Ecologies of Construction

Global Impacts and Measures

Learning objective

Purpose: To introduce the various measures used to determine the impact of individual, societal and global human activities. To discuss in some depth the ecological footprint and the notion of 'overshoot' as it relates to work in the limits of growth (Meadows), resource depletion (Hubbert and Graedel) and degradation of biocapacity (again, Meadows and systems thinking and Wackernagel).

Primary reference texts for lecture:

Donnella, D. Randers, J. and D. Meadows 2004. ***Limits to Growth – 30 year update***. Chelsea Green Publishing Company.

Wackernagel, M. et al. 2002. "Tracking the Ecological Overshoot of the Human Economy." PNAS 99, no.14, 9266-9271.

global impacts *(of human activity)*

Input – Impact

I. Energy – Fossil fuels, environmental degradation
   - M.K. Hubbert's Peal Oil Production

II. Material – Material depletion, waste production
   - D&D Meadows, J. Jacobs, T. Graedel

Output – Impact

I. CO_2 emissions – global warming
   - R. Revelle and Global Warming

II. Pollution – human health, biodiversity

III. Toxic substances – health, biodiversity

IV. Loss of resilience or 'wealth'
   - M. Wackernagel and Ecological Footprint

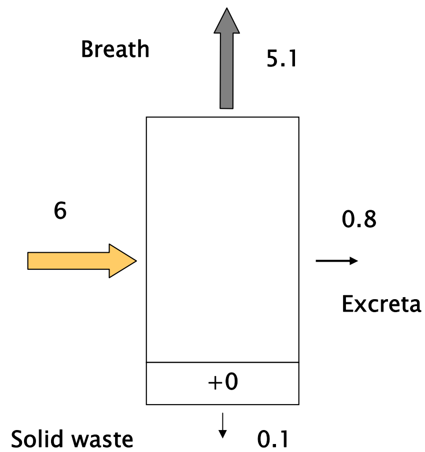
measures *(of human activity)*

I. Individual Consumption
II. Ecological footprint

Total neolithic* human material consumption

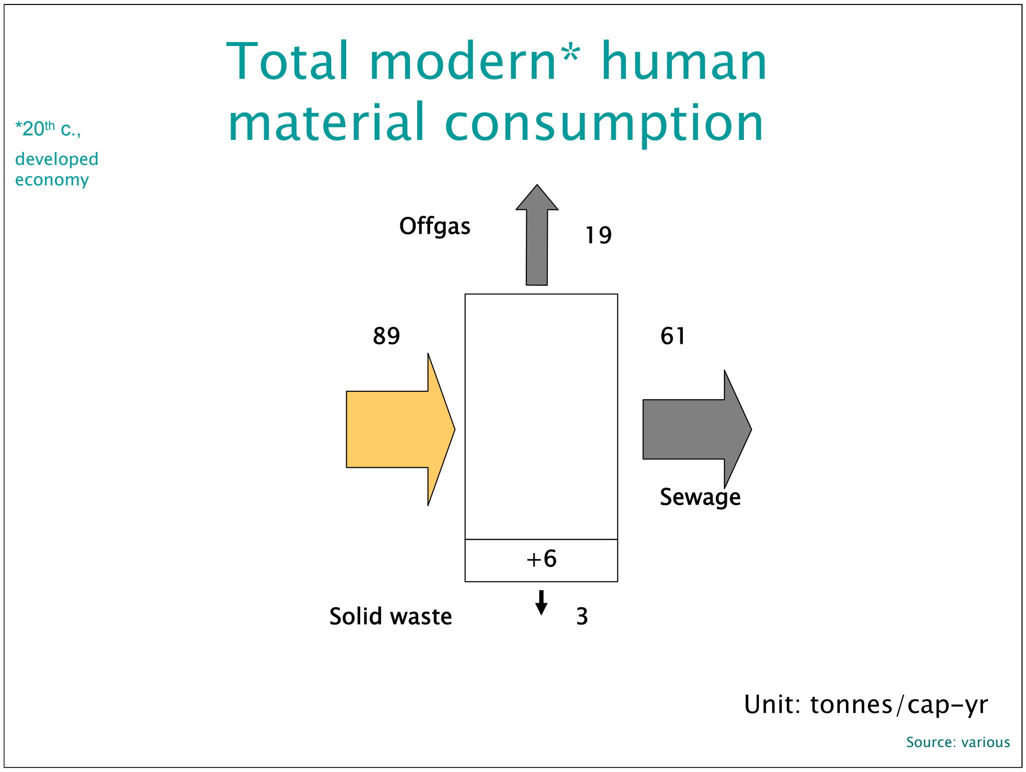
*11k-7.5k BC

This periods includes the period that defines the end of the Stone Age when farming was developed and spread and ends with the invention and use of metal tools (the Bronze Age).



Unit: tonnes/cap-yr

Sources: various



Clearly modern consumption has increased dramatically.

Are there limits?

What characterizes the process of reaching and exceeding a limit?

Who has been instrumental in articulating the actual limits that we face?

"Our ignorance is not so vast as our failure to use what we know."

"The end of the oil age is in sight,' says U.S. petroleum geologist M. King Hubbert.... If present trends continue, Dr. Hubbert estimates, production will peak in 1995 -- the deadline for alternative forms of energy that must replace petroleum in the sharp drop-off that follows." from "Oil, the Dwindling Treasure," National Geographic

(June, 1974)

M. King Hubbert

Hubbert's contention was that after Peak Oil Production occurs, demand will quickly tighten and prices will rise dramatically. Yet, despite higher prices, catastrophic economic consequences will follow because demand – at any price – will progressively outstrip supply at greater rates, leading to the possibility of violent conflict, aggressive supply hoarding and distribution control and volatile prices in oil, oil-related fuels, plastics and many manufactured products. Countries will become increasingly alarmed at the trend and decisive steps will be taken to secure the largest oil reserves (US in the Middle East, China in Africa and Canada). Prolonged recessions will reduce consumption but not enough to offset the structural change in the dynamics between supply and demand of this resource.

The M. King Hubbert Center(Petroleum Engineering Department) at the Colorado School of Mines published in Hubbert Center Newsletter #2002/2003 (July 2002), reminds us that there is a fundamental disagreement between monetary economics and natural scientists on this question. The Newsletter offers Professor M.A. Adelman's opinion that…"Minerals are inexhaustible and will never be depleted. A stream of investment creates additions to proven reserves from a very large in-ground inventory…How much was in the ground at the start and how much will be left at the end are unknown and irrelevant."

This contrast sharply with those predicting a looming energy crisis, especially with regard to transportation energy.

Oil provides 40% percent of global energy needs and 90% of global transportation energy.

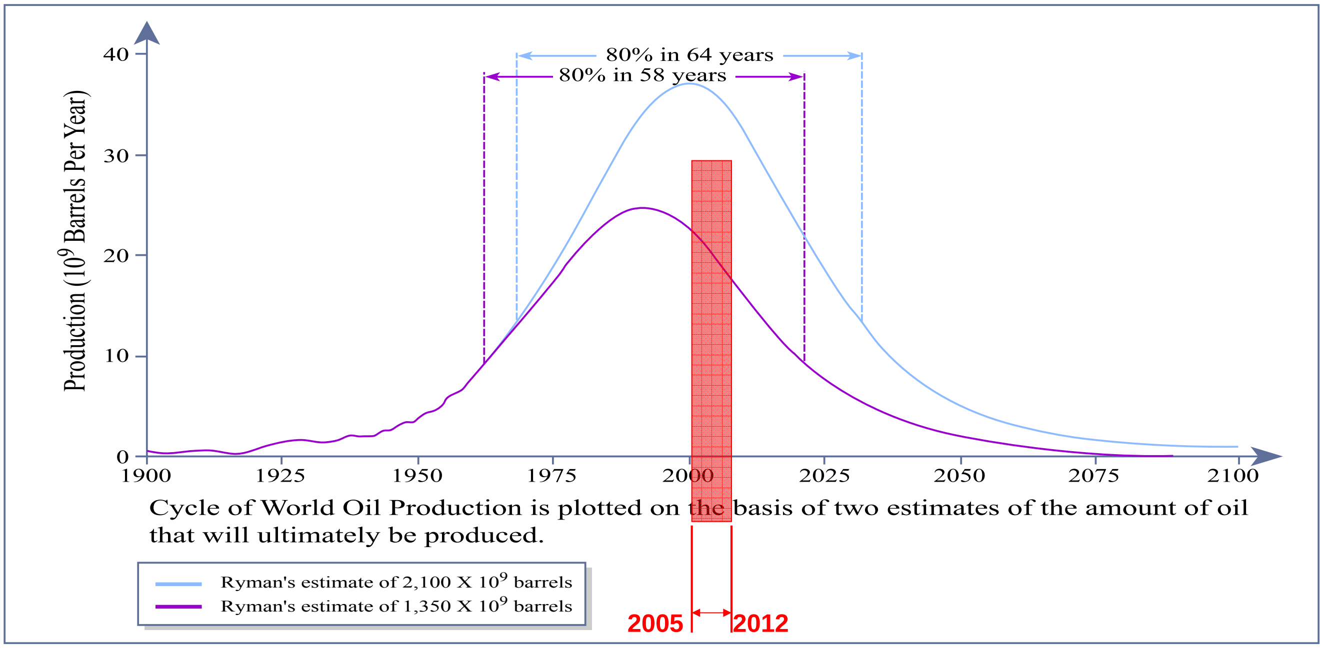


Figure by MIT OCW.

The M. King Hubbert Center(Petroleum Engineering Department) at the Colorado School of Mines published in Hubbert Center Newsletter #2002/2003 (July 2002), predicts that Peak Oil will be reached between 2005 and 2012.

