Systems Analysis for Sustainable Development

Spring 2013
Lecture 1, Monday 21 Jan

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Today's session
Lecture 1

- Information about the course
- Orientation: where are we and where are we going?
- Introduction to Systems Analysis
- Basic concepts
- Some examples

Contents

- Global issues: flows of energy and matter
- Major problems: climate change and biodiversity depletion
- Systems thinking for Sustainable Development

Objectives

The objective of this course is to provide basic understanding of different systems in nature and society and how they can interact in a sustainable development. In particular, you will learn how different types of systems and processes can be analyzed and modelled with tools of systems analysis. A holistic approach to the world is central.

Learning Outcomes

Upon completion of the course, the student should be able to:

- list and explain basic ideas, concepts and methods in systems analysis,
- summarize how a project in systems analysis is carried out,
- analyse and explain the problems involved in systems identification and system boundaries,
- describe different methods in systems analysis applicable to primarily biological, ecological, environmental and technical systems, and especially analyse interactions between such systems for a sustainable development,
- have basic insight and skill in the most usual types of modelling and simulation tools for complex systems, in particular for socio-natural systems.

Description of course 1

Systems analysis is used for describing and analysing problems within many different disciplines, and is therefore highly interdisciplinary in its character.

Depending on the perspective, reality can be considered as a set of systems, which can be described with the aid of various types of models, e.g. static/dynamic, deterministic/ stochastic, local/global, or a combination of these.

Description of course 2

Problems related to sustainable development, and of current interest, will be presented and discussed from a systems analysis perspective.

Different solutions with methods from systems analysis will be discussed, together with how the system (model) is affected by various factors.

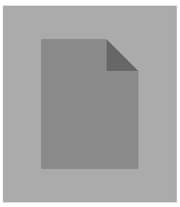
Description of course 3

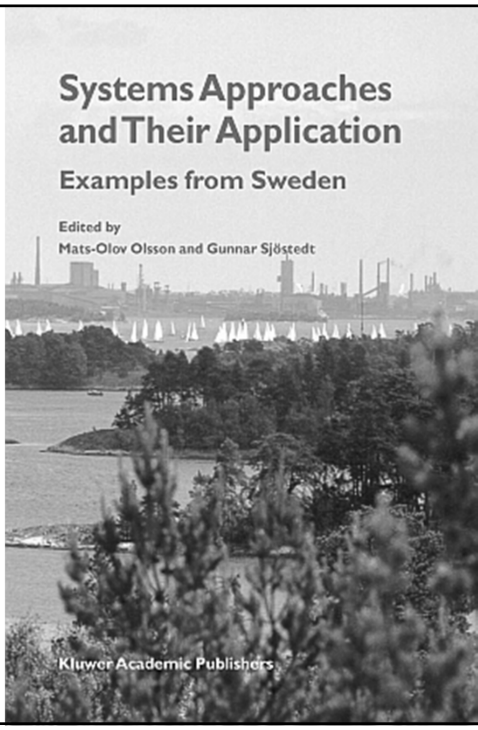
- Fundamentals of systems philosophy, with stress on concepts, such as *system, model, purpose, feed-back, relation between structure and behaviour, stability, sensitivity* etc.
- A major effort is devoted to the understanding of relations between structure and behaviour of a system.
- General techniques, such as model fitting, sensitivity analysis and optimisation are treated and practiced in the computer exercises.
- A special focus is on human effects on environment and climate, and how these effects can be minimized for a sustainable development.

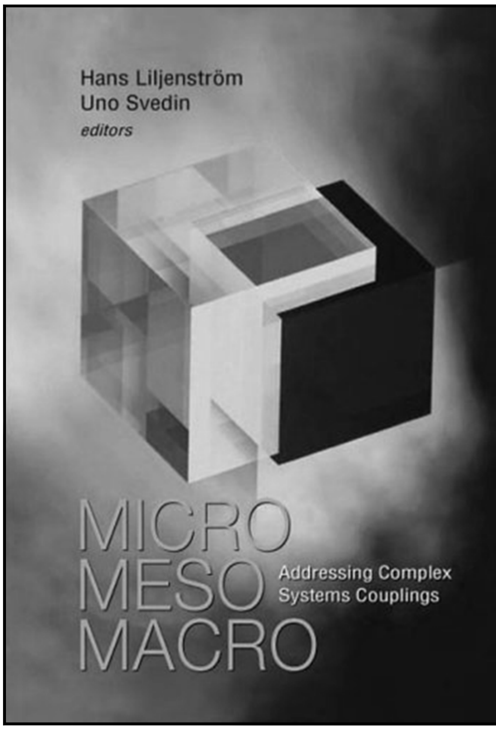
Main parts of the course

- problem analysis, based on current problems related to sustainable development,
- the systems analysis perspective, concepts and theory,
- the methodology of systems analysis,
- construction and simulation of static and dynamic models,
- applications with examples for current problems related to sustainable development,
- project work, related to the background and interest of the student,
- computer exercises: Use of computer simulation for description, analysis and understanding of complex systems, and practice of different general techniques.

Preliminary course plan 2013







Contents

Preface VII

1 *Hans Liljenström & Uno Svedin*
System Features, Dynamics, and Resilience
– Some Introductory Remarks 1

PART I THE "VERTICAL" SYSTEM STRUCTURE AND MESO-LEVEL CHARACTERISTICS

2 *Hermann Haken*
Mesoscopic Levels in Science
– Some Comments 16

3 *Walter Freeman*
The Necessity for Mesoscopic Organization to Connect Neural Function to Brain Function 25

4 *Peter Århem, Hans A. Braun, Martin T. Huber & Hans Liljenström*
Dynamic state transitions in the nervous system: From ion channels to neurons to networks 37

