

**CLIMATE CHANGE AND  
SUSTAINABLE DEVELOPMENT:  
analysing the linkages with Sustainomics**

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**WHAT ?** is the sustainomics framework  
and its key elements

**WHICH ?** are the key issues linking climate  
change and sustainable development

**HOW ?** to apply sustainomics to identify  
practical options

# Understanding Sustainomics and its key elements

## **Sustainable Development will be undermined by Climate Change, especially in Developing Countries**

### **The sustainable development challenge:**

- **alleviate poverty:** 1.3 billion people live on less than \$1 per day and 3 billion people on less than \$2 per day. Top 20% income group uses 86% of resources, while bottom 20% uses under 1.3%
- **food:** 800 million people malnourished today -- food production must double in the next 35 years
- **water:** 1.3 billion people without clean water; 2 billion without sanitation
- **energy:** 2 billion people without electricity
- **healthy environment:** 1.4 billion people exposed to dangerous levels of *outdoor pollution* and even larger number exposed to dangerous levels of *indoor air pollution and vector-borne diseases*
- **safe shelter:** many live in areas susceptible to civil strife, environmental degradation, and natural disasters

## **Ideal Goal:**

### **Sustainable Development**

**Sustainable development is a process for *improving the range of opportunities* that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time**

**Source: Munasinghe (1992)**

## **Practical Target:**

### **Making Development More Sustainable**

‘An approach that will permit *sustained improvements in the quality of life* at a lower intensity of resource use, thereby preserving for future generations an undiminished or even *enhanced stock of productive assets* (manufactured, natural and social capital)’

**Source: Munasinghe (1992)**

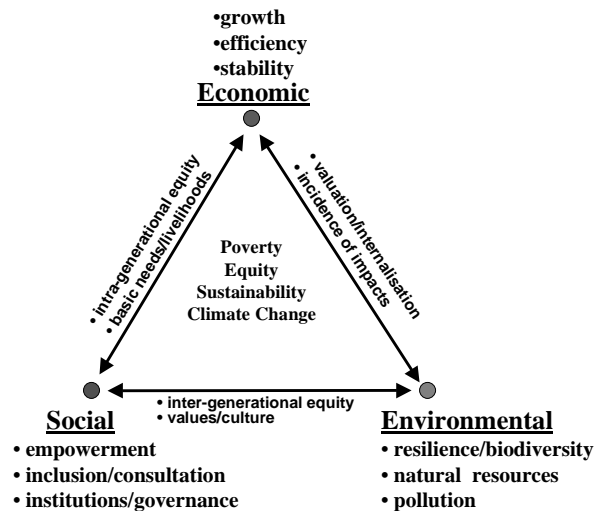
## Application Framework:

# SUSTAINOMICS

***“meta-framework for making development more sustainable, which is transdisciplinary, integrative, comprehensive, balanced, heuristic and practical.”***

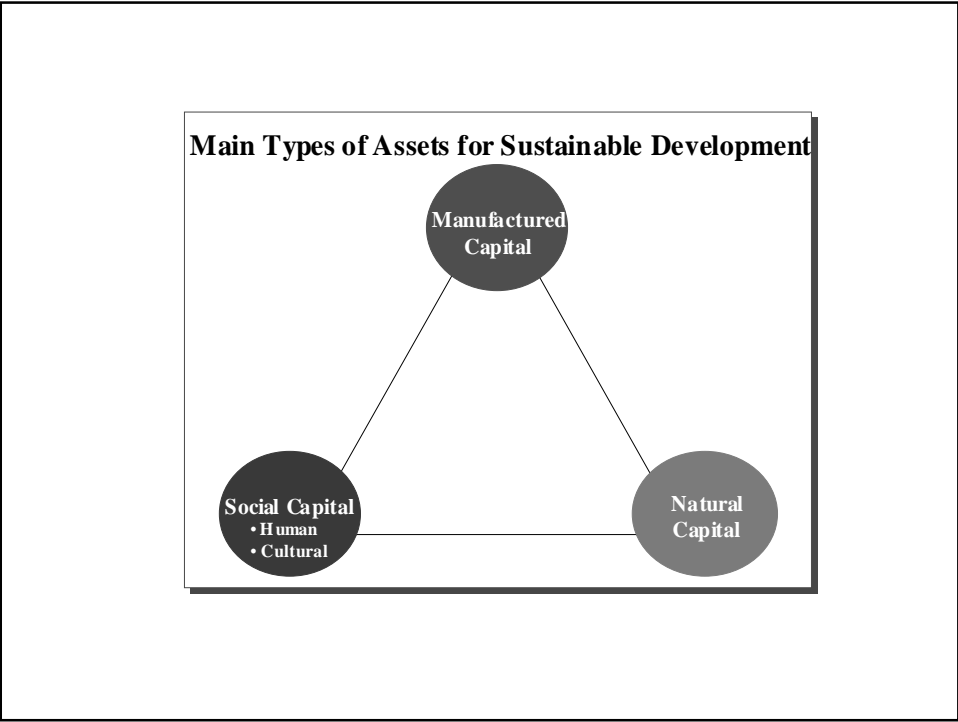
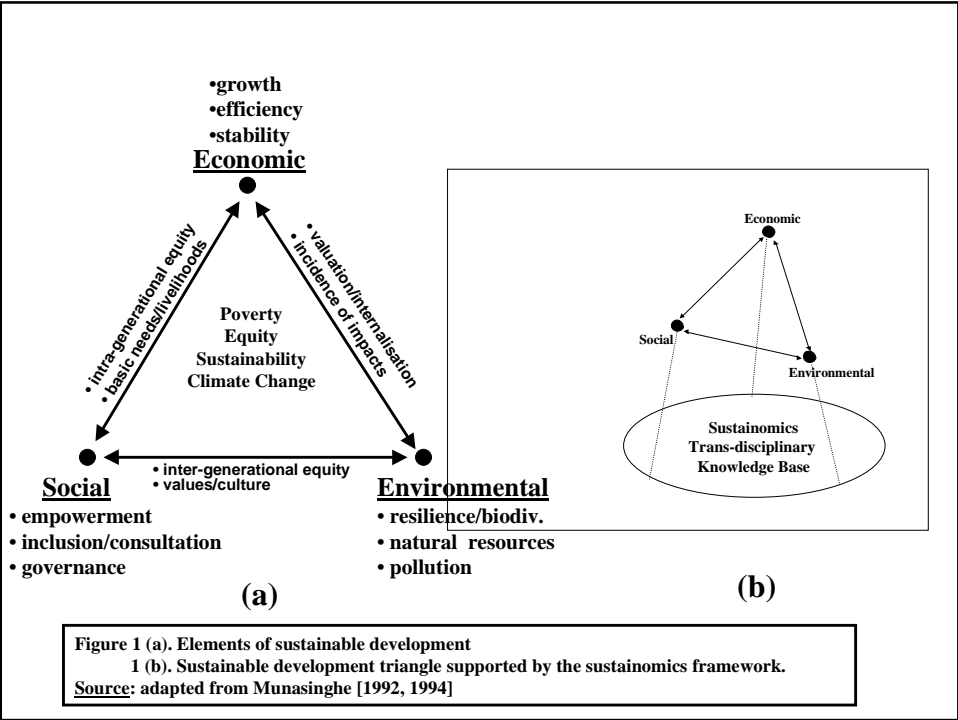
**Source:** Munasinghe (1994)

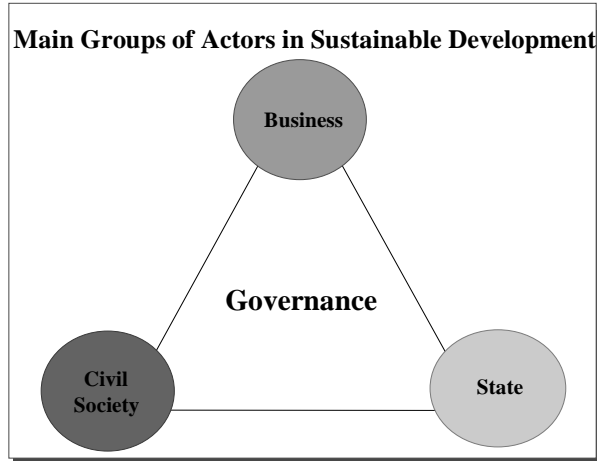
**Neologism focuses attention on sustainable development and avoids suggestions of disciplinary bias or ‘hegemony’.**



**Key elements of sustainable development and interconnections**

**Source:** Munasinghe [1992]





**All three groups have a vital and balanced role to play**

**Optimality-based approaches:**

Maximize welfare (or utility), subject to non-decreasing stock of productive assets (or welfare itself). A simple example of maximization of the flow of aggregate welfare (W), cumulatively discounted over infinite time (t), is:

$$\text{Max} \int_0^{\infty} W(C, Z) \cdot e^{-rt} dt.$$

Here, W is a function of C (the consumption rate), and Z (a set of other relevant variables), while r is the discount rate. Side constraints satisfy sustainability needs – e.g., non-decreasing stocks of productive assets (including natural resources).

**Durable development paths:**

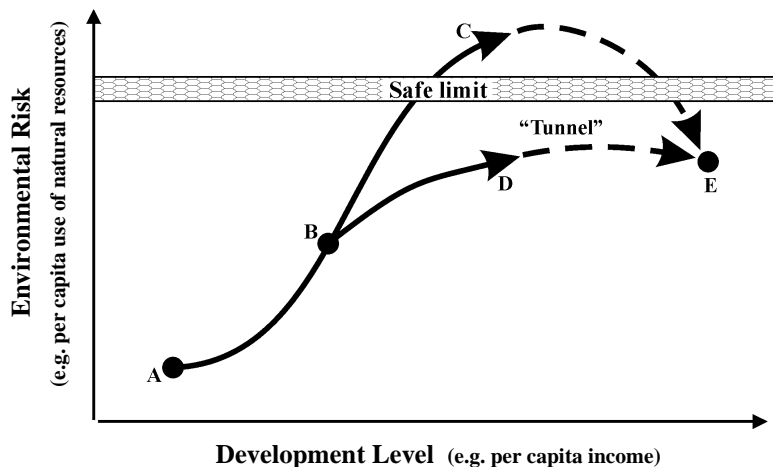
Focus mainly on sustaining the quality of life – e.g., by satisfying environmental, social and economic sustainability requirements. They permit growth, but are not necessarily economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety, in order to stay within critical economic, environmental and social limits.

A simple durability index (D) for an organism or system is its expected lifespan (in a healthy state), as a fraction of the normal lifespan:

$$D = D(R,V,O,S) ;$$

specifies durability (D) as a function of resilience (R), vigour (V), organization (O), and the state of the external environment (S) – especially in relation to damaging shocks.

**“Tunneling” to make development more sustainable:**  
**Environmental Risk versus Development Level**



Source: M. Munasinghe (1995) "Making Growth More Sustainable," *Ecological Economics*, 15:121-4.

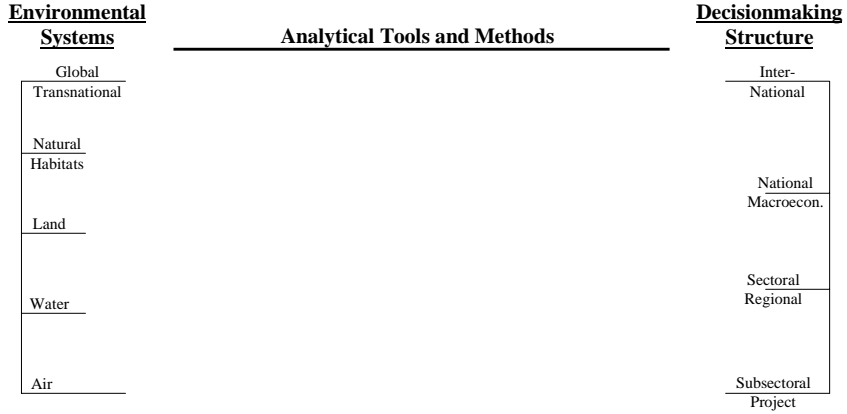
## **Key steps to make development more sustainable**

- **define development activity (project or policy)**
- **identify relevant indicators of sustainability (pressure, state, impact: P-S-I)**
- **assess vulnerability and impacts**
- **determine remedial response (R)**
- **modify development activity accordingly**

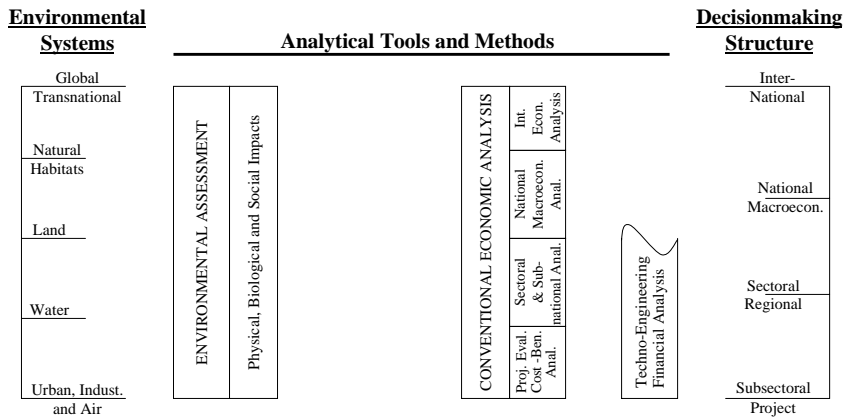
## **Sustainable Development Assessment** (partial equilibrium analysis at the project level )

1. Economic/Financial Assessment (CBA)
2. Environmental Assessment (EA)
3. Social Assessment (SA)
4. Technical Assessment (TA)

**Incorporating Environmental Concerns Into Decisionmaking**



**Incorporating Environmental Concerns Into Decisionmaking**



## Incorporating Environmental Concerns Into Decisionmaking

### Environmental Systems

Global  
Transnational

Natural Habitats

Land

Water

Urban, Indust. and Air

### Analytical Tools and Methods

ENVIRONMENTAL ASSESSMENT

Physical, Biological and Social Impacts

SUSTAINOMICS  
ENVIRONMENT-ECONOMY INTERFACE

Integrated Resource Mgmt.

Macro. Econ. Anal. & Env. Account.

Global Env. Econ. Analysis

CONVENTIONAL ECONOMIC ANALYSIS

Proj. Eval. Cost-Ben. Anal.

Sectoral & Sub-national Anal.

National Macroecon. Anal.

Int. Econ. Analysis

Techno-Engineering  
Financial Analysis

### Decisionmaking Structure

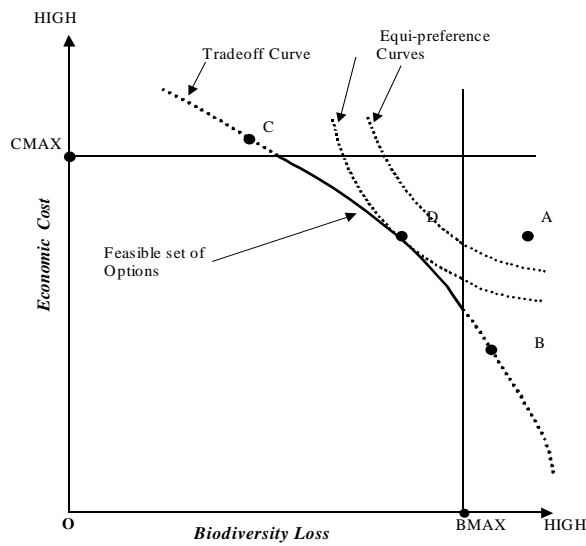
Inter-National

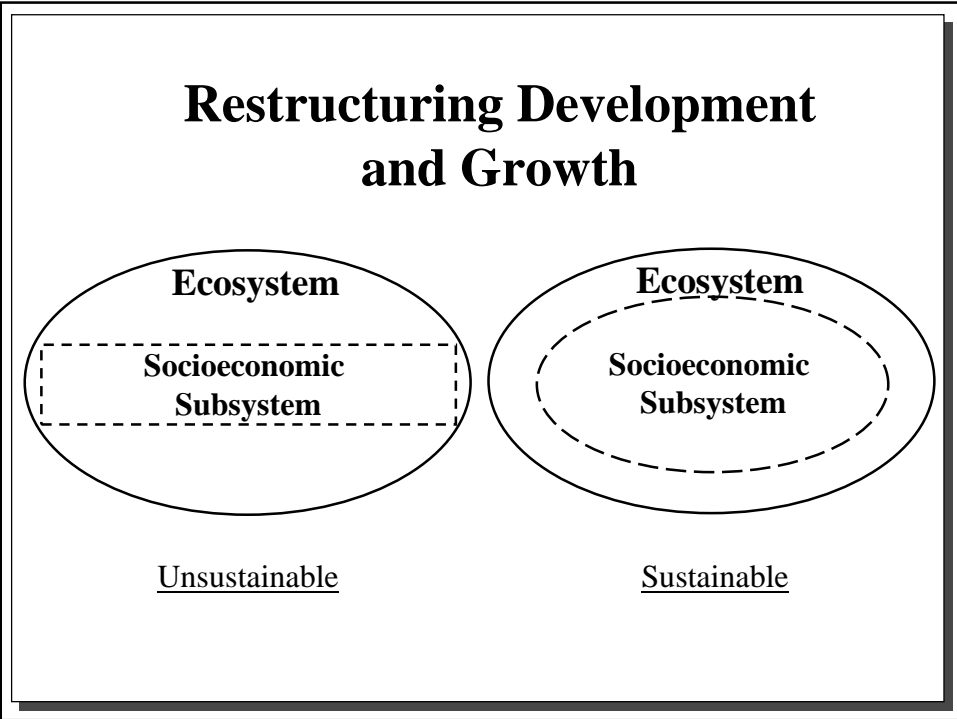
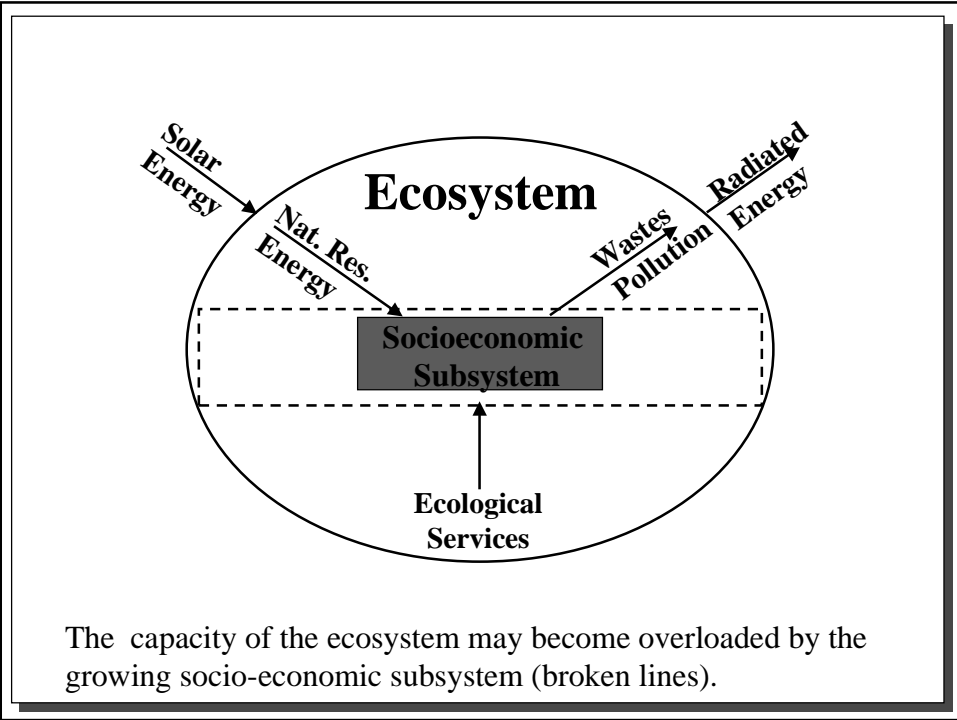
National Macroecon.

Sectoral Regional

Subsectoral Project

### Simple Two-Dimensional Example of Multi-criteria Analysis (MCA)





## Expanded National Income Accounts for SD

**[economic]  
Input-Output  
Table**

**[economic-  
environmental]  
Satellite  
Environmental  
Accounts**

**[economic-social]  
Distribution of Income**

**[envir.-social]  
Distribution of  
Environmental  
Impacts**

## Action Impact Matrix (AIM) for Macro Level SDA

**Simplified Action Impact Matrix (AIM) for Macroeconomic Sustainability Analysis**

Activity/Policy	Main (Economic) Objective	Impacts On Key Sustainable Development Issues			
		Land Degradation & Biodiversity Loss	Water Scarcity & Pollution	Resettlement & Social Effects	Climate Change Effects (eg., vulnerability and adaptation)
<b>Macroeconomic &amp; Sectoral Policies</b>	Macroeconomic and sectoral improvements	Positive impacts due to removal of distortions Negative impacts mainly due to remaining constraints			
<i>Exchange Rate</i>	Improve trade balance and economic growth	(-H) (deforest open-access areas)			(-M) (more vulnerable, less adaptive & mitigative capacity)
<i>Water Pricing</i>	More efficient water use and economic efficiency		(+M) (water use efficiency)		(+M) (less vulnerable, better adaptive capacity)
<i>Others</i>					
<b>Complementary Measures and Remedies</b>	Specific socio-economic and environmental gains	Enhance positive impacts and mitigate negative impacts (above) of broader macroeconomic and sectoral policies			
<b>Market Based</b>			(+M) (pollution tax)		(+L) (less vulnerable)
<b>Non-Market Based</b>		(+H) (property rights)	(+M) (public sector accountability)		
<b>Investment Projects</b>	Improve effectiveness of investments	Investment decisions made more consistent with broader policy and institutional framework			
<i>Project 1 (Hydro Dam)</i>		(-H) (inundate forests)		(-M) (displace people)	(+M, -L) (less fossil fuel use, more vulnerable)
<i>Project 2 (Re-afforest and relocate)</i>		(+H) (replant forests)		(+M) (relocate people)	(+M) (absorb carbon, less vulnerable)
<i>Other Projects</i>					

Source: adapted from Munasinghe and Cruz [1994]

## **Key Issues Linking Climate Change and Sustainable Development: adaptation (and mitigation) in the context of vulnerability, poverty and equity**

### **Future Climate: Key Conclusions**

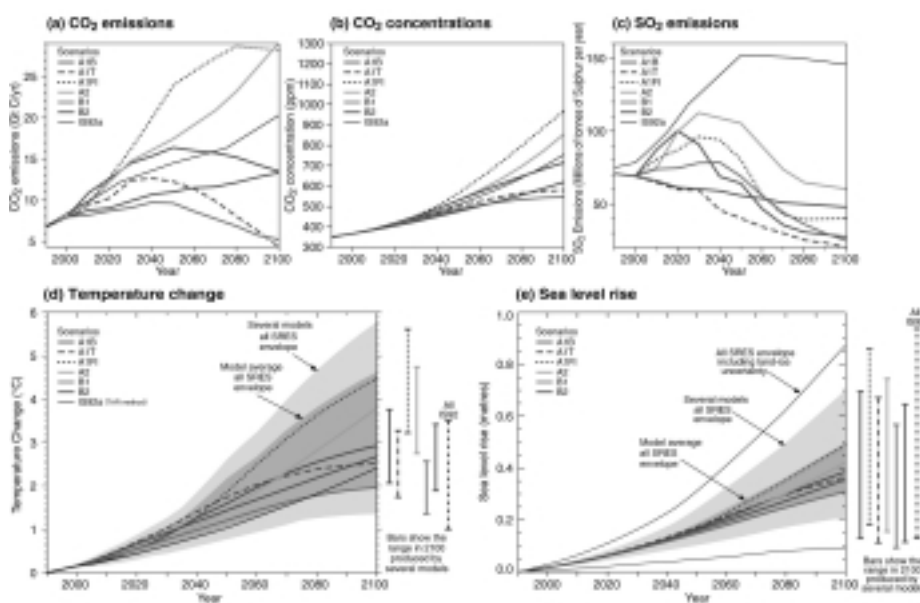
- Climate models up to 2100, project that:
  - Earth's mean surface temp. rise of 1.4 to 5.8°C; land warmer than oceans
  - sea level rise between 9-88 cm
  - precipitation increases globally, with more heavy precipitation events
  - incidence of extreme weather events rises, e.g., floods, droughts, heat waves
  - stabilization levels between 450 and 1000 ppm of CO<sub>2</sub> will increase temperature and sea level by 1.5 to 9°C and 0.5 to 10 metres.

Note: Future emissions of greenhouse gases and sulfate aerosol precursors depend on population growth, economic growth, technological changes and governance structures. Increase in the atmospheric concentrations of GHGs over the next 100 years, but decreases in sulfate aerosols by 2100

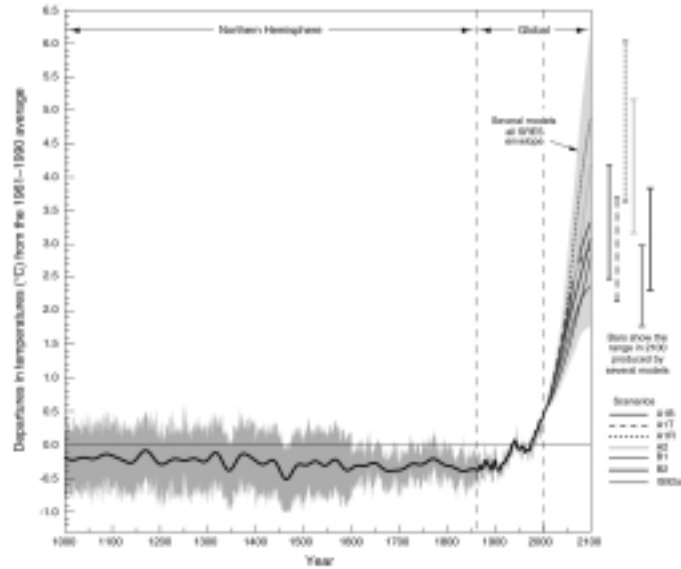
## Scenarios

	1990	2100
• Population (billion)	5.3	7.0 - 15.1
• World GDP ( $10^{12}$ 1990US\$/yr)	21	235 - 550
• Per capita income ratio: developed countries to developing countries	16.1	1.5 - 4.2
• Final energy intensity ( $10^6$ J/US\$) <sup>a</sup>	16.7	1.4 - 5.9
• Primary energy ( $10^{18}$ J/US\$)	351	514 - 2226
• Share of coal in primary energy (%) <sup>a</sup>	24	1 - 53
• Share of zero carbon in primary energy (%)	18	28 - 35

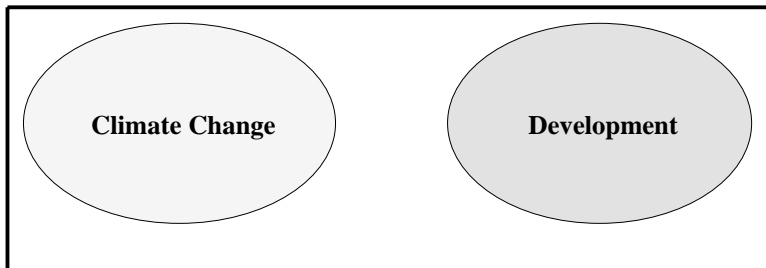
## The Global Climate of the 21st Century



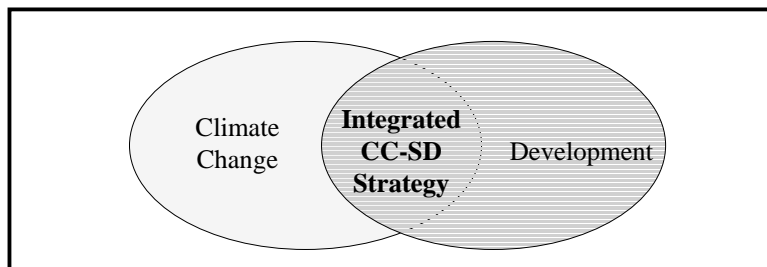
## Variations of the Earth's Surface Temperature: 1000 to 2100



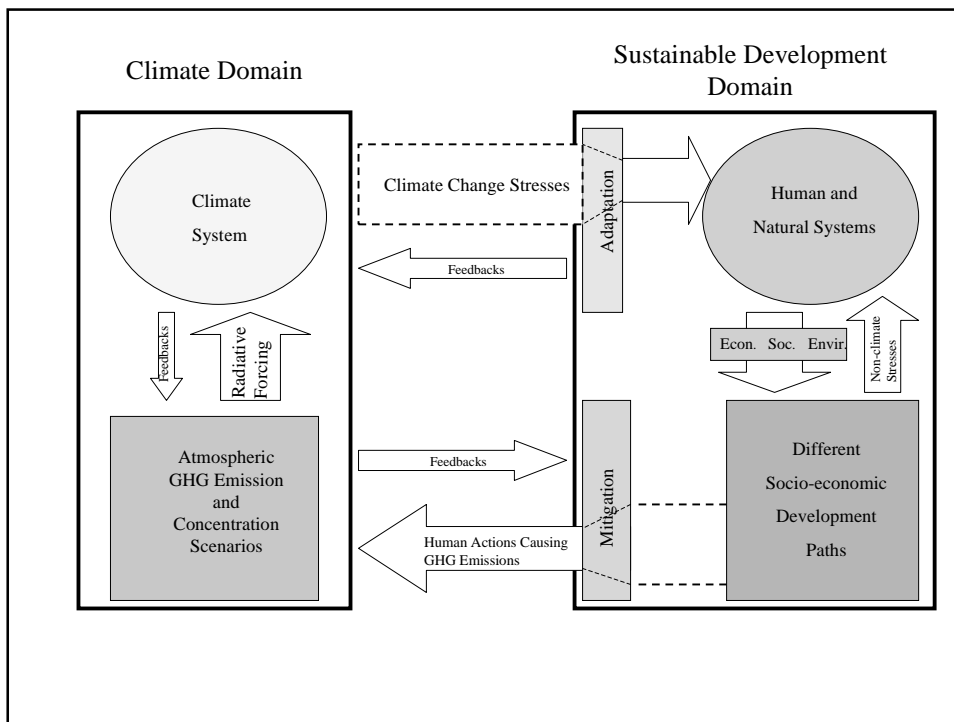
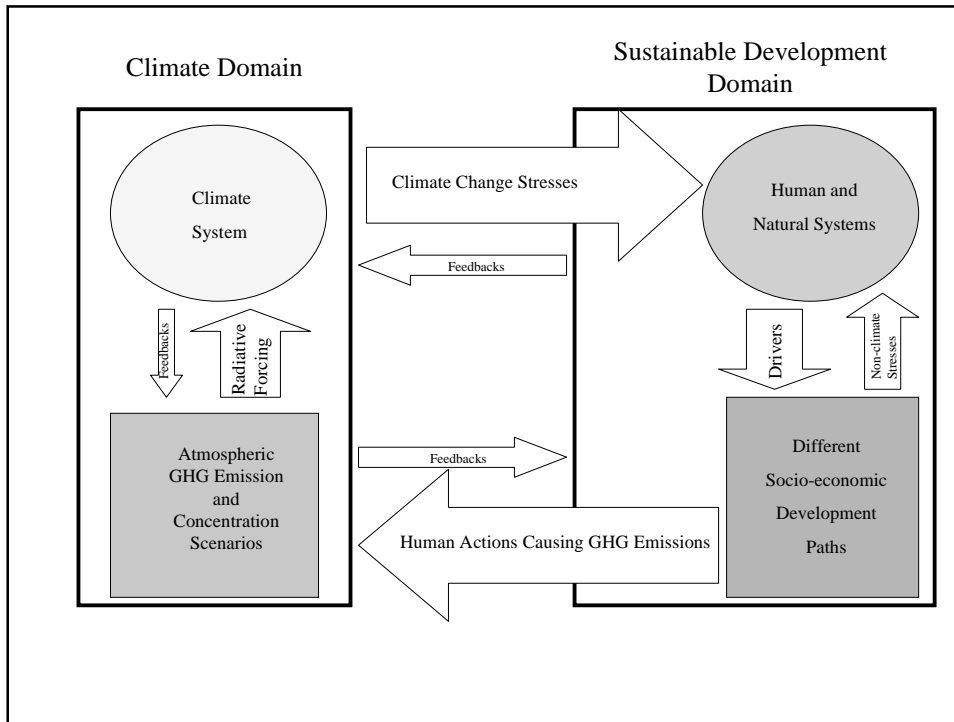
- 1000 to 1861, N. Hemisphere, proxy data;
- 1861 to 2000 Global, Instrumental;
- 2000 to 2100, SRES projections

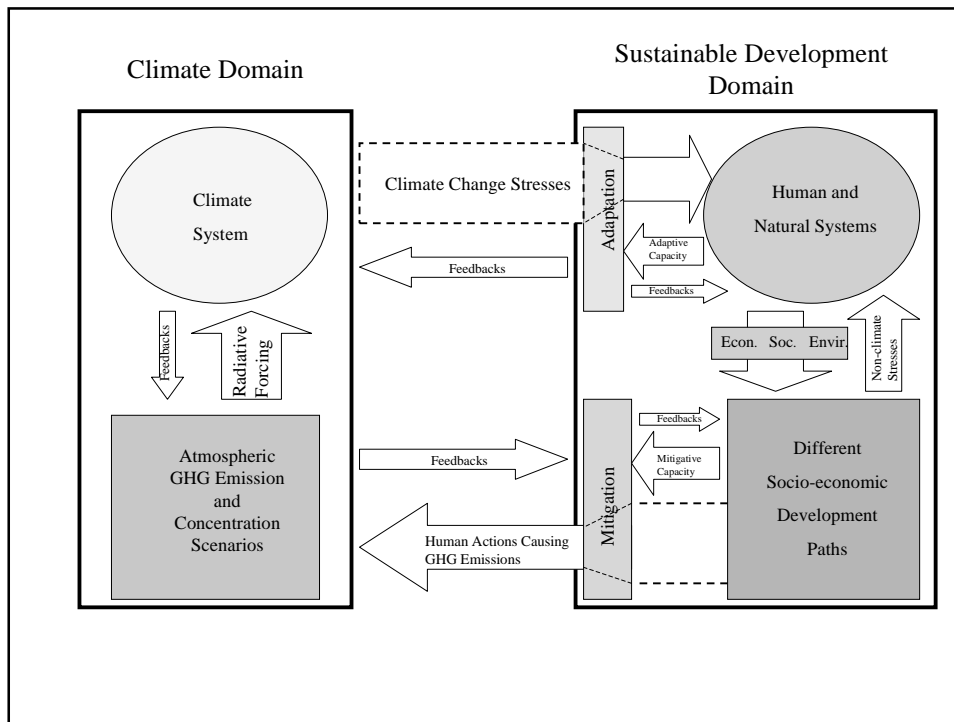


**Former Viewpoint**



**Desired Viewpoint (policy relevant)**

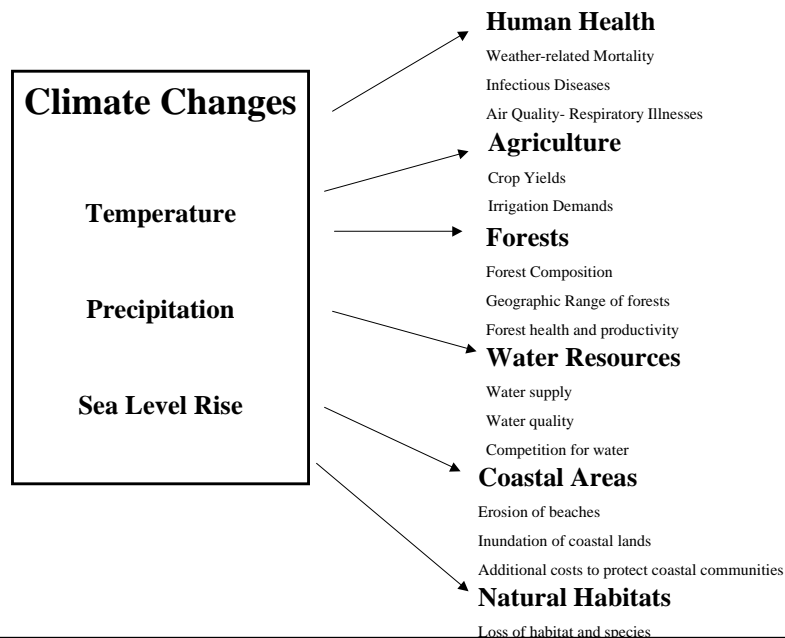




## Causes of Development and Change

- **Economic Growth and Consumption**
- **Demographic shifts (pop. growth and rural/urban transition)**
- **Broad Technological Changes**
- **Governance Structures**
  - increased consumption of natural resources and energy
  - inefficient use of technologies and failure to invest in R&D for the technologies of the future
  - institutional and government failures to regulate the use of natural resources and energy
  - policy and market failures, including lack of recognition of the true value of natural resources; failure to appropriate the global values of natural resources to the local level; failure to internalize the social costs of environmental degradation into the market prices of resources; and subsidies that lead to inefficient use of resources and act as barriers to the market penetration of environmentally friendly technologies

## Potential Climate Change Impacts



## Adverse Impacts of Climate Change

- decreased water availability in many water scarce regions, especially in arid and semi-arid lands in the sub-tropics
- reduction in agricultural productivity: (a) in the tropics and sub-tropics for almost any warming, and (b) in mid-latitudes for warming more than a few degrees
- changes in the productivity and composition of ecological systems, with coral reefs and forests being most vulnerable
- increased risk of floods, potentially displacing millions of people, due to sea level rise and heavy rainfall events, especially in small island states and low-lying deltaic areas
- increased incidence of heat stress mortality, and the number of people exposed to vector-borne diseases, such as malaria and dengue and water-borne diseases such as cholera, especially in the tropics and sub-tropics

## Climate Change and Ecological Systems

- **Biological systems affected** by changes in climate at the regional scale
- **Structure, functioning of ecological systems altered** and the biological diversity will decrease, especially in niche systems, e.g., alpine and arctic
  - **forests**, especially tropical and boreal forests are vulnerable due to changes in disturbance regimes (pests and fires), likely to change species composition
  - **coral reefs** are threatened by increases in temperature, more than increases in sea level - increased mortality
  - **terrestrial uptake of carbon** will likely diminish over time and forest systems may become a source of carbon

## Beneficial Impacts of Climate Change

- increased agricultural productivity in some mid-latitude regions for increases in warming of up to a few degrees
- increased water availability in some water-scarce regions, e.g., in some parts of S. East Asia
- reduced winter mortality in mid- and high-latitudes
- increase in timber supply (with well managed forests)

## Vulnerability to Climate Change

- Vulnerability is a function of three factors
  - degree of climate change
  - sensitivity of sector/system to climate change
  - adaptive capacity

## Developing Countries are the Most Vulnerable to Climate Change

- **Impacts disproportionately on the poorest countries and poorest persons within countries, who have contributed least GHG emissions:** exacerbates inequities in health status and access to adequate food, clean water and other resources.
- **Net effects negative in most developing countries,** but mixed for developed countries for a warming of up to a few degrees Centigrade.
  - A warming of greater than a few degrees Centigrade is likely to result in net effects becoming negative for most countries

## Why Developing Countries Are More Vulnerable:

### a) Impacts are worse

#### **Closer to margin of tolerance**

for temperature and precipitation changes (more drought- and flood-prone areas)

#### **Vulnerable economic structure**

Larger share of the economy in climate sensitive sectors, such as agriculture

#### **Coastal vulnerability**

49 out of 50 countries with shore protection costs due to climate change above 0.5% of GDP are less developed countries

#### **Poorer nutrition and health infrastructure**

and therefore higher losses of human life

## Why Developing Countries Are More Vulnerable:

### b) Lower capacity to adapt

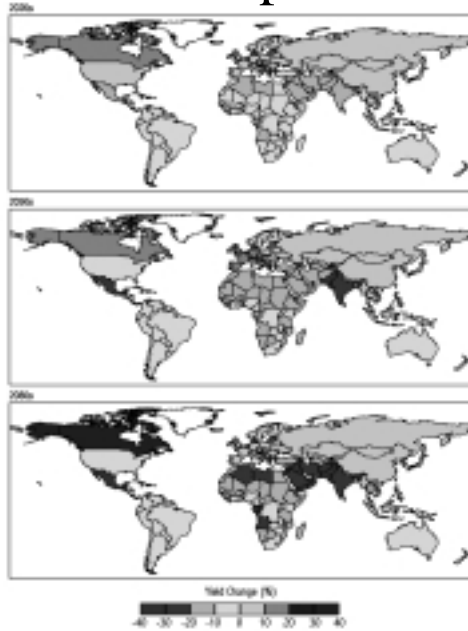
#### **Availability of technology**

#### **Know-how and education**

#### **Institutional capacity**

#### **Financial capacity**

# Crop Yield Change

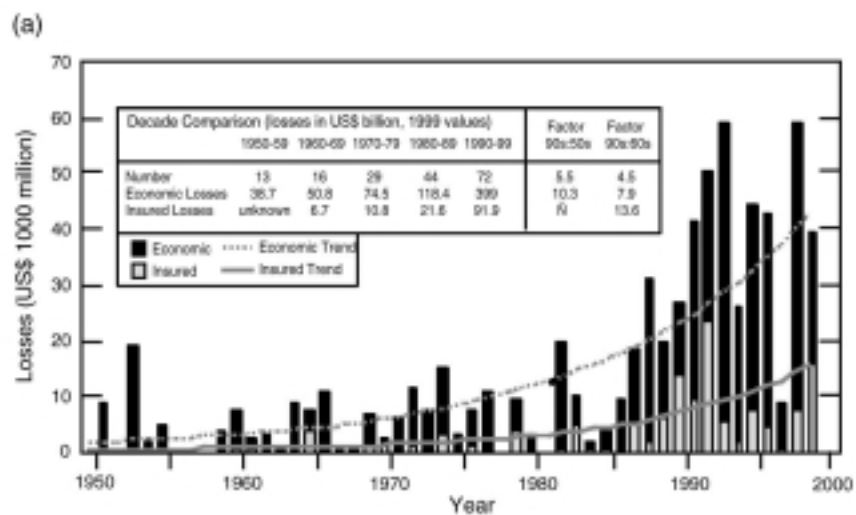


Percentage change in average crop yields for the climate change scenario. Effects of CO<sub>2</sub> are taken into account. Crops modeled are: wheat, maize and rice.

Jackson Institute, University College London / Goddard Institute for Space Studies / International Institute for Applied Systems Analysis

