Limits to Sustainability

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Aims of Talk

- Consider the limits to concept of sustainability for the Earth’s biosphere and human civilization
- Discuss five concerns
- Show why coastal areas, especially deltas, are a particular dilemma vis a vis the present perception of sustainability
- Frame how the sustainability concept might be most useful
- Offer more questions than answers to promote critical thinking
Title of Talk Borrows from this Series
The Coastal “Triple Whammy”

Interactive Drivers, e.g.:
- Climate change
- Hydrologic changes
- Direct human impacts
- Demographic change

Coastal Impacts:
- Relative sea level rise
- Eutrophication
- Land-use changes
- Ecosystem changes

From the Land
- Sediments ↓
- Nutrients ↑

From the Sea
- Eustatic sea level ↑
- Severe storms ↑
Definitions of Sustainability can be Ambiguous

• Are often very descriptive and vague
• Are typically qualitative
• Do not include either clear metrics or assessment criteria
• Can be logically erroneous – the premise is often the basis for the argument (“false premise”) or the proof of a proposition is based on a premise that itself requires proof (“begging the question”), e.g. that endless growth is achievable
• Do not take into account that “a chain is no stronger than its weakest link”
• May be predicated upon unanticipated, unexpected, unlikely, rare or completely unpredictable occurrences (“gray swan” and “black swan” events)
The word "sustainable" is unsustainable.
UN Brundtland Commission - the “Standard” Definition

• Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

• The Three “Pillars of Sustainability” Identified in the Brundtland Report are:
  1. Economic Growth
  2. Environmental Protection
  3. Social Equality

The above definition assumes that the three pillars of sustainability are simultaneously achievable, but is growth always sustainable? What are the limits?
Herman Daly on Sustainability
(As Cited in Beyond the Limits)

• For a renewable resource - soil, water, forest, fish - the sustainable rate of use can be no greater than the rate of regeneration of its source.

• For a nonrenewable resource - fossil fuel, high-grade mineral ores, fossil groundwater - the sustainable rate of use can be no greater than the rate at which a renewable resource, used sustainably; can be substituted for it.

• For a pollutant - the sustainable rate of emission can be no greater than the rate at which that pollutant can be recycled, absorbed, or rendered harmless in its sink.
Sustainability (or Lack Thereof) from an Individual Perspective

• I want to have in the future at least what I have today
• I want my children to be better off than I am
• Carpe diem, the future is not my problem
• He who dies with the most toys wins
• Rarely, is it: I want to enjoy a happy and productive life, but perhaps with a less material lifestyle
Considers economics to be governed by stocks, flows and transformations of energy and materials...

Thus...

Human economies are ultimately biophysical systems governed by the Laws of Thermodynamics, market forces, goods and services notwithstanding.
The Relevance of Thermodynamics

1. Law of conservation of matter and energy
2. Law of entropy

Significance and Ramifications:
• Energy can neither be created nor destroyed
• No energy transformation can be 100% efficient
• Energy passes from a hotter body to a colder body
• Energy dissipates as heat
• Perpetual motion machines cannot exist
How is this rather constrained view of sustainability relevant to society

THE BOTTOM LINE:

- Growth in human annual consumption above rate at which solar energy can be assimilated by adjacent land and sea eco-geophysical systems must be viewed as UNSUSTAINABLE

Ok... then what... questions are important

- How long can consumption at a given rate last for a given population?
- How is the total consumption increasing or decreasing?
- What are the upper limits of upon which we can draw from ecosystems?
- Can we use our knowledge of thermodynamic laws to design better development patterns, do benefits of new investments outweigh costs?
Concern 1: Human Demography

• Global population growth rate and age structure
• Population distribution and the migration to the coasts
• Human impact factor and the increasing footprint of each individual

\[ \text{Impact} = \text{Population} \times \text{Impact Factor} \]
Human Population: Too many of us?
Some Disturbing Facts about Population

- From November 16 online estimator at U.S. Census Bureau:  
  *World population is now about 7,286,250,000*

- *Estimate* of population when I was born is 2,228,135,537

- That is approximately a *325% increase in my lifetime* and double the population in 1968 when Paul Ehrlich published his bestselling book!
Coastal Demographic Trends