5 *Robert E. Ulanowicz*
A Revolution in the Middle Kingdom 73

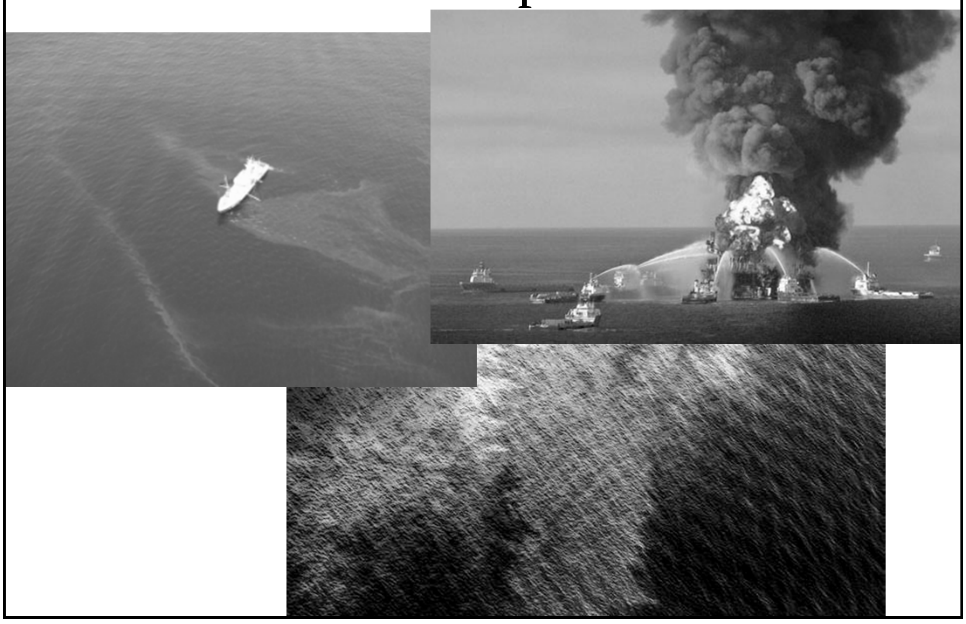
6 *Abir Igamberdiev*
The Mesoscale Level of Self-Maintained Reflective Systems 91

PART II INNER AND OUTER DYNAMICS

7 *Igor Rojdestvenski & M.G. Cottam*
Time Rescaling and Generalized Entropy in Relation to the Internal Measurement Concept 115

Pollution

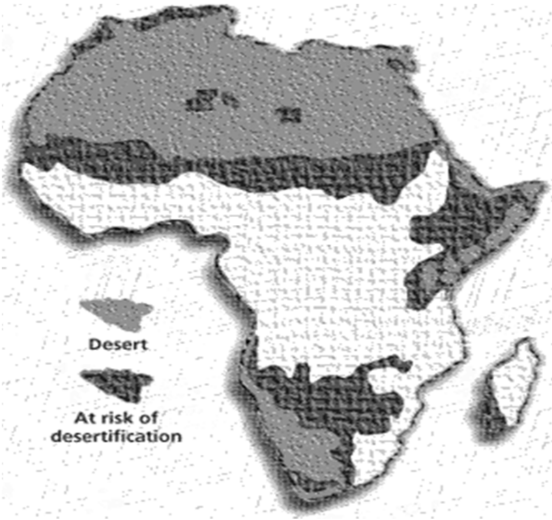
Oil spill



Waste

Desertification

Global Desertification: the case of Africa



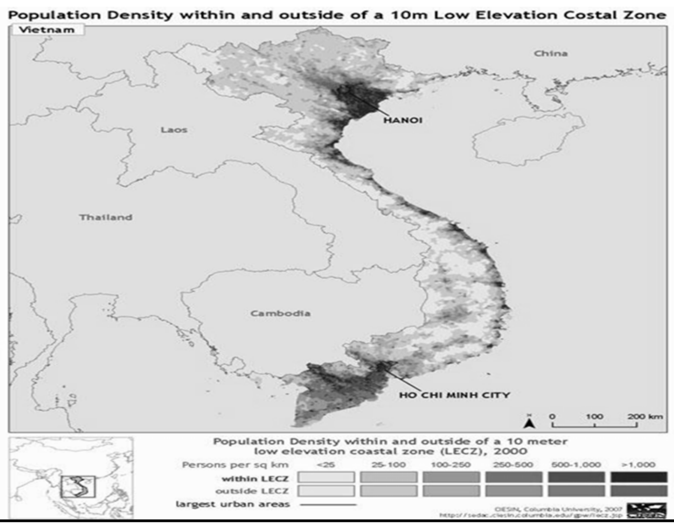
Dramatic desertification in China

Desertification in Latin America

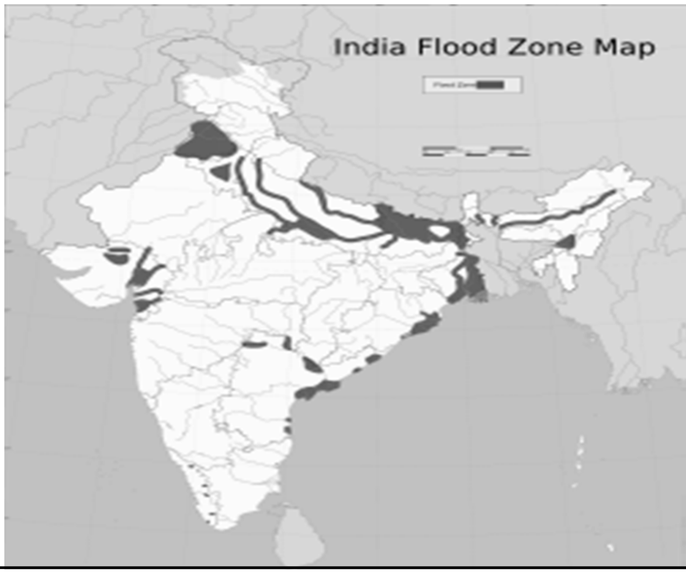
Disappearance of glaciers

Wildfires

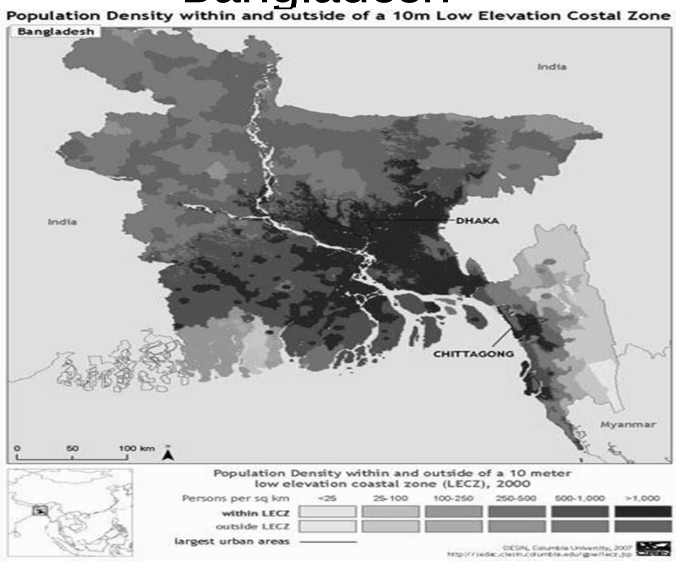
Vietnam High Risk Areas for Flooding

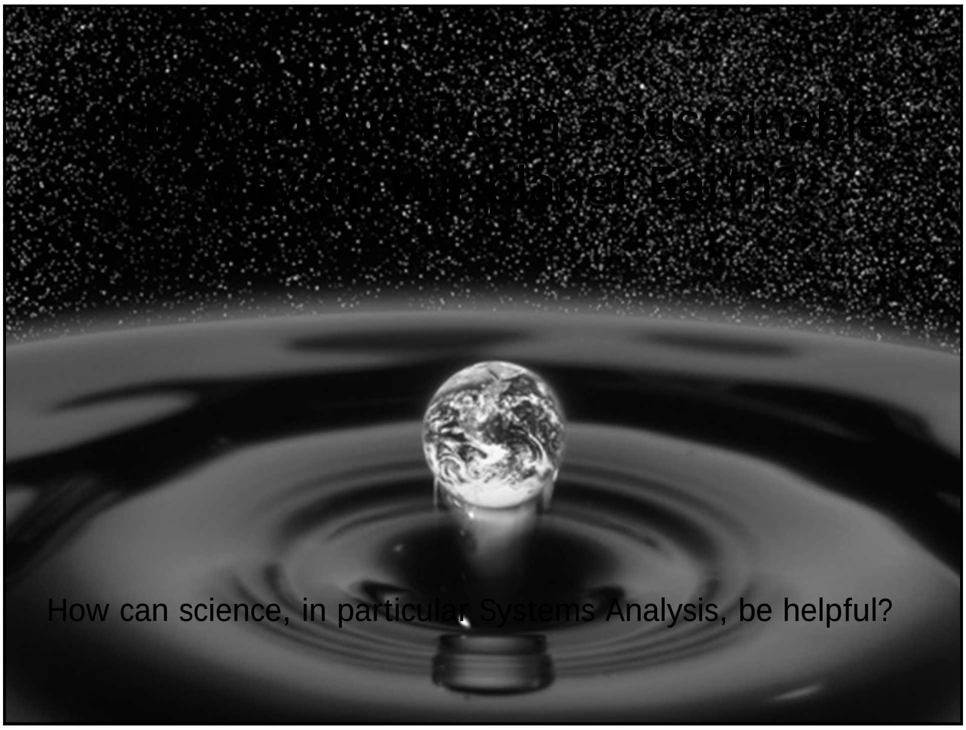


High Risk Flooding Zones in India

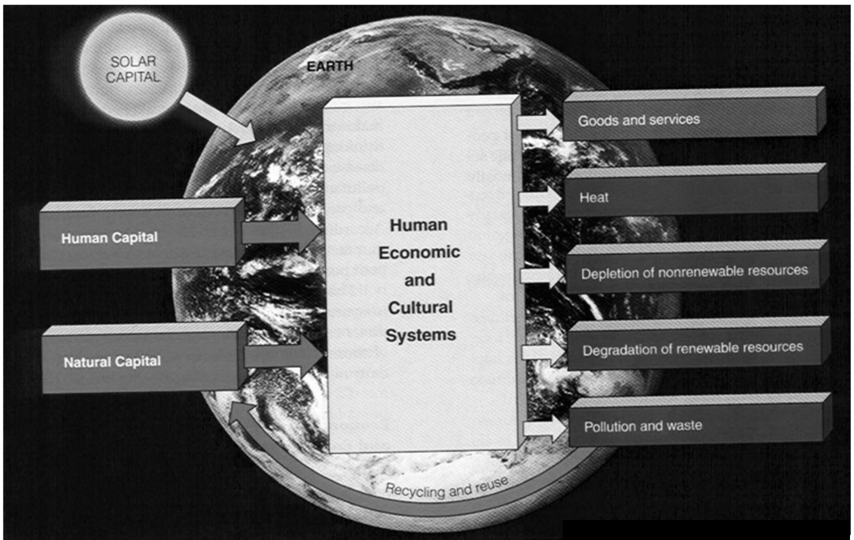


Increasing Risk of Major Floods in Bangladesh





How can science, in particular Systems Analysis, be helpful?



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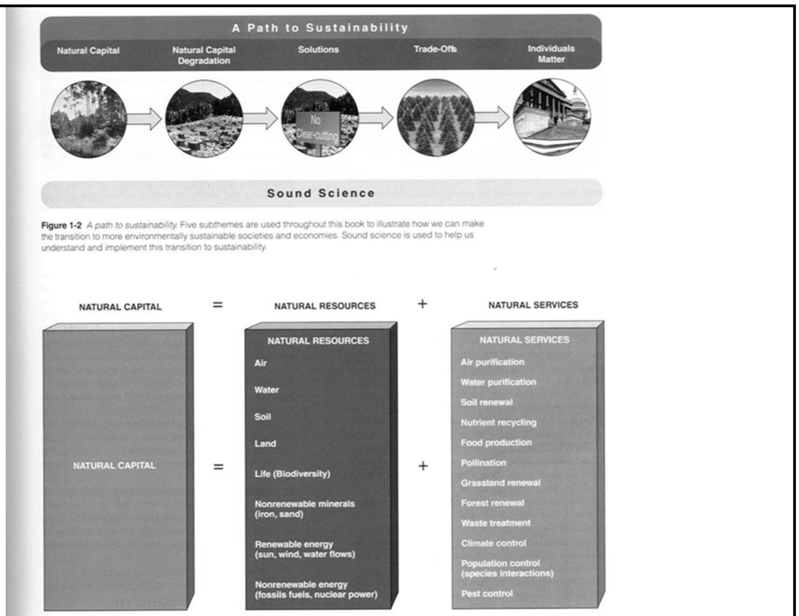


Figure 1-2 *A path to sustainability.* Five subthemes are used throughout this book to illustrate how we can make the transition to more environmentally sustainable societies and economies. Sound science is used to help us understand and implement this transition to sustainability.

Figure 1-3 **Natural capital:** the natural resources (left) and natural services (right) provided by the earth's *natural capital* support and sustain the earth's life and economies. For example, *nutrients*, or chemicals such as carbon and nitrogen that plants and animals need as *resources*, are recycled through the air, water, soil, and organisms by the natural process of *nutrient cycling*. And the interactions and competition of different types of plants and animals (species) for *resources* (nutrients) keeps any single species from taking over through the natural service of *population control*. Colored wedges will be shown at the beginning of most chapters in this book to show the *natural resources* (blue wedges) and *natural services* (orange wedges) discussed in these chapters.

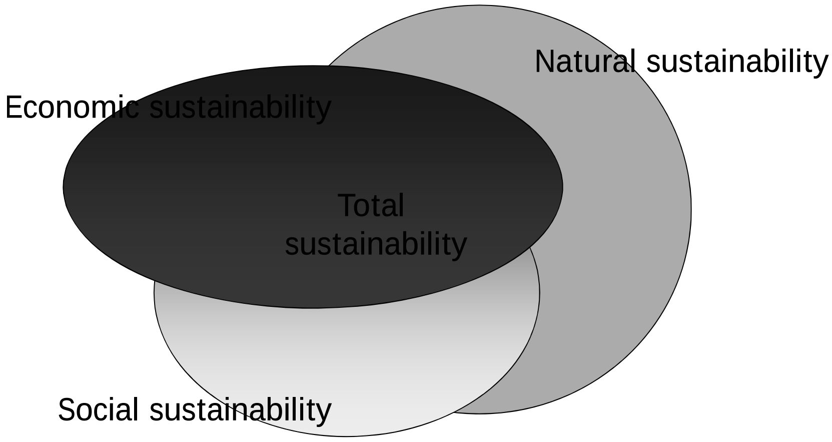
What is sustainable development?

”Sustainable development seeks to reconcile environmental protection and development; it means nothing more than using resources no faster than they can regenerate themselves, and releasing pollutants to no greater extent than natural resources can assimilate them”

”If we are to move toward sustainable development, the industrialized countries will have to accept special responsibility--not only because of their past ecological sins, but also because of their present technological know-how and financial resources. Yet, one must keep in mind that sustainable production and consumption involve not merely technical progress, but also cultural patterns of individual behavior and values.”

(*Angela Merkel, 1998*)

Sustainable development



Defining sustainability of systems

Sustainabilty must be defined with respect to three aspects:

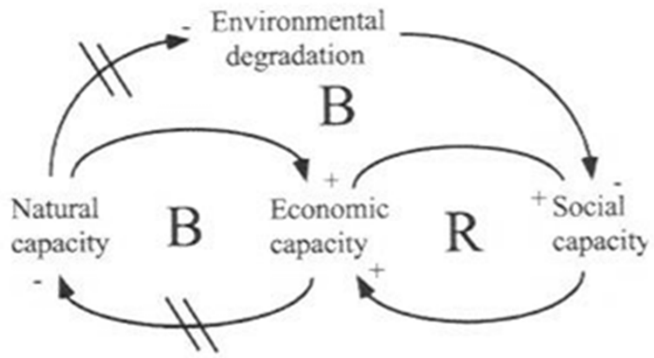
- Natural sustainability, which defines the max long term use of a natural resource system as source of raw material and energy, the capacity of destruction of waste and exploitation of living organisms
- Social sustainability defines the self-organizing stabiluty systems of a social organization and its components. It defines the minimum requirement for system resilience, individual rights, limitations and duties for sustainability.
- Economic sustainability in absolute value terms, dreived from mass balance and economic feedback principles.

Defining sustainability of systems

The parameters of social and economic sustainability must stay within the bounds set by the physical and thermodynamic sustainability criteria of the natural system in order to be relevant. The natural sustainability overreaches the other domains.

Natural ⟶ Social ⟶ Economic

Different types of sustainability

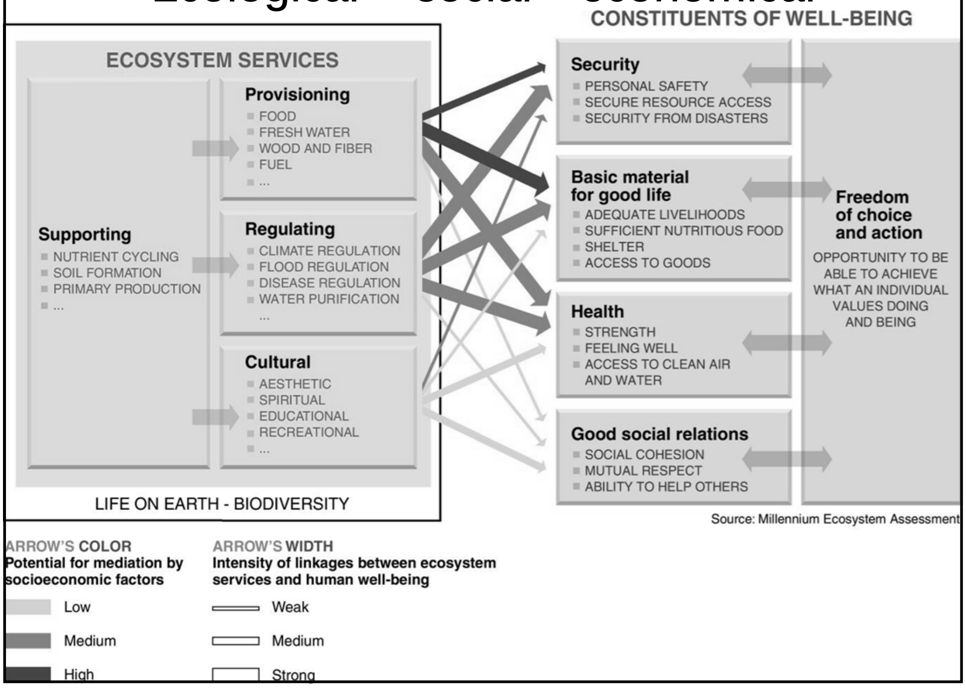


Science and sustainable development

"Sustainable development can succeed only if all areas of the political sector, of society, and of science accept the concept and work together to implement it. A common basic understanding of environmental ethics is needed to ensure that protection of the natural foundation of life becomes a major consideration in all political and individual action. A dialogue among representatives of all sectors of society is needed if appropriate environmental policies are to be devised and implemented".

(*Angela Merkel, 1998*)

Ecological – social - economical



The bottom line

- We are spending Earth's natural capital, putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted.
- At the same time, the assessment shows that the future really is in our hands. We can reverse the degradation of many ecosystem services over the next 50 years, but the changes in policy and practice required are substantial and not currently underway.

Source: Millennium Ecosystem Assessment 2005

Science and sustainable development

Science can play different roles for the sustainable development we seek.

Partly, it can, together with technology, provide tools for reaching a sustainable use and governance of the natural resources.

Partly, it can provide a deeper understanding of the natural conditions for life and to maintain biodiversity, where man can live in harmony with other species.

Science and sustainable development

Science must play an important role in the pursuit of sustainable development, especially in the following categories:

1. *Energy use*
2. *Closure of substance cycles*
3. *Environmentally compatible mobility*
4. *Biotechnology*

Sustainable systems

The U.S. Environmental Protection Agency (EPA) proposes a new scientific framework for a more systematic and holistic approach to environmental protection that considers the complex nature of environmental issues and the welfare of future generations. The EPA has come to understand (2006) that designing sustainable systems encompasses several important challenges:

- Addressing multiple scales over time and space.
- Capturing system dynamics and points of leverage or control.
- Representing an appropriate level of complexity
- Managing variability and uncertainty.
- Capturing stakeholder perspectives in various domains.
- Understanding system resilience relative to foreseen and unforeseen stressors.

According to the EPA, a systems view can inform research prioritization in technology, decision-support tools, and collaborative decision-making, which in turn will enable more effective movement toward sustainability.

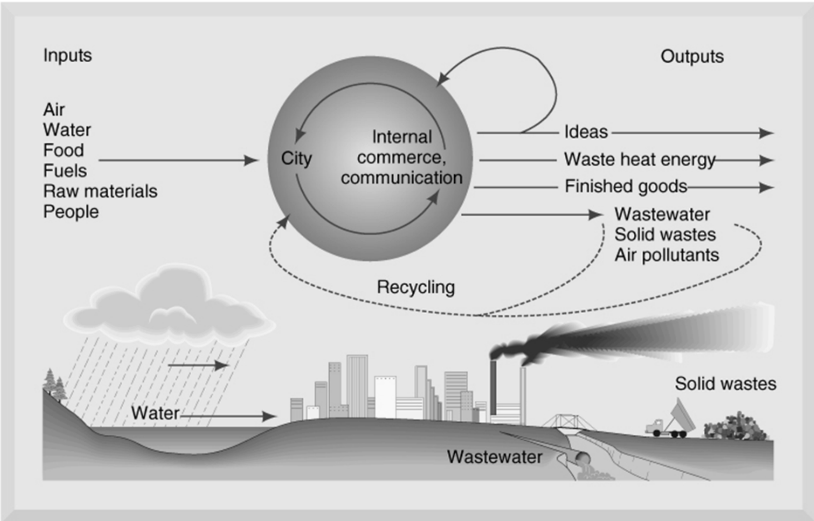
Physical conditions for sustainable development

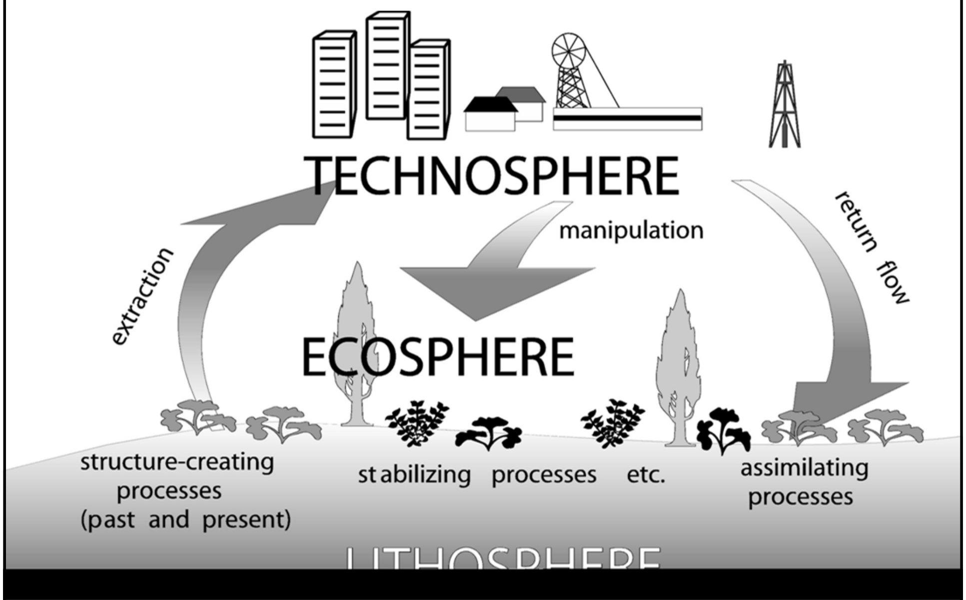
1. The productive capacity of the ecosphere must not systematically decrease.
2. Substances from the litosphere must not systematically accumulate in the ecosphere.
3. Artifical substances must not systematically accumulate in the ecosphere.
4. The use of natural resources must be efficient and with respect to natural stability and biodiversity.

Biological conditions for sustainable development

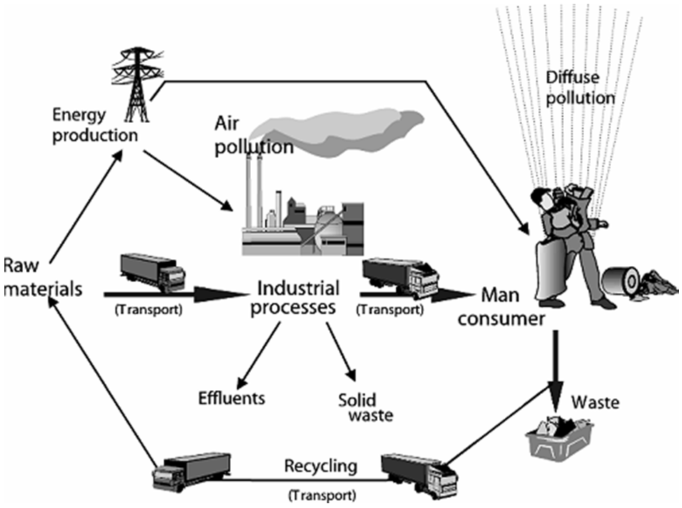
1. Waste and nutrient deployment must result in recycling of all substances.
2. The ultimate source of energy must come from the solar influx.
3. The consumer population must not exceed the carrying capacity.
4. Biodiversity must be maintained.

Socio-natural systems

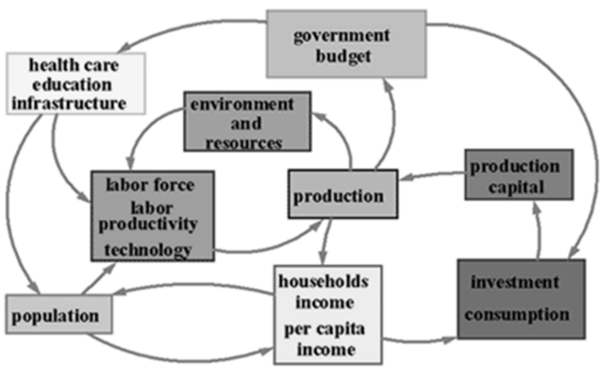




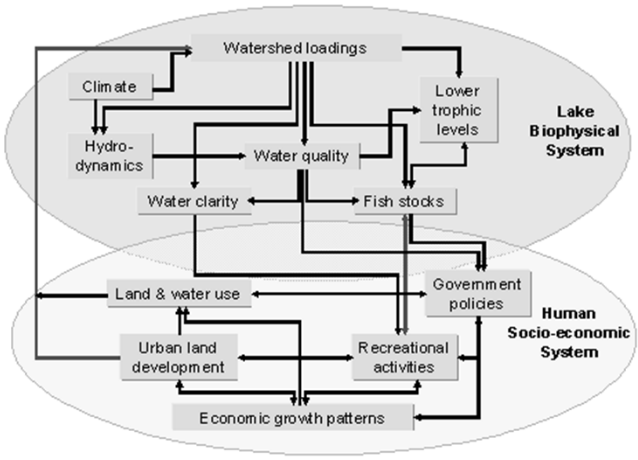
Material flows and pollutions in industrial processes



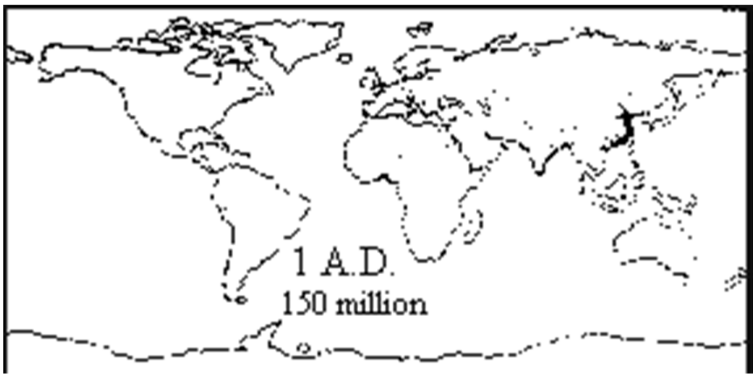
Interactions in socio-natural systems



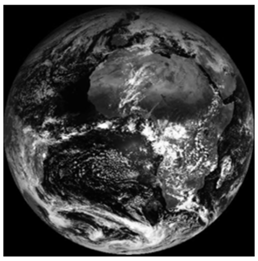
Interactions in socio-natural systems



Human population growth

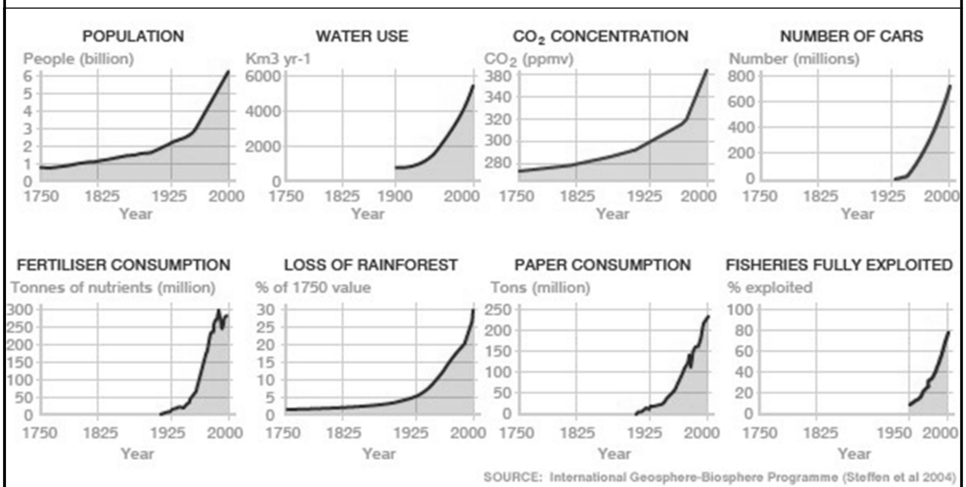


Development 1900-2000



- global population 4 x
- global economy 14 x
- industrial production 40 x
- energy usage 16 x
- carbon dioxide emissions 17 x
- sulphur dioxide emissions 13 x
- sea fish captures 35 x
- number of pigs 9 x
- forest area 0.8 x
- field area 2 x
- blue whale 0.0025 x

Exponential growth



Human population growth and hyper-development drive the extinction of birds and mammals!

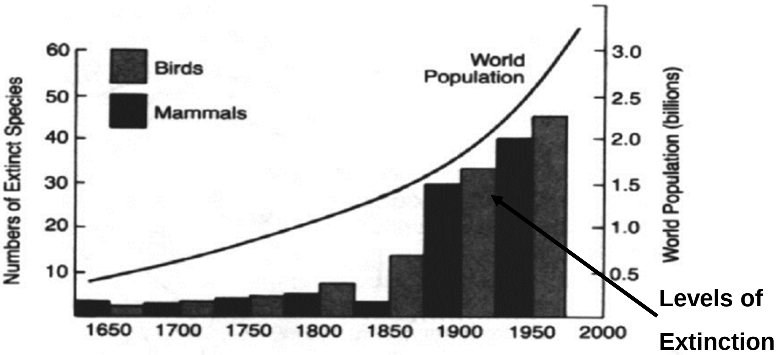
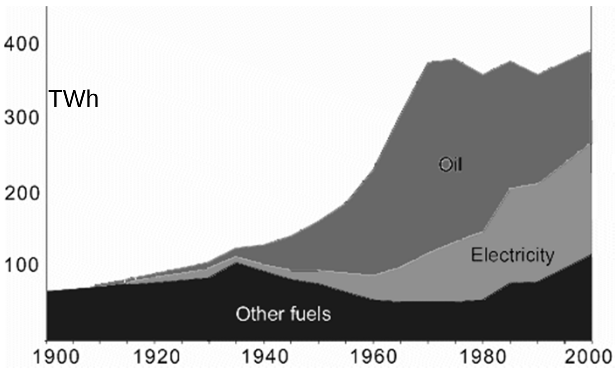


FIGURE 2.7
Increase in the human population paralleled by increase in the extinction of birds and animals. (Reproduced, by permission, from V. Ziswiler, *Extinct and Vanishing Species* [New York: Springer-Verlag, 1967].)

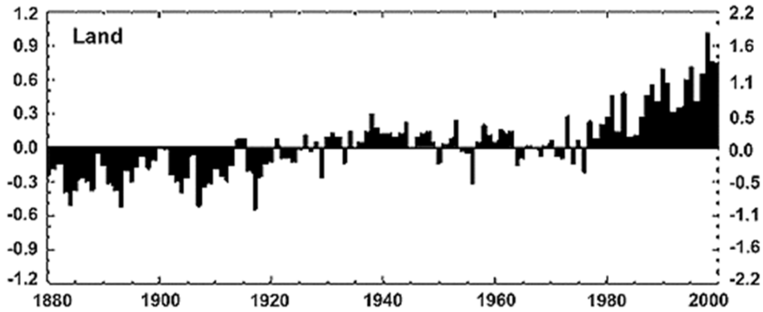
Sweden's development 1900-2000

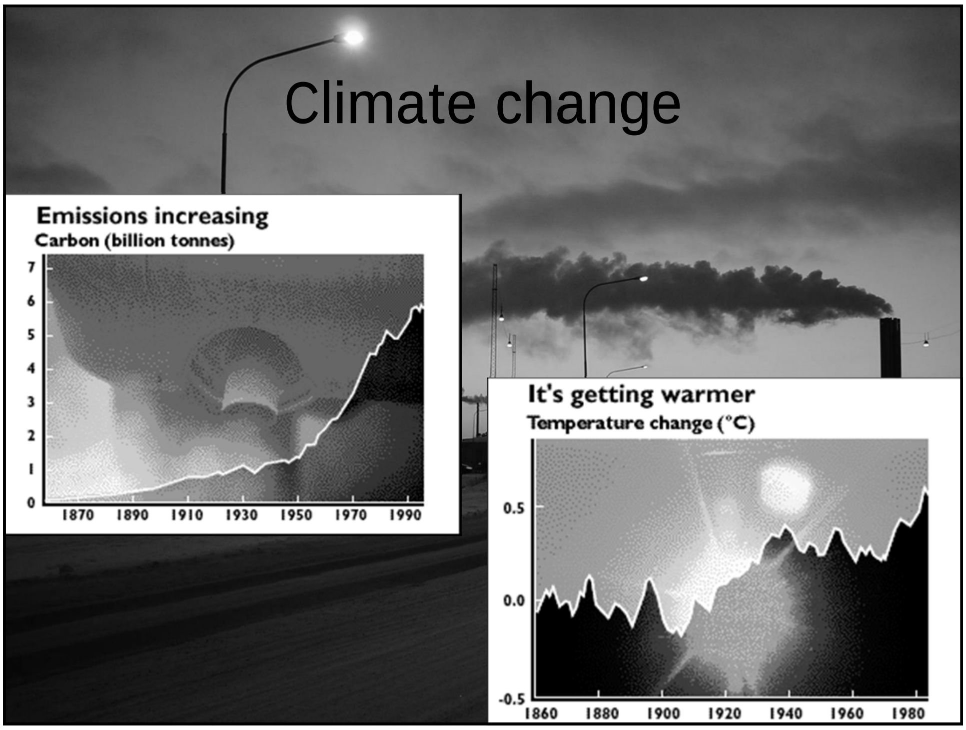
- **Energy budget 6-8 x**
- **Fishing in Baltic Sea 4-6 x ?**
- **Forest production 2-4 x ?**



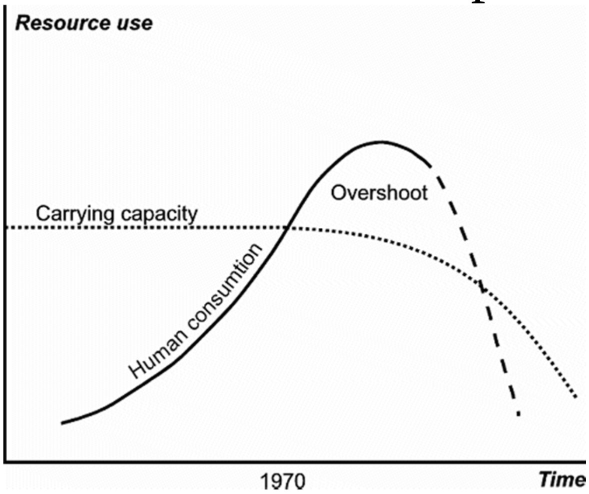
Swedish energy budget 1900-2000

Global change in average temperature 1880-2000





Unsustainable development



Sustainability demands that society stays within the carrying capacity of Nature

Overshoot

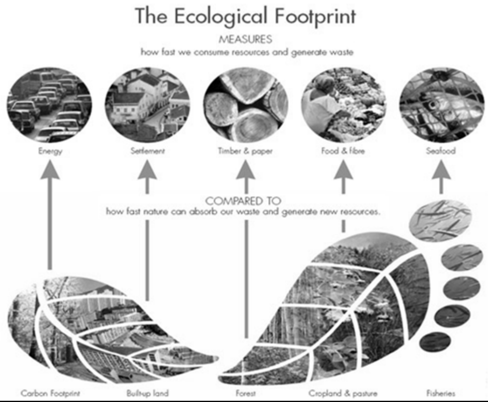
Turning resources into waste faster than waste can be turned back into resources puts us in global ecological overshoot, depleting the very resources on which human life and biodiversity depend.

The result is collapsing fisheries, diminishing forest cover, depletion of fresh water systems, and the build up of carbon dioxide emissions, which creates problems like global climate change. These are just a few of the most noticeable effects of overshoot.

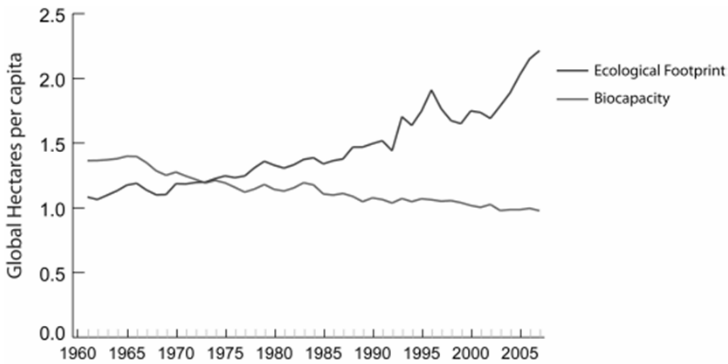
Overshoot also contributes to resource conflicts and wars, mass migrations, famine, disease and other human tragedies—and tends to have a disproportionate impact on the poor, who cannot buy their way out of the problem by getting resources from somewhere else.

Ecological Footprint

The *Ecological Footprint* has emerged as the world's premier measure of humanity's demand on nature. It measures how much land and water area a human population requires to produce the resource it consumes and to absorb its carbon dioxide emissions, using prevailing technology.



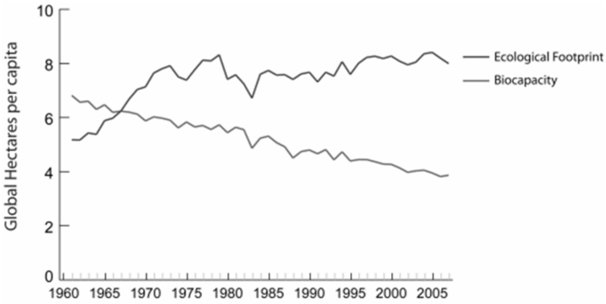
Ecological Footprint



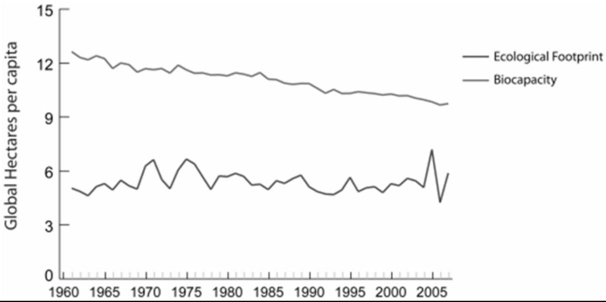
China

The figure tracks the per-person resource demand (Ecological Footprint) and resource supply (Biocapacity) in China since 1961. Biocapacity varies each year with ecosystem management, agricultural practices (such as fertilizer use and irrigation), ecosystem degradation, and weather.

Ecological Footprint



USA

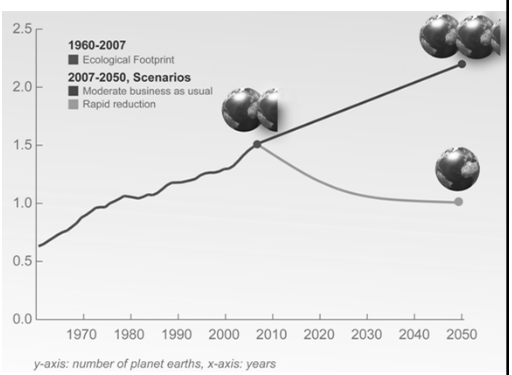


Sweden

Do we fit on the planet?

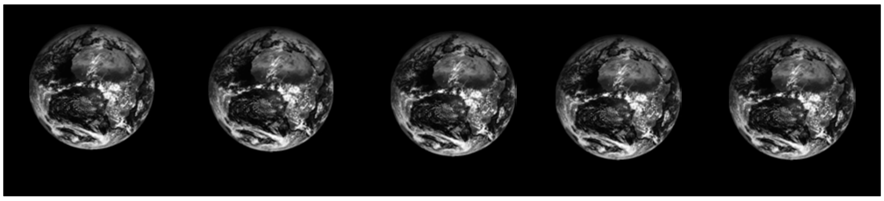
Today humanity uses the equivalent of 1.5 planets to provide the resources we use and absorb our waste. This means it now takes the Earth one year and six months to regenerate what we use in a year.

Moderate UN scenarios suggest that if current population and consumption trends continue, by the 2030s, we will need the equivalent of two Earths to support us.

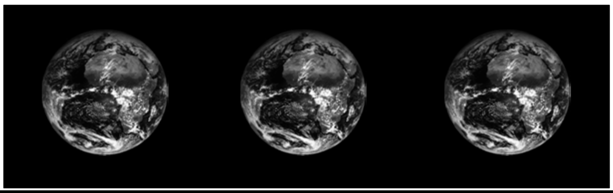


Do we fit on our planet?

If everyone lived the lifestyle of the average American,
we would need 5 planets



If everyone lived the lifestyle of the average European,
we would need 3 planets



Ending Overshoot

What will it take for humanity to live within the means of one planet?

- Individuals and institutions worldwide must begin to recognize ecological limits. We must begin to make ecological limits central to our decision-making and use human ingenuity to find new ways to live within the Earth's bounds.
- This means investing in technology and infrastructure that will allow us to operate in a resource-constrained world. It means taking individual action, and creating the public demand for businesses and policy makers to participate.
- Using tools like the Ecological Footprint to manage our ecological assets is essential for humanity's survival and success. Knowing how much nature we have, how much we use, and who uses what is the first step, and will allow us to track our progress as we work toward our goal of sustainable, one-planet living.