Resource depletion**: water, oil, fisheries, topsoil, etc.
- Resource wars and civil conflicts
- Malnutrition and world hunger
- Lack of resources for education and health care, especially in poor countries
- Best farmland converted to urban and suburban sprawl
- Garbage disposal and need to find more landfill space
- Species extinction…

- Population growth was made possible by the use of fossil fuels to grow food: we use orders of magnitude more fossil fuel calories than the calories we get from the food.
- **We are drawing from the natural stocks as if they were infinite** (H Daly)
- **This is unsustainable**
The Club of Rome commissioned a group at the MIT Sloan School of Management to study:
“Are current policies leading to a sustainable future or to collapse?”

When the results appeared in 1972, the conclusion that with finite natural resources growth would overshoot and collapse was dismissed as absurd by many economists.

35 years later the “standard run” model compares well with reality.
(Graham Turner, CSIRO, 2009)
The “World3” model they used:

The model is relatively simple:

There are “stock” variables [boxes]: population, cultivated land, industrial capital, non-renewable resources, pollution, etc.

There are interactions (arrows) with positive or negative feedbacks.

The model is then integrated from 1900 to 2100.
Feedbacks of Population, Capital, Agriculture and Pollution (left) and Population, Capital, Services and Resources (right)
The model could have four possible types of outcomes:

- Infinite World
- Ideal (no overshoot)
- Overshoot and Collapse
- Overshoot and Oscillation

You are here...

Or here...

Hopefully...
Need to develop regional models.

The model aggregates the whole world into a single model. Therefore it cannot include:

- Rich vs. poor (differential consumption rates)
- Resource wars
- International migration
- Government policies
- …

To include these important factors we need to develop regional population models.

We could start with 20-30 regions like

- Brazil
- Argentina, Uruguay and Chile
- …

This is computationally very feasible (about 10 stocks and 1000 parameters per region)
Can government policies be effective?

Vegetation productivity (NDVI) in South America: red is maximum primary (vegetation) productivity
Government policies are important!

The red (highest NDVI) is in the province of Misiones, Argentina, that protects the forest. Compare Misiones with Brazil, Paraguay and the rest of Argentina!
In the 1960's Argentina's fertility rate was less than half of Brazil and Mexico.

With government support for family planning, Brazil and Mexico have now much lower fertility rates than Argentina.

Government policies matter!
A proposal to DOE, NASA, NOAA, NSF, State Dept., and others

We already include in Earth System models coupled modules for land-ocean-atmosphere-vegetation, carbon emissions and chemistry.

Push for Earth System modelers and economists to develop coupled scenarios for climate change with regional modules for population:

An interactive human population module to the Earth System Models could start with regional World3-type models, or other economic models and add

- human interaction with land,
- separate resources: oil, water, fisheries,…
- government policies,
- international policies and treaties,
- investment policies,
- international migration…
Call for Earth System modelers and economists to develop coupled scenarios for climate change with regional modules for population:

This would achieve two major goals:
1) Study different scenarios for world development and population policies.
2) Force us to look at the population problem from a scientific point of view.

It would eliminate “the elephant in the room”
Population and climate change: a proposal
Standard Neoclassical Economic Model

- No Inputs (resources), Outputs (pollution), Stocks of Natural Capital
- No Dissipation of Energy (i.e., a Perpetual Motion Machine)
- No Depletion, Destruction or Transformation of Matter
- Therefore, no effects on the Earth System, and No Limits to Growth.
Realistic Ecological Economic Model

- Incorporates INPUTS, including **DEPLETION** of SOURCES
- Incorporates OUTPUTS, including **POLLUTION** of SINKS
Feedbacks in an Ecological Economic Model

Of course, the OUTPUTS and the **filling up** of SINKS, can have large impacts on the Human Economy, the Quantity and Quality of the INPUTS, and the **depletion** of SOURCES:

**Earth System**

**Sources:**
- Stock of Natural Capital
- Flows of Energy

**Inputs:**
1. **Energy**
   - Oil, Coal, Gas, Nuclear, Biomass, Renewables, etc
2. **Matter**
   - Soil, Minerals, Lumber, and Other Material Resources

**Human Economy**
- Population $\leftrightarrow$ Technology
  - Population growth rate
  - Energy Use / Capita
  - Resource Use / Capita
  - Emissions / Capita
  - Waste / Capita
  - Economic expansion / Capita

**Outputs:**
1. **Emissions**
   - CO2, Methane, etc
2. **Waste Products**
   - Garbage, Toxics, etc
3. **Surface Changes**
   - Urbanization, Deforestation, Desertification, etc

**Sinks:**
- Oceans, Atmosphere Land
“Empty World” Ecological Economic Model

- Throughout most of human history, the **Human Economy** was so small relative to the **Earth System**, that it had little impact on the **Sources** and **Sinks**.
- In this scenario, the standard isolated economic model might have made sense.
But Population and Economic Output per Capita have grown

- 9.1 billion at 2050?
- 6.8 billion in 2009

![World population growth graph]

![Global average per capita GDP (1990 $) graph]
“Full World” Ecological Economic Model

• Today, the **Human Economy** has grown so large, it has very large **Effects** on the **Earth System**, **Depleting** the **Sources** and **Filling** the **Sinks**. It is clear that **growth cannot continue forever**.
Regional Population Models

Earth System

Global Sources:
- Oceans
- Atmosphere

Global Sinks:
- Oceans
- Atmosphere
- Land

Local Sources:
- Oceans
- Atmosphere
- Land

Local Sinks:
- Oceans
- Atmosphere
- Land

Human

Pop ⇔ Techn
REGION 1

Pop ⇔ Techn
REGION N

Inputs

Outputs:
Toy Earth System / Human System Feedbacks

UMD Earth System (Zeng et al.)

Global atmosphere (temp, wind, fluxes, CO2)

Land (region n)

- Land-vegetation model
  - Forests
  - Cropland
  - Grass
  - Urban

- Leaf, root, wood, fast & slow soil carbon pools

- Fossil Fuels
- Water
- Pollution

Ocean

Fisheries

Human System

Region n

- Policies
- Technology
  - Pollution, Emission, Depletion
- Socio-economics
  - Migration, Trade, Wars

Demography

Vulnerabilities
  - Food - Health - Sea level - Extreme Weather - Changed seasons – Diseases/pests
Some of the Essential Feedbacks in the toy model

- Vegetation $\leftrightarrow$ albedo (climate change)
- CO2 emissions $\leftrightarrow$ climate change $\leftrightarrow$ vegetation
- Vegetation $\leftrightarrow$ water use, fossil fuel use $\leftrightarrow$ crops
- Population $\leftrightarrow$ crops, food/capita $\leftrightarrow$ mortality
- Population $\leftrightarrow$ food/capita $\leftrightarrow$ fisheries
- Population $\leftrightarrow$ CO2 emission, pollution $\leftrightarrow$ atmosphere, land
- Population $\leftrightarrow$ urban sprawl $\leftrightarrow$ loss of cultivated land
- Technology $\leftrightarrow$ non-renewable resources $\leftrightarrow$ alternative resources
- Policies $\leftrightarrow$ education, birth rate, pollution, emission
- Resource depletion $\leftrightarrow$ trade, resource wars
- CO2 emissions $\leftrightarrow$ climate change $\leftrightarrow$ vulnerability

Realistic model

CCSM with more realistic population/economic feedbacks