• Globally about 630 million people live below 10m (above sea level)
• 11 of 15 the world’s cities of over that are larger than 10 million are situated below 10m
• 340 million people are living in urban areas below 10m
• China alone has 143 Million people living in areas below 10m (11% of the total population)
• China 78 million people living in urban areas below 10m

Concern 2: Human impact factor is increasing

- Increases in wealth bring the benefits of modern technology to whole world
- Automobiles are a good proxy for this
- Other major factors include changes to human food systems (more energy intensive), use of air conditioning (more energy intensive), urbanization (unlikely to be more sustainable), and other benefits of modern society
Global Auto Growth

Dargay, Gately and Sommer (2006)
Where the Cars Are
(Source: International Organization of Motor Vehicle Manufacturers)

Motorization rate 2011—WORLDWIDE

NAFTA: 644
EU 27/EFTA: 559
RU/TK/Other Europe: 241
J&SK: 534
C&S America: 142
AFRICA: 41
Asia (exc J&SK)/Oceania/Middle east: 62

Average rate: 165 veh./1000 inh.

http://www.oica.net/category/vehicles-in-use/
Concern 3: Climate Change and Eustatic Sea Level Rise

- Climate changes - it always has, always will
- Climate deniers notwithstanding, burning of fossil fuels and CO$_2$ emissions appear to exacerbate global warming
- Plenty of evidence for eustatic sea level rise now exists, irrespective of cause, anthropogenic or natural
Components of Relative Sea Level Rise

Relative Sea Level = Eustatic Sea Level (sea itself rises) + Isostatic Subsidence (land sinks)
SEA LEVEL RISE IS ACCELERATING...

Figure 29. Sea level change based on satellite altimetry data (Nerem et al., 2010, updated at http://sealevel.colorado.edu) and tide gauge data (Church and White, 2011) with the latter change rate multiplied by 0.78, as required to yield a mean 1901–1990 change rate 1.2 mm yr\(^{-1}\) (Hay et al., 2015).

From Hansen et al. 2015
Relative Sea-Level Trends

Measured by tide gauges
Concern 4: Alteration of Hydrologic and Sedimentary Systems on Land

• Human engineering to alter water structure for use and safety concerns

• Increased human consumption and use of water resources - can result in all water being used before it reaches the sea (Colorado River flow has been vastly reduced)

• Climate change - drought, alterations in soil water retention, earlier thaws, later freezes, etc.
Dams: Major Renewable Energy Source
Human Alteration of Natural Waters

- Activities
  - Build dams, levees, dykes, canals, etc.
  - Enhance deforestation and agriculture
  - Irrigate
  - Construct pavement; urbanize

- Water control structures have tripled water residence time in impoundments and reduced water held in upland sediments

- Humans now use 17% of global river volume

- Reservoirs intercept more than 40% of global river discharge (and perhaps 1/3rd of sediments, too)
Control of Hydrologic Processes to Support Coastal Urban Development

- High risks of living in the coastal zone combined with large populations and the need for consistent and predictable transportation routes has led to grand scale engineering of coastal waterways.
  - Damming of rivers
  - Channelization of Coastlines
  - Levees and Jetties
  - Constant Dredging of Ports
- The damming of the world’s rivers is pervasive (>50,000 large dams now span the watersheds on 6 continents).
- This construction is both highly energy dependent and often vulnerable to sea-level rise
Value and Risks: World’s Deltas

- The World Delta Database lists about 75 deltas worldwide, many at risk
- Deltas are easy places to locate cities: more than 500 million people (1 of every 14 humans) worldwide live on deltas, many in sprawling megacities such as Shanghai, Dhaka and Bangkok
- High economic value (trillions of dollars)
- Very rich soils, excellent farmland
- Good transportation access to inland areas
- Areas for fossil fuel development
Sediment Input Deficiency Concerns

IN THE RED
Most large- and medium-sized deltas cannot grow fast enough to keep up with sea-level rise in the next century. Damming reduces sediment load further and pushes more deltas into the red.

Source: Giosan et al. 2014
THE MISSISSIPPI RIVER LEVEE SYSTEM
Declining Sediment loads in the Lower Mississippi River.

- Prior to 1960 sediment loads consistently above 500 mg/l
- From 1960 to 1990 sed. loads have fallen to 200 mg/l
- The 40-70% decline in the last half century has been attributed to the construction of dams on major tributaries, artificial levees, river straightening, wingdams, bank revetments, and soil conservation practices.