By the way, **Peak Oil Production in the US** was reached in **1970, forty years after Peal Oil Discovery**.

World Peak Oil Discovery occurred in 1964. It follows that it is possible that Peak Oil Production will occur in the time period listed above.

There is greater consensus than ever that this will be the case because of the enormous economic activity of China and India – especially since China has been building roads and producing cars at an alarmingly high rate.

Today, roughly World Oil numbers are as follows:

1. Produced to date: 875 billion barrels (45%)
2. Discovered reserves: 900 billion barrels (47%)
3. Possible undiscovered reserves: 150 billion barrels (8%)

To a reporter asking why he had received the National Medal of Science in 1991, Revelle said “I got it for being the grandfather of the greenhouse effect.”

Roger Revelle

In 1896 Svante Arrhenius, working in Stockholm Sweden, calculated the effect of global temperature change due to changes in atmospheric CO2 concentrations. He calculated that a doubling of atmospheric CO2 would raise average global temperatures about 5-6 degrees C. Around this time, others were noting the fact that industry was increasingly adding CO2 to the atmosphere. Yet, Arrhenius and others working at the time calculated that rates of CO2 emissions would not affect temperatures for many hundreds, if not thousands of years (a conclusion resulting partly from their overestimate of the moderating effects of the absorption of CO2 by oceans). Therefore, warming by anthropogenic CO2 emissions was largely left as a footnote in geological and meteorological research.

In 1938, the theory was picked up by an English steam engineer, **Guy Stewart Callendar** who became interested as a popular movement attempted to explain recent warming of the seasons. He concluded that over the previous 100 years, the concentration of the gas had increased 10% - an amount that he asserted explained the recent warming.

Revelle took up this topic as a by-product of his work in the chemical composition of the sea. Essentially the key component of Revelle’s work was to show that oceans did not absorb nearly as much CO2 as had been previously predicted. Therefore, the buffering of the sea had been overestimated. Revelle was the first to note that exponential increases in anthropogenic CO2 emissions would lead to greenhouse effect warming that…”may become significant during future decades if industrial fuel combustion continues to rise exponentially.”

While others had described the chemistry of global warming and CO2 absorption of he oceans, Revelle was the first to make a direct connection between increased modern human industrial activities and warming due to the greenhouse gas effect.

Revelle writing in 1957 (with **Hans Suess**):

“Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future.”

Curiously, but not inconsequentially, Revelle went on to become very interested in the question of population – that is, the P in the IPAT equation.

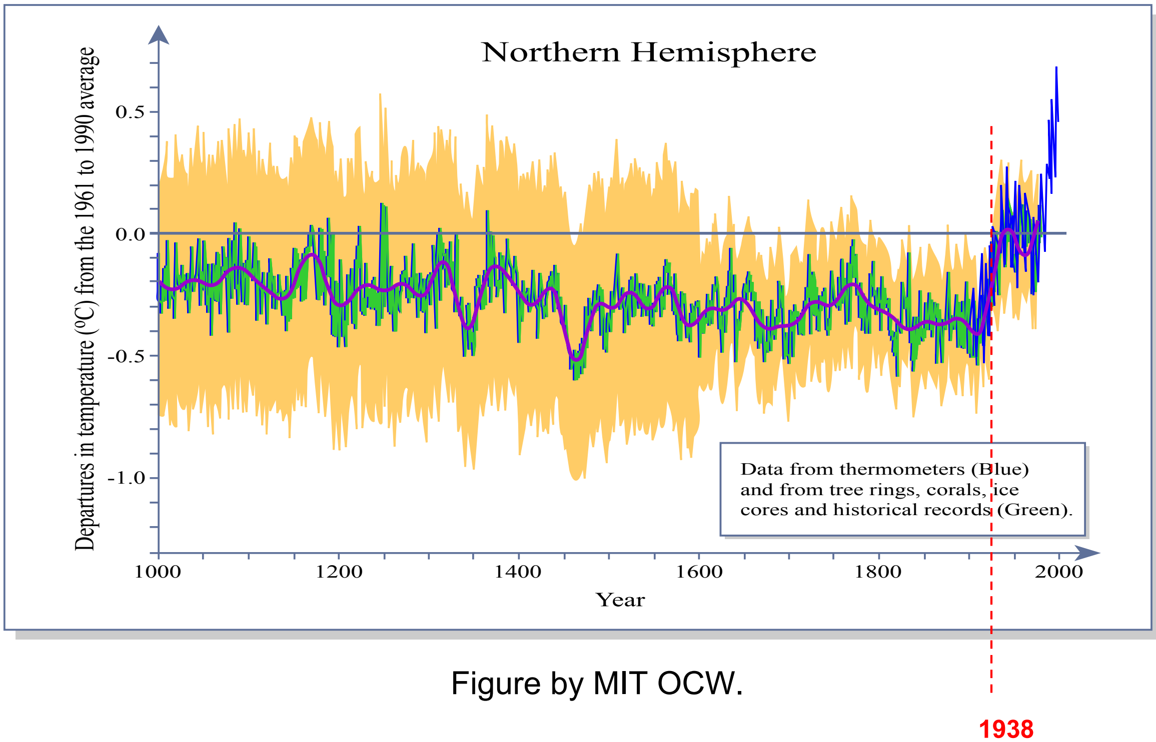


Figure by MIT OCW.

Adapted from: Houghton, J.T. et al. (2001) *Climate Change 2001: The Scientific Basis.* Cambridge University Press, Cambridge, UK: pg. 29

Note the prescience of Callendar who noted the rise in temperatures as a result of CO2 concentrations.

Global Climate Change (IPCC 2007)

The Climate Change 2007 Report of the IPCC states that, "Warming of the climate system is unequivocal…" How have you assimilated this fact into your life, especially since CO2 additions will not likely plateau for some time to come?

Does a lack of will have a solution?

Will knowledge of the systems behavior aid in understanding the need for change (or is it just too complex)?

Source (reading): IPCC 2007. *Climate Change 2007: The Physical Science Basis*. IPCC Secretariat.

"The necessity of taking the industrial world to its next stage of evolution is not a disaster – it is an amazing opportunity. How to seize the opportunity, hot to bring into being a world that is not only sustainable, functional, and equitable but also deeply desirable is a question of leadership and ethics and vision and courage, properties not of computers models but of the human heart and soul."

Limits to Growth – The 30-year update. (2004)

Donella Meadows

Meadows comes from the line of researchers synthesizing methods and tools for systems analysis. Worked with one of the preeminent systems people – Jay Forrester at MIT.

Kay, (An ecosystem approach for sustainability) and Holling (Understanding the complexity), both establish the intellectual and theoretical foundation for systems analysis. Others then have taken these theories and tried to develop tools and other instruments that allow application in the field.

Meadows, D., Randers, J. and D. Meadows. 2004. Limits to Growth – The 30-Year Update. Chelsea Green.

Excerpt

It's very courageous to provide an update on a prediction of the future because predictions of the future are easy to make and easy to defend – they are predictions.

In the 30 year update, Meadows, Randers and Meadows reassert their contention that anthropogenic activities are approaching possibly catastrophic conditions resulting from dramatic 'overshoot' of consumption versus natural capital.

Read Excerpt from Limits to Growth.

Pages x-xiv, Author's Preface

Complex systems (Holling)

How are limits and the adaptive capacity of a complex system related? (Holling, Meadows)

What is your assessment of Holling's diagrammatic representations of hierarchies and adaptive cycles?

What is meant by a panarchy?

Source (reading): Holling, C.S. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems*. 4:390-405.

Question 1:

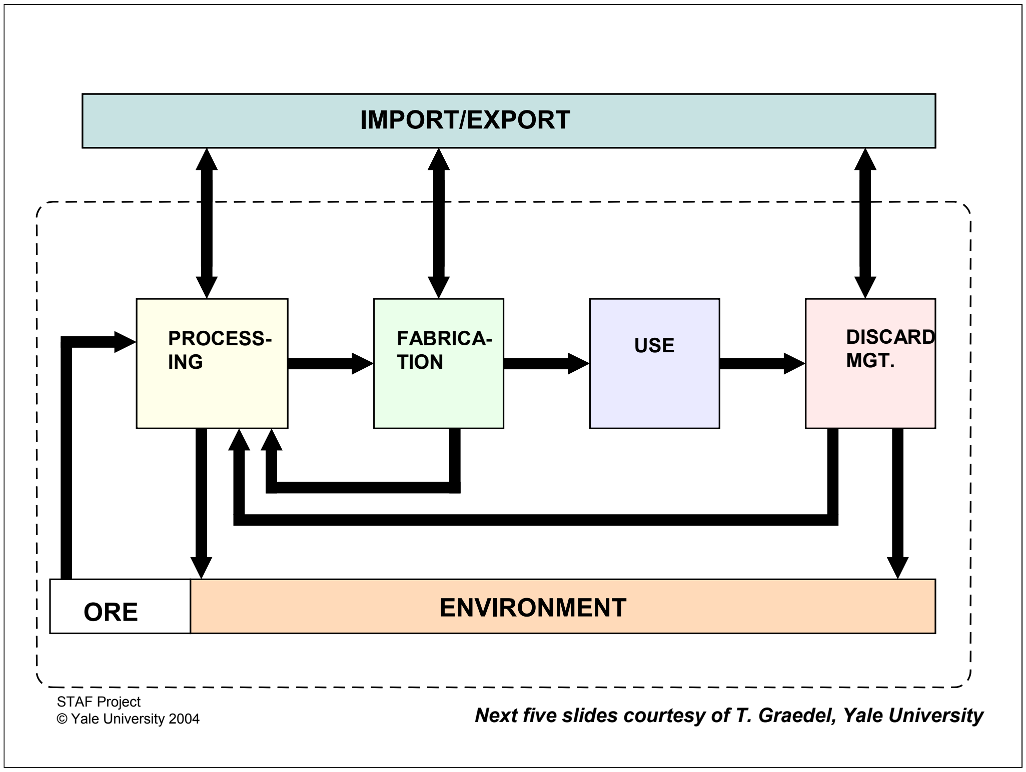
See Holling: "Potential, or wealth, sets limits for what is possible – it determines the number of alternative options for the future." Therefore, it would seem that adaptive capacity, is somewhat dependent on wealth in that, the resilience of the system is greater when there is greater access to larger forms of wealth.

Also, given overshoot conditions, it is likely that a system will be less resilient as it carries less capital to use in adjusting to changes. Thus resilience and wealth are intimately linked.

Example: City of New Orleans. The system of levees was not resilient partly because the actual wealth of the system (as a measure by the quality and extent of the construction of the levees) was very low.

Holling's diagrams, while seemingly representative of his theories, seem unnecessarily complex and convoluted.

Panarchy is the 'meta'-hierarchy of a complex system. Holling defines it as the, "evolving nature of complex adaptive systems. Panarchy is the hierarchical structure in which systems of nature (for example forests, grasslands, lakes, rivers, and seas) and humans (for example, structures of governance, settlements, and cultures), as well as combined human-nature systems (for example, agencies that control natural resource use)… are interlinked in never-ending adaptive cycles of growth, accumulation, restructuring, and renewal."



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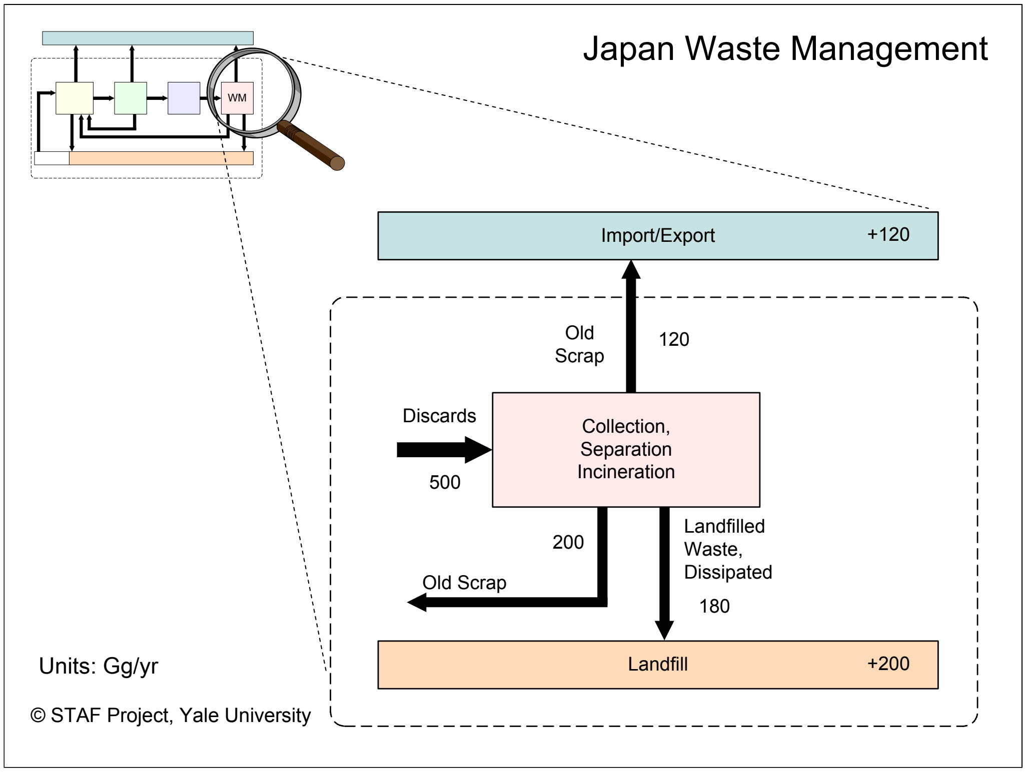

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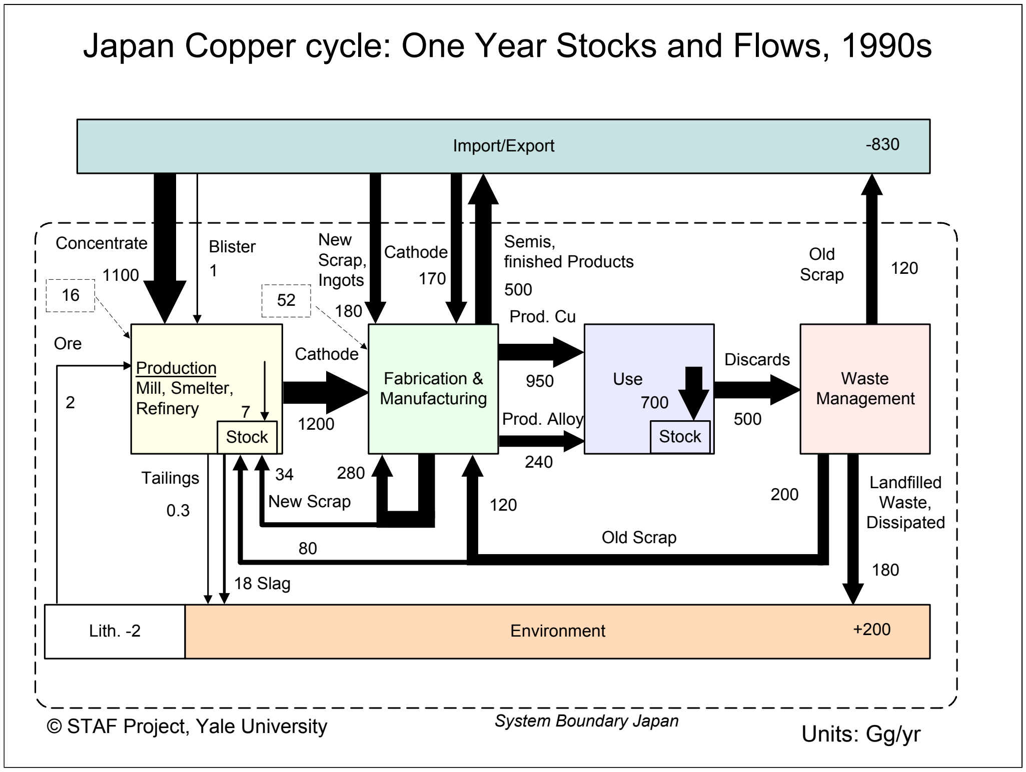

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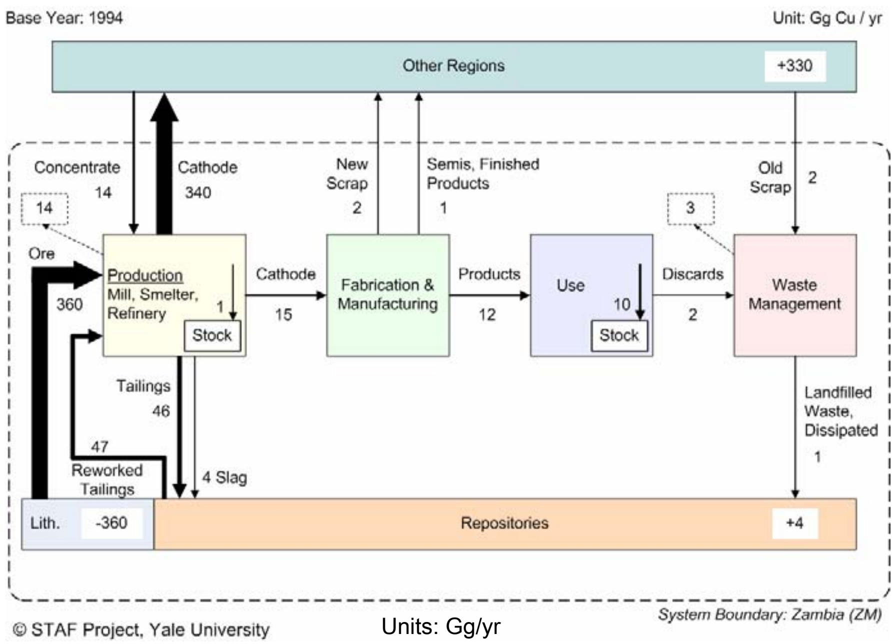
Zambia's Copper Cycle: One Year Stocks and Flows, 1994



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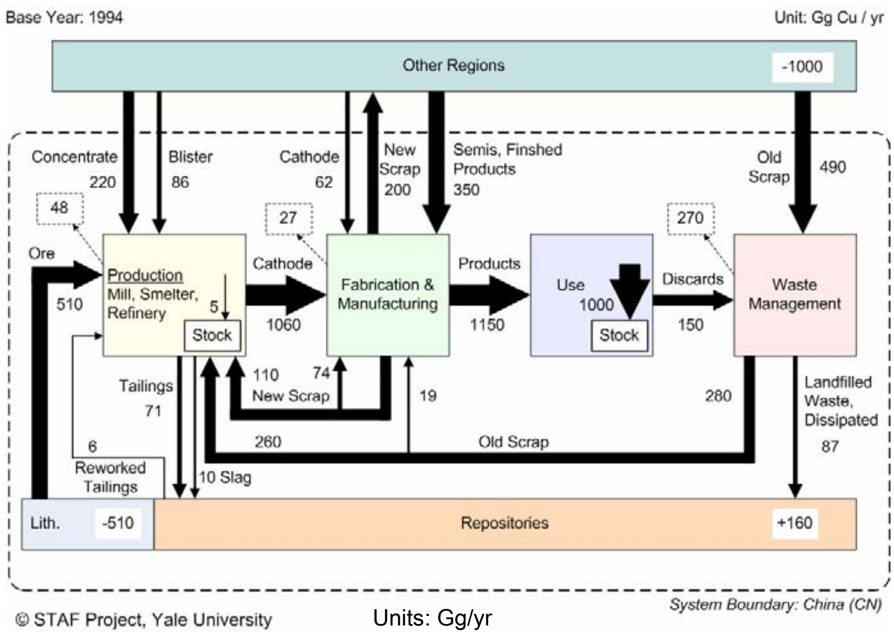
China's Copper Cycle: One Year Stocks and Flows, 1994



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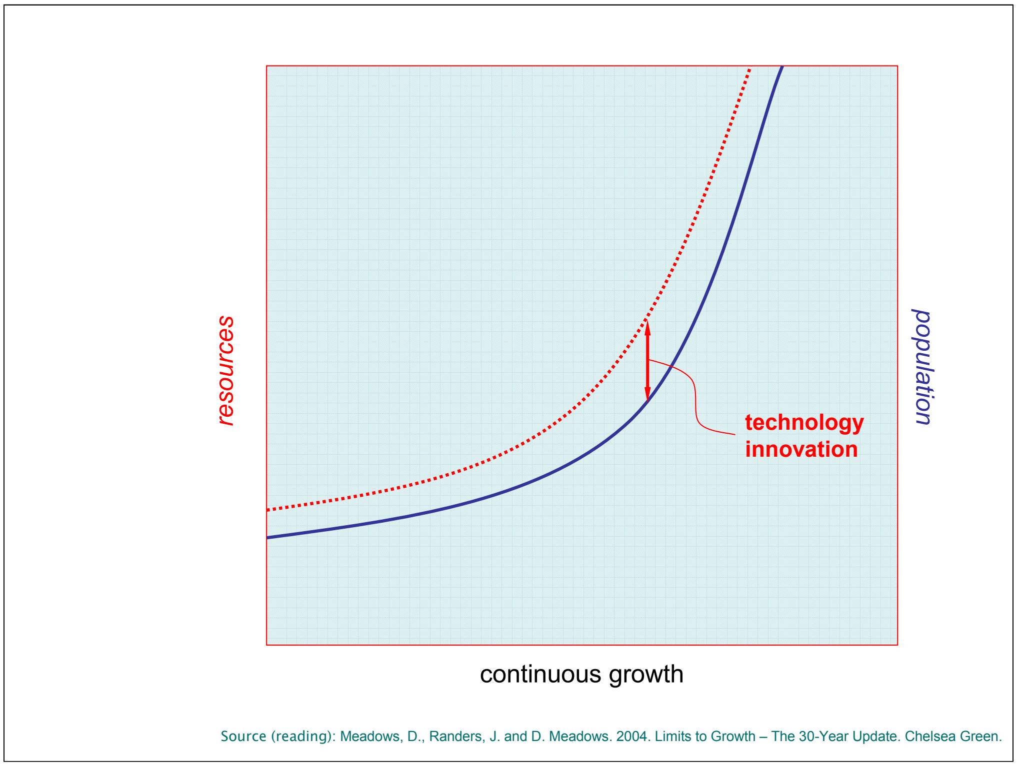
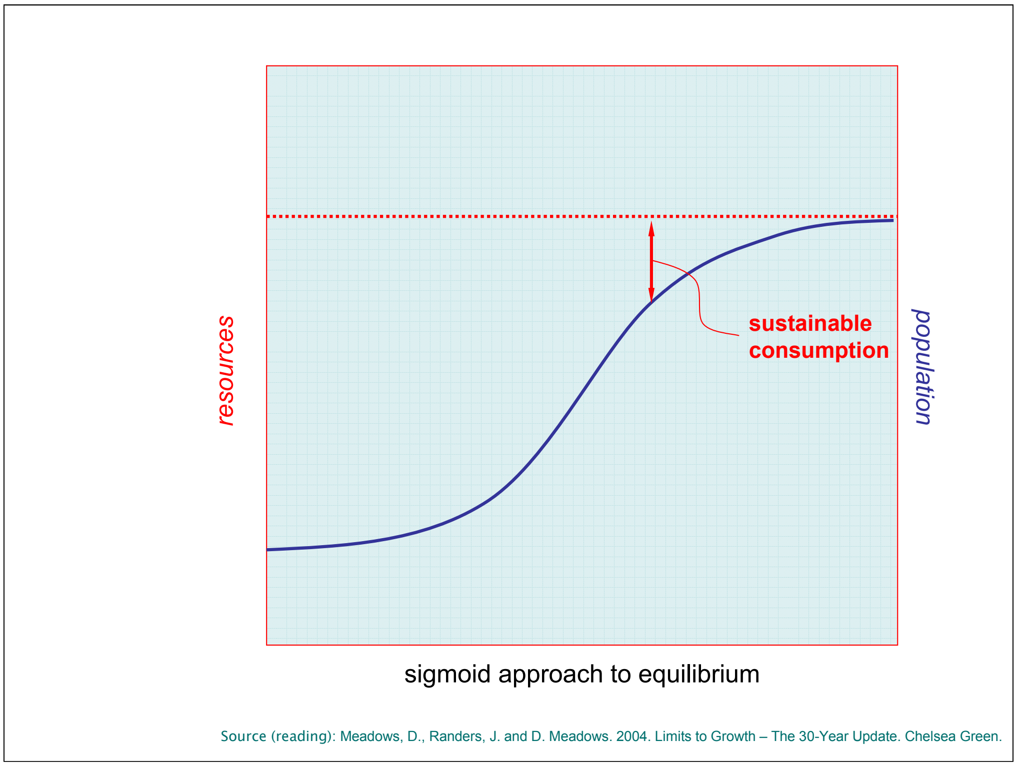
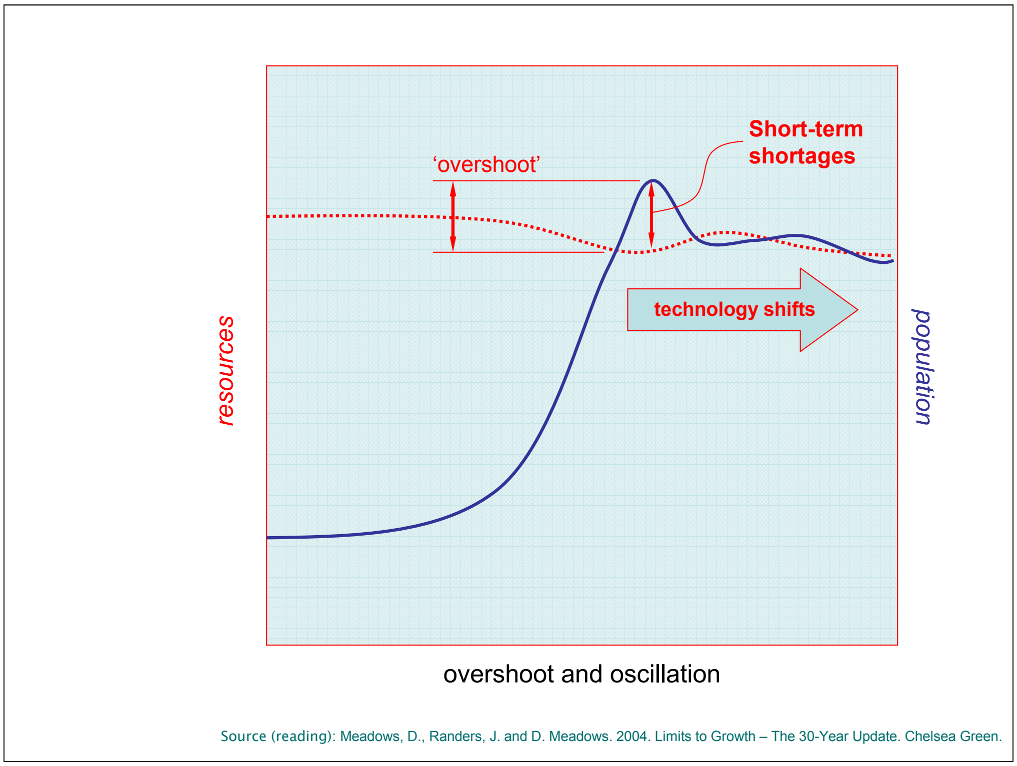


Limits to Growth specifies several typologies of curves that relate resources and population. Another way to consider these curves is resources and consumption.

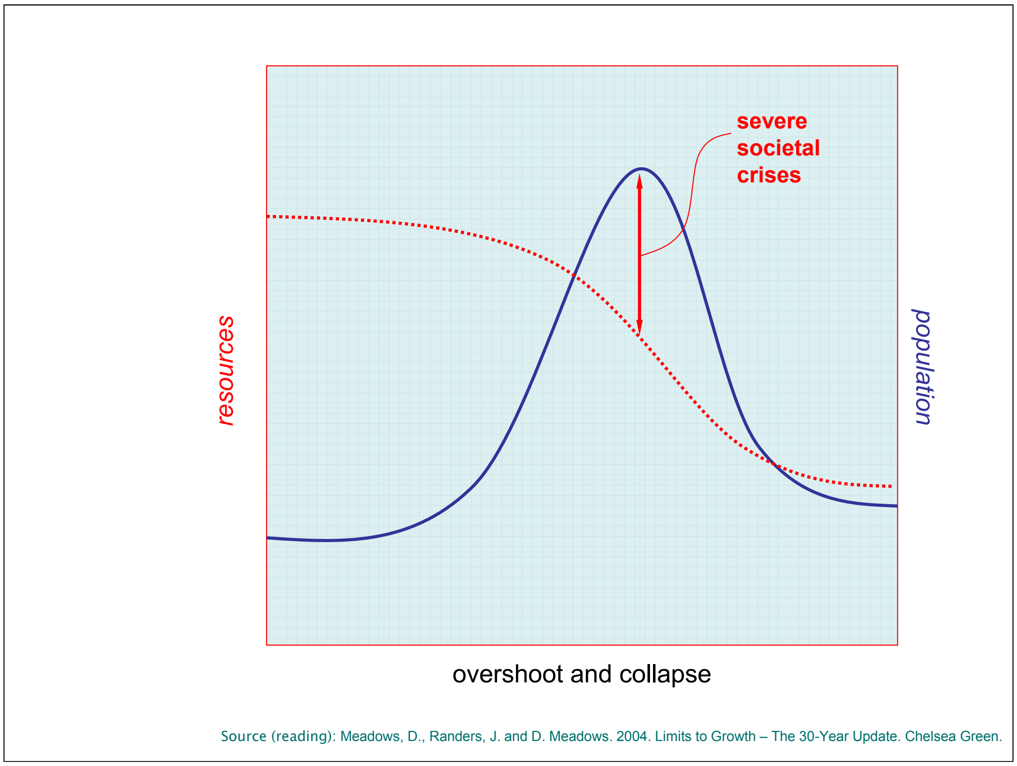
These curves illustrates the case in which **technology is always ahead of population increases** and thus, growing consumption demands.



These curves illustrate the condition in which **long-term sustainable consumption is slowly approached**. A convergence of the population and resource curves suggests that a sustainable situation has been achieved (one way of another).



These curves demonstrate both the **independence of the consumption and resource curves that typifies** many real-world situations. They also illustrate the delayed feedback (or lag time) between overshoot and correction. Again here the situation resolves to correct itself along a sustainable path in which demand is satisfied by sustainable supply.



What characterizes overshoot and collapse is not only societal crises, huge political and economic disruptions, conflict and massive social disorder, but a vast and quick degradation of resource supplies. Thus a rapid downturn in the resource curve.

"To our knowledge, no government operates comprehensive accounts to assess the extent to which human use of nature fits within the biological capacity of existing ecosystems. Assessments like the one presented here allow humanity, using existing data, to monitor its performance regarding a necessary ecological condition for sustainability: the need to keep human demand within the amount that nature can supply."

Wackernagel, M. et al. 2002. Tracking the ecological overshoot of the human economy. PNAS. Vol.99, No.14:9266-9271.

Mathis Wackernagel

Mathis Wackernagel and the ecological footprint.

So, now let's turn to the ecological footprint.

From Living Planet 2006 (page 38)

"The ecological footprint measures the amount of biologically productive land and water area required to produce the resources an individual, population, or activity consumes and to absorb the waste they generate, given prevailing technology and resource management."

This area is expressed in **global hectares** – that is, a hectare of land of average productivity. Different kinds of land (forest, crop-land, wetland) have different productivity levels and therefore these need to be weighted to arrive at a total world biocapacity.

The ecological footprint does not:

•Attempt to predict the future – it is a snapshot of the recent past,

•Account for non-renewable resource consumption (but renewable resources used for extraction and processing is counted),

•Account for intensity of use of any particular area,

•Pinpoint specific location-based biodiversity issues,

•Evaluate social and economic issues.

Also, the ecological footprint does account for the biocapacity (mostly forests) needed for natural sequestration of CO_2 that is not sequestered by humans less that absorbed by the oceans. One 2003 global hectare can absorb the CO_2 released by burning approximately 1,450 litres of petrol per year.

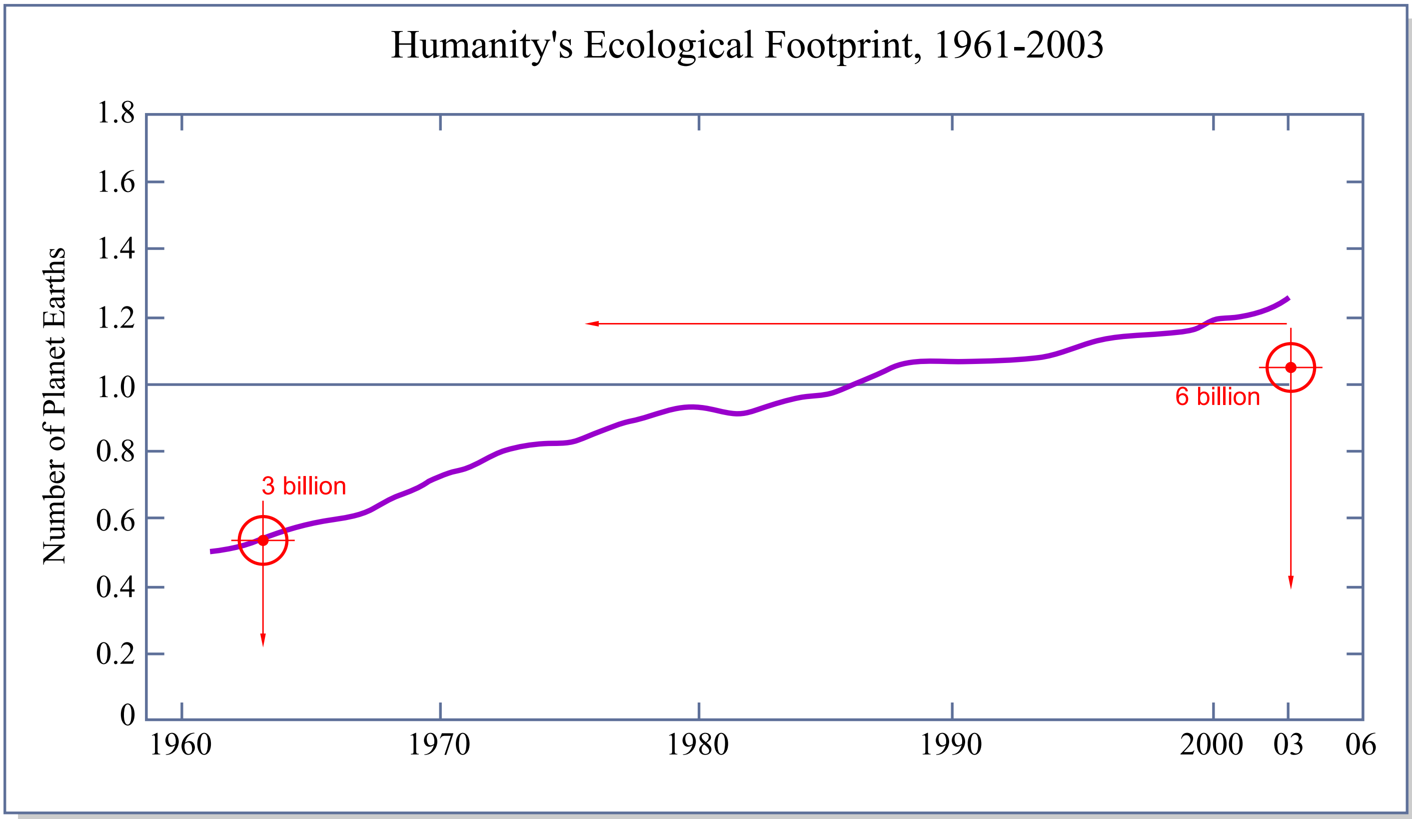


Figure by MIT OCW.

Ecological Footprint

The ecological footprint – ***humanity's demand on the biosphere in terms of the area of biologically productive land and sea required to provide the resources we use and absorb the wastes we produce.***

Humanity's footprint first grew larger than the global biocapacity in the late 1980s.

Today, per capita ecological footprint demand = 2.2 gha/person. (ha = hectare, 100 x 100 meters or 2.47 acres)

Biocapacity per capita = 1.8 gha/person

Demand exceeds supply by about **25 percent** today (2003).

That is, we would need **1.25 earths** to satisfy our needs (1.25 x biologically productive land area).

Or another way to say it – we would need one year and three months for the earth to produce the ecological resources we used in that year.

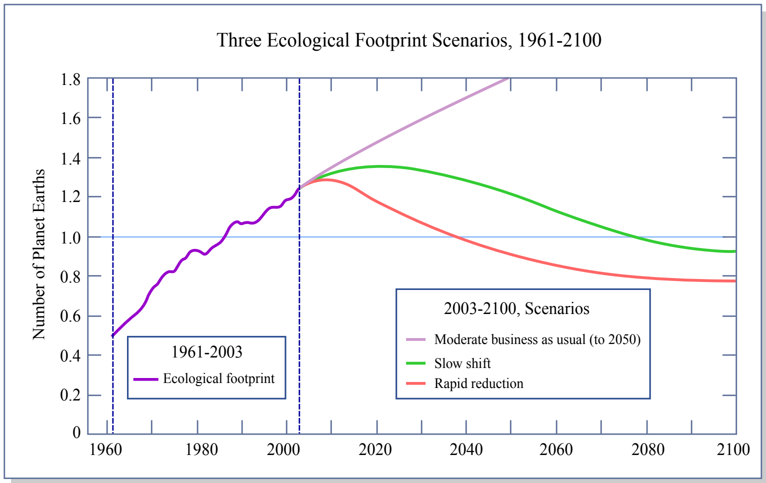


Figure by MIT OCW.

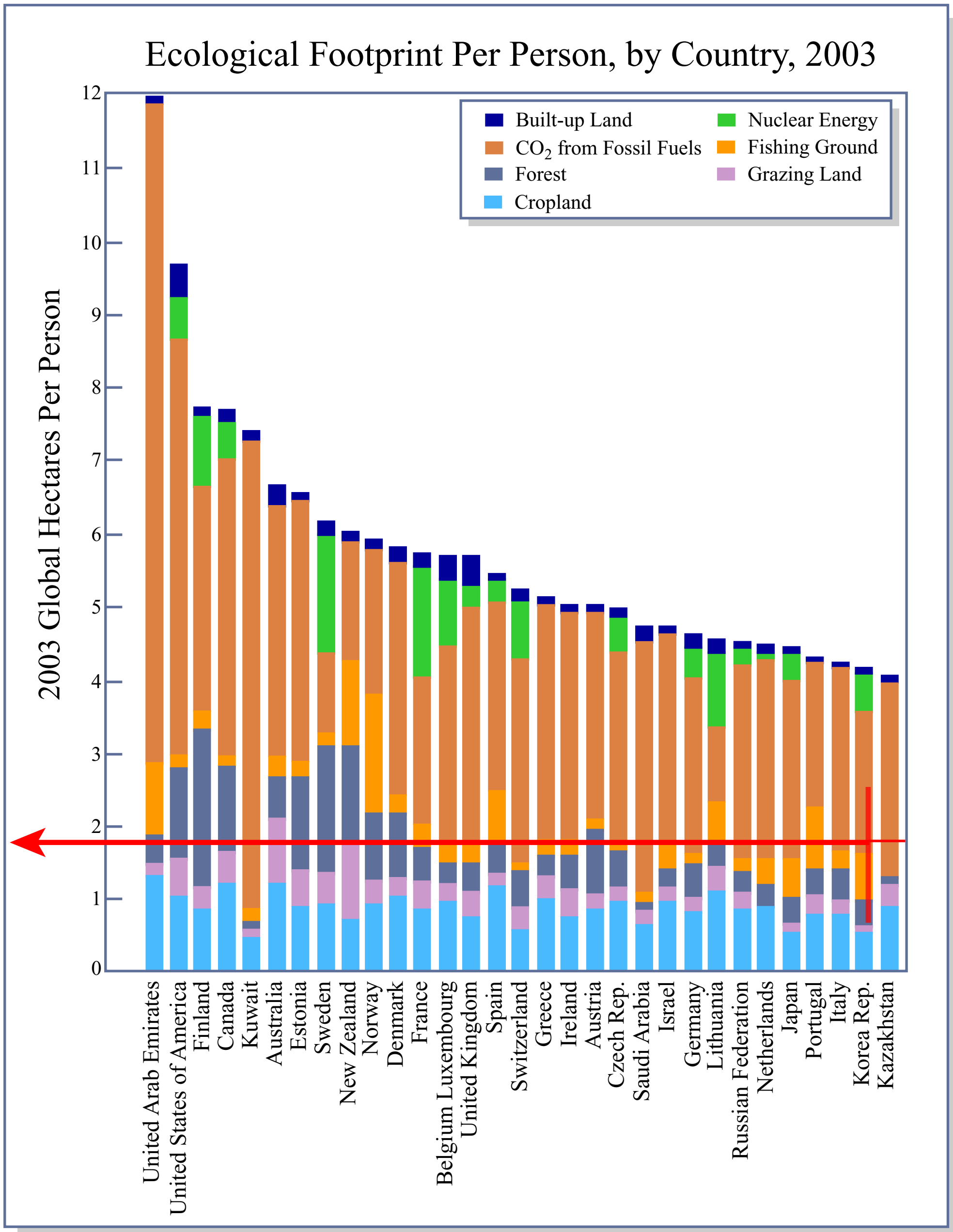
Adapted from (reading): Living Planet Report

Overshoot scenarios

Ecological Demand and Supply in Selected Countries, 2003				
	Total ecological footprint (million 2003 gha)	Per capita ecological footprint (gha/person)	Biocapacity (gha/person)	Ecological reserve/deficit (-) (gha/person)
World	*14 073*	*2.2*	*1.8*	*-0.4*
United States of America	2 819	9.6	4.7	-4.8
China	2 152	1.6	0.8	-0.9
India	802	0.8	0.4	-0.4
Russian Federation	631	4.4	6.9	2.5
Japan	556	4.4	0.7	-3.6
Brazil	383	2.1	9.9	7.8
Germany	375	4.5	1.7	-2.8
France	339	5.6	3.0	-2.6
United Kingdom	333	5.6	1.6	-4.0
Mexico	265	2.6	1.7	-0.9
Canada	240	7.6	14.5	6.9
Italy	239	4.2	1.0	-3.1

Figure by MIT OCW.

Adapted from (reading): Living Planet Report

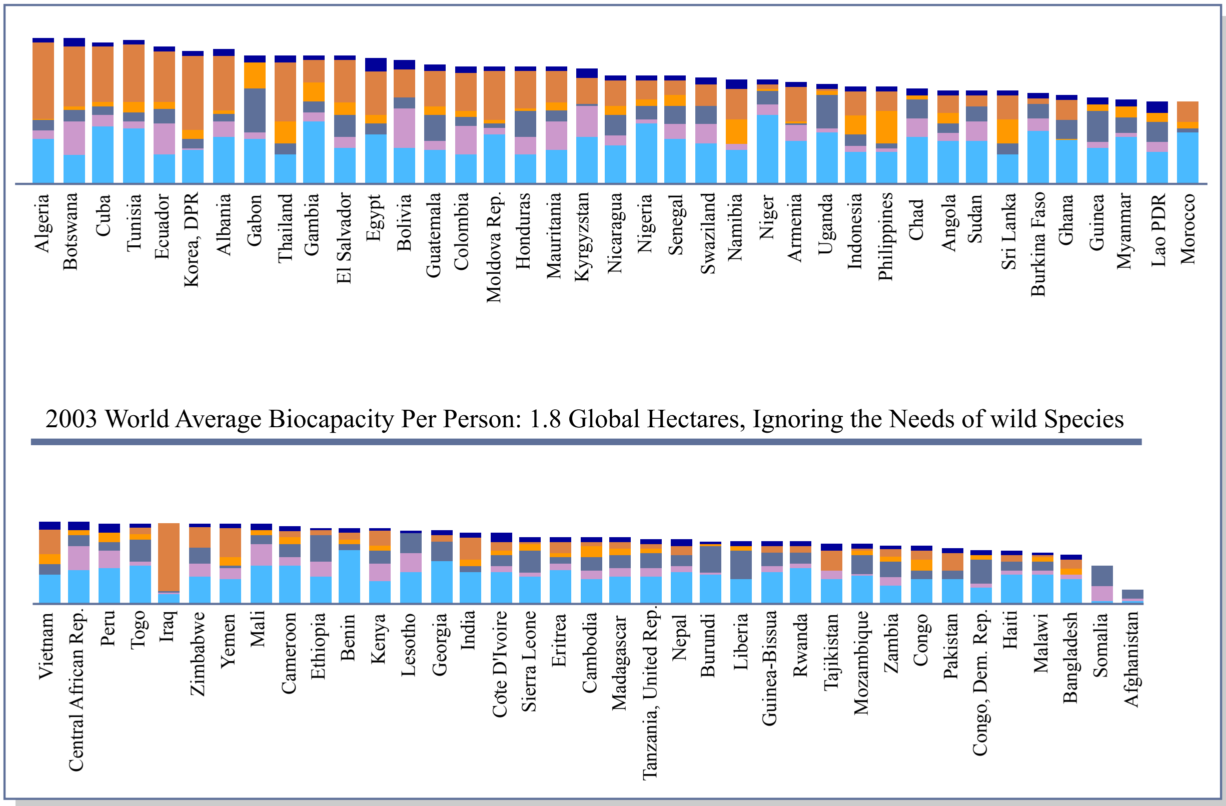


1.8 gha/person

per capita global biocapacity

Adapted from (reading): Living Planet Report

Figure by MIT OCW.



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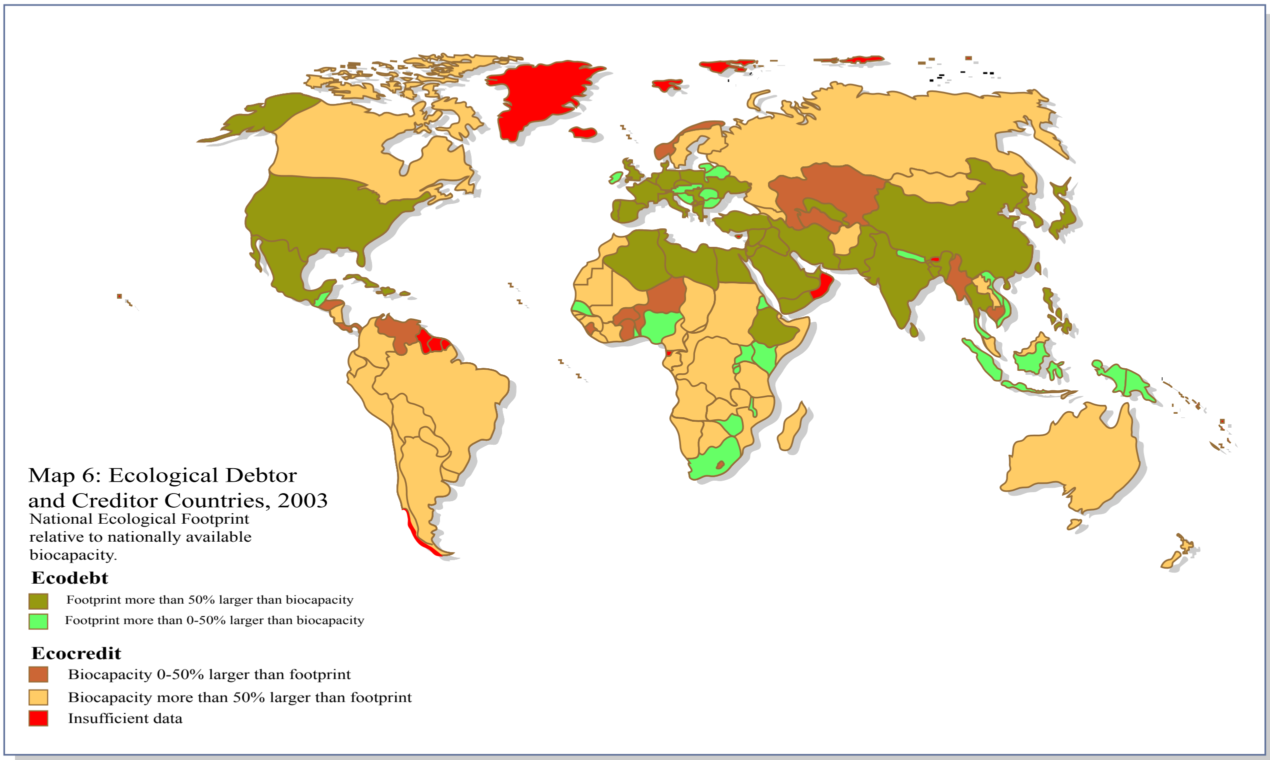

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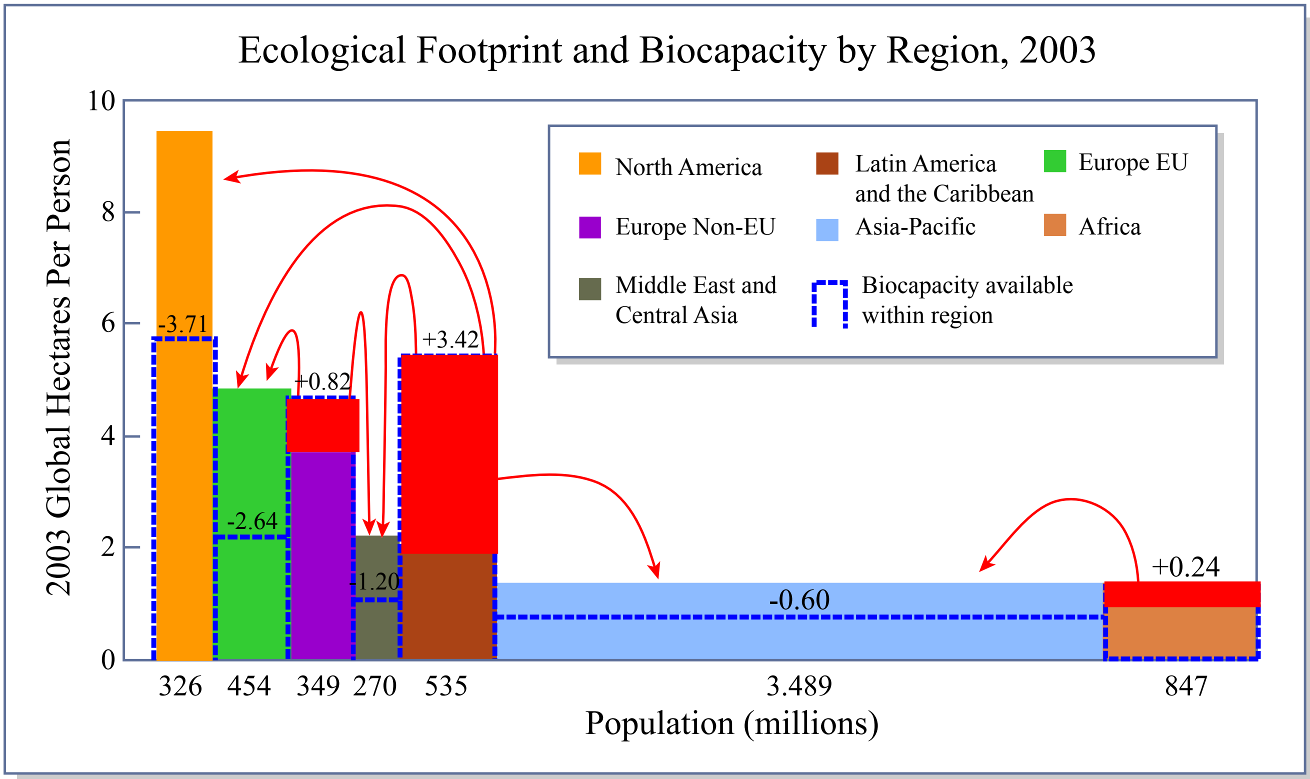

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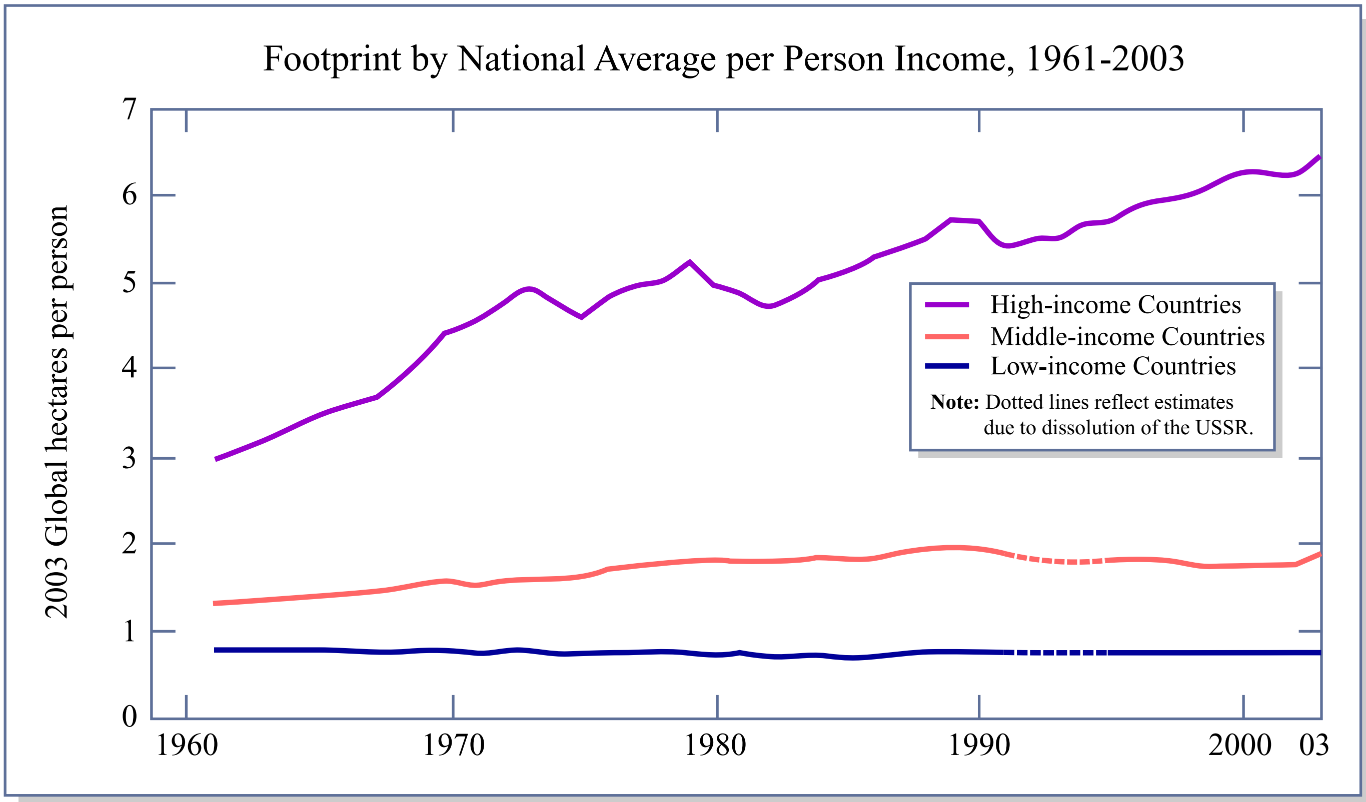

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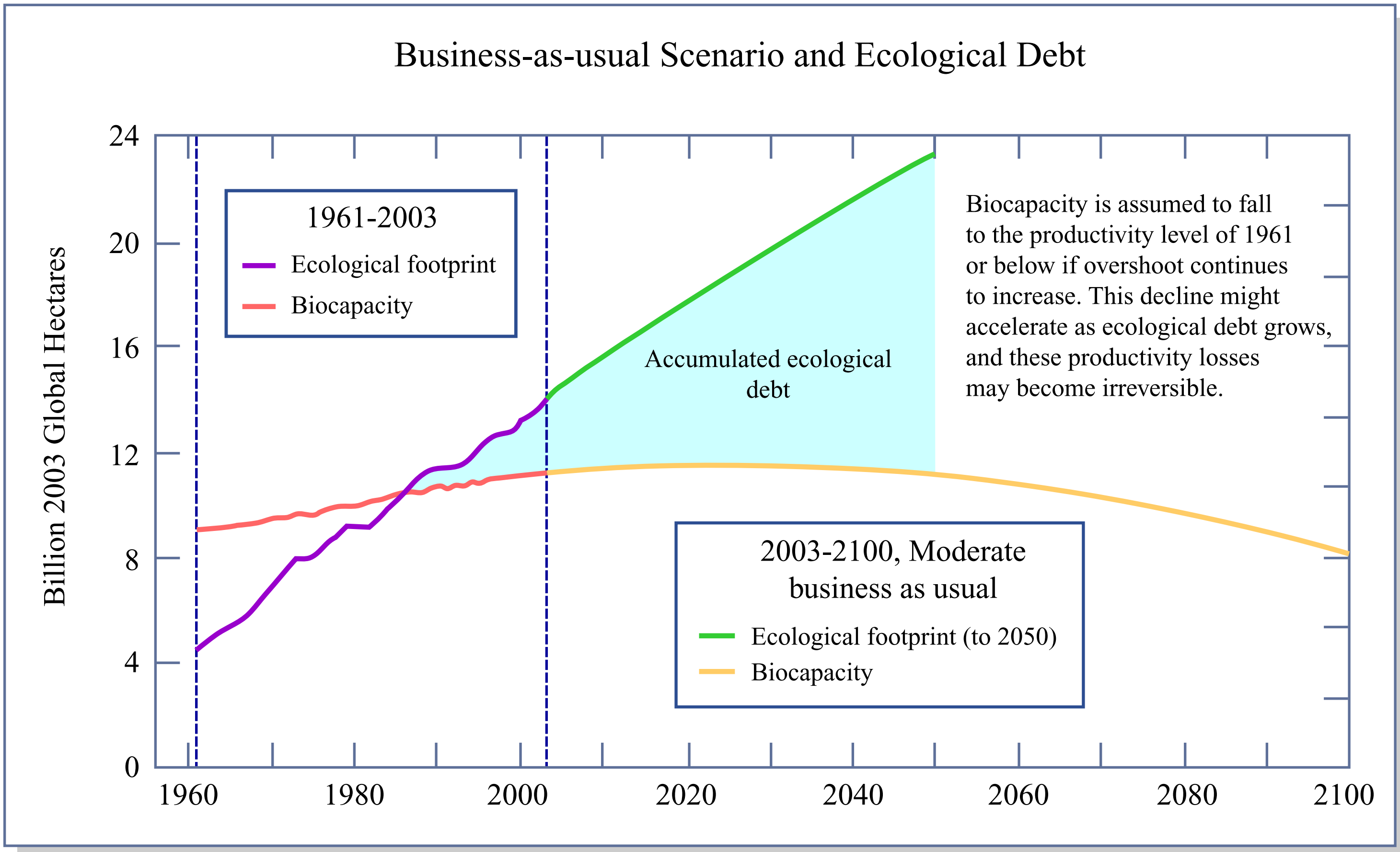
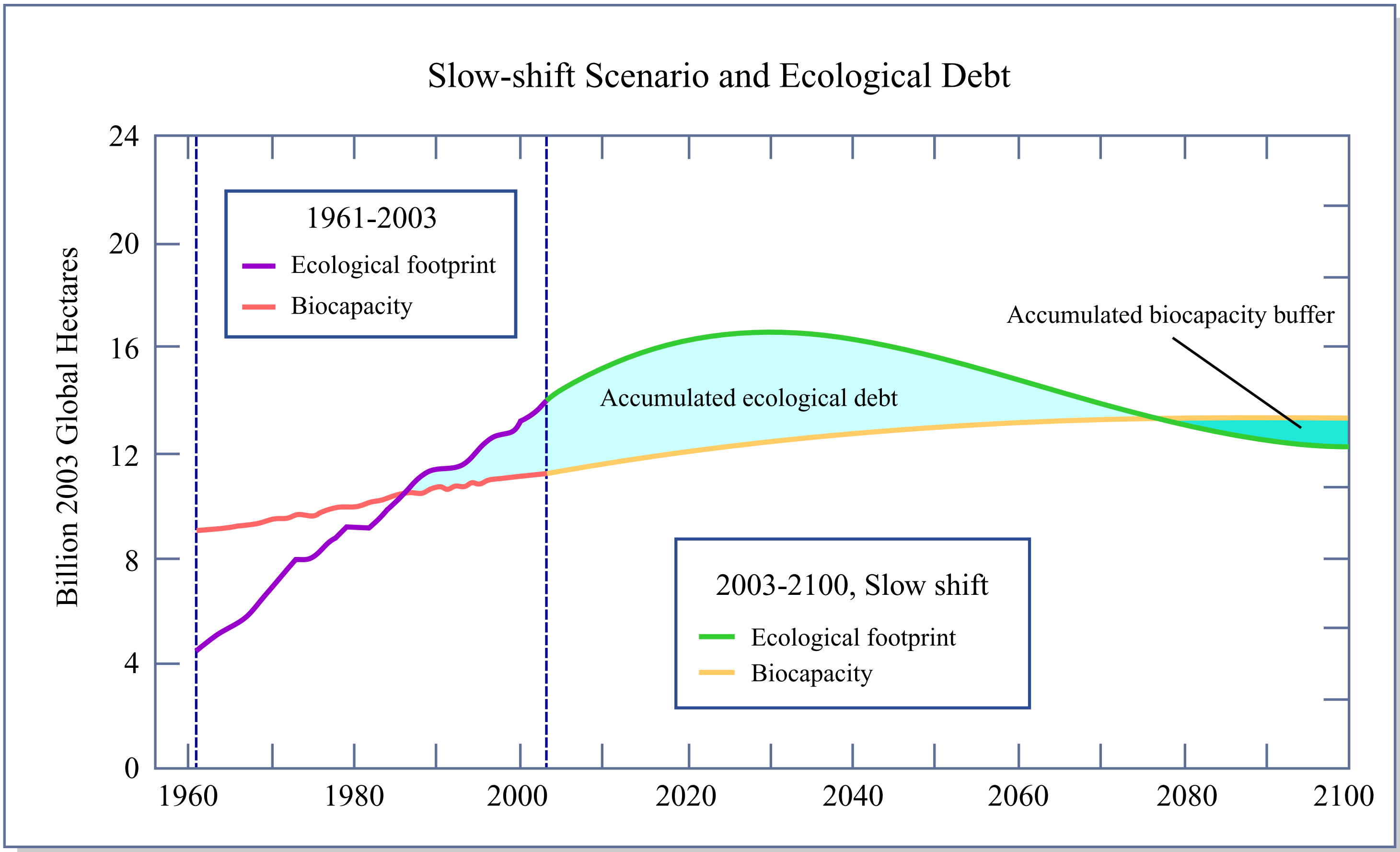


Figure by MIT OCW.

Adapted from (reading): Living Planet Report

Notice the fall in the biocapacity curve due to overburden (deforestation, desertification, eutrophication, etc.)



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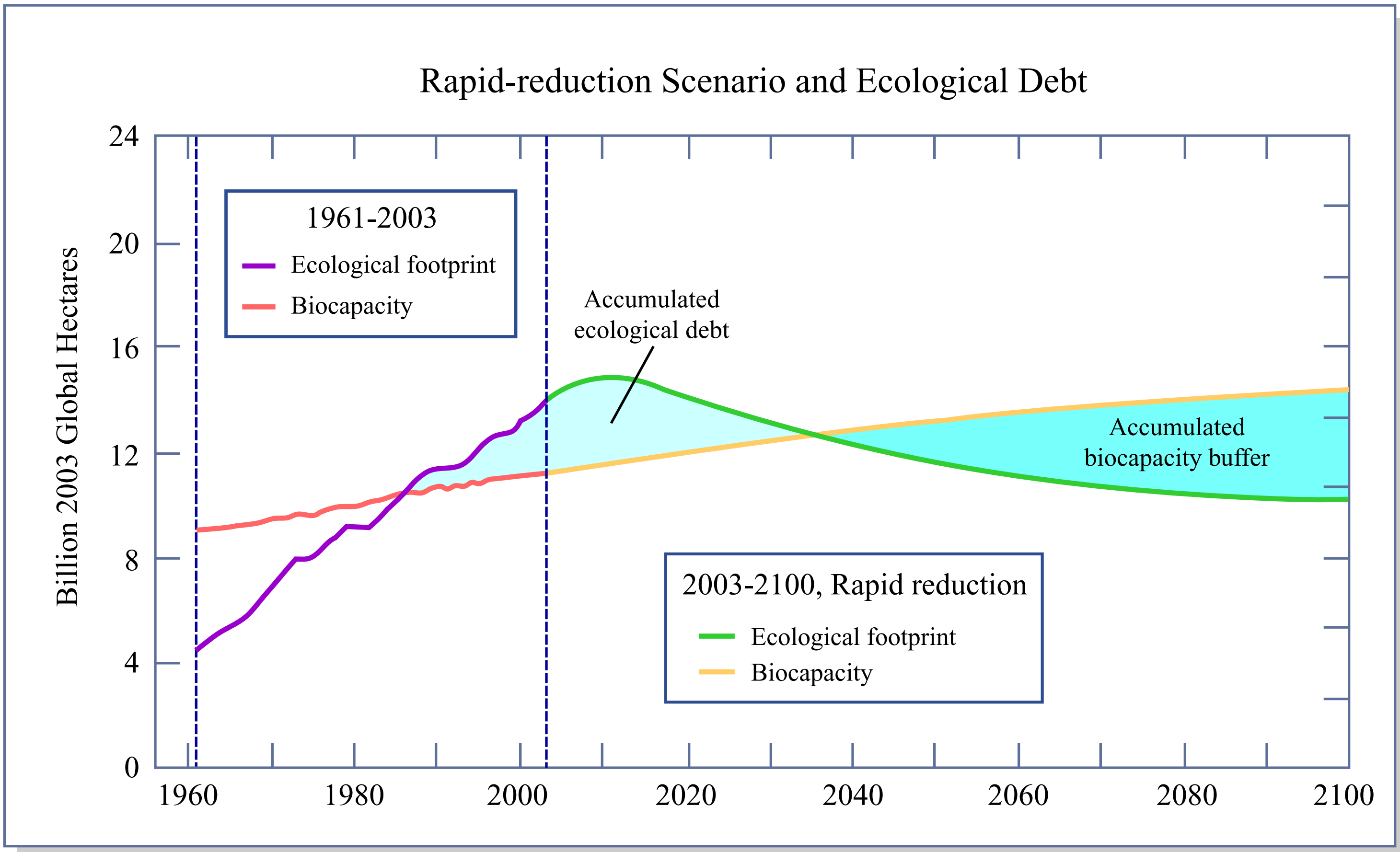

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