Source: Allison & Meselhe, 2010
Hydrological alterations accelerating impacts of sea level rise

The Transformation of the Mississippi River: The Future

Proposed Coastal Restoration in the Mississippi Delta

- Creating Marsh with Dredging
- Creating Fastlands with Levees
- Diverting River Water & Sediment
- Flood Control Structures
Aswan High Dam (1970)

**Benefits:**
- Controlled the annual flood
- Provided ample hydroelectric power
- Aided agriculture by adding an extra crop
- Created the world's largest man-made lake: Lake Nassar

**Costs:**
- Resulted in much lower transport of nutrients to Mediterranean and has thus reduced fisheries greatly, which is also a proxy elsewhere (e.g. Yangtze)
- Reduced silt deposition along Nile Delta by 12 million tonnes and thus has indirectly enhanced the rate of coastal erosion
The Nile River Delta – A Desert Oasis

Source: NASA earth observatory
Nile Delta

- Alluvial deposits & sediment from Nile River are essential in renourishment of Nile Delta
- Aswan High Dam construction caused serious reductions in the delivery of sediment, which is the consistent problem seen globally in deltas
- Climate changes may further reduce Nile discharge and compound the problem - again, a globally worrisome situation for deltas
Nile Delta

- Prospects are not encouraging
- Even a relatively modest MSL rise of 0.5 m causes substantial loss of land
- Question is: even so, would it have been done differently knowing then what we know now?
MAP OF YANGTZE DRAINAGE BASIN IN CHINA:
Sediments, nutrients, and organic matter from the watershed flow into the river. Eventually these materials enter the sea and nourish coastal ecosystems, which sequesters carbon.

Satellite Image of Sediment Plume in The Yangtze Delta, April 2002

Eventually Fecal Matter And Detritus Sinks...
Storing Carbon on The Ocean Floor


Source: NASA Earth Observatory
Yangtze River – Three Gorges Dam

- Largest Electric Power Facility In the World
- “Renewable” energy
- Cost: 180 Billion Yen ($22.5 Billion USD)
- Construction Started: 1994
- Completed: 2012
- Electricity Gen. 80-100 TWh
- Width 2.3 km
- Concrete: 27.2 Million m³
- Payback of Construction reached after 1000 TWh has been generated (~12 years)
Concern 5: Future Energy Supply

• Is our current energy system sustainable?
• Can we tackle the challenges of coastal living if we no longer have abundant fossil fuels?
• What can we do to ensure a hopeful and prosperous future for our children?
Energy Return on Energy Investment (SUNY ESF Professor C.A.S. Hall)

• “EROI” or “EROEI” is the multiplier effect, how many times you get back in yield the energy you invested, or

• Analogous to ROI, or “Return on Investment,” which is financial return delivered relative to financial investment put in

\[
\text{EROI} = \frac{\text{Energy Delivered to Society}}{\text{Energy Put into that Activity}}
\]
The economy is held up by three primary energy pillars: High EROI *Coal, Oil and Natural Gas.* (Each Pillar is proportional to its contribution to the Primary Energy Mix, data from IEA 2013 )

Credit: Adrian R. Wiegman
Take away renewable energy sources and fossil fuels will support the modern economy with little small sacrifices but little noticeable changes.
Take away fossil fuels overnight and the economic system would collapse; agriculture, global transportation and the industrial complex would fail. Famine and Societal Upheaval would, as people struggle to live off local resources.
Without fossil fuels stability is reached only if when the demands of human consumption. At this stage comprehensive management and conservation of ecological systems would be essential for human survival.
A structural change in the western lifestyle would lead to a more “sustainable,” but definitely more modest (and less comfortable) trajectory....world-wide. We may not like the change.
How the Sustainability Concept Might Be Better Used

- View sustainability as a direction more than the specific objective
  
  Reduction of our “human footprint” is a worthy goal

- Remember that technology per se is not a magic bullet
  
  Employ the “Small is Beautiful” model of “appropriate technology”

- Use the benefits of the Information Age to understand and work more compatibly with natural systems – cannot “engineer” our way out of all problems
  
  Remote sensing, GIS, GPS and better computer models can help understand and solve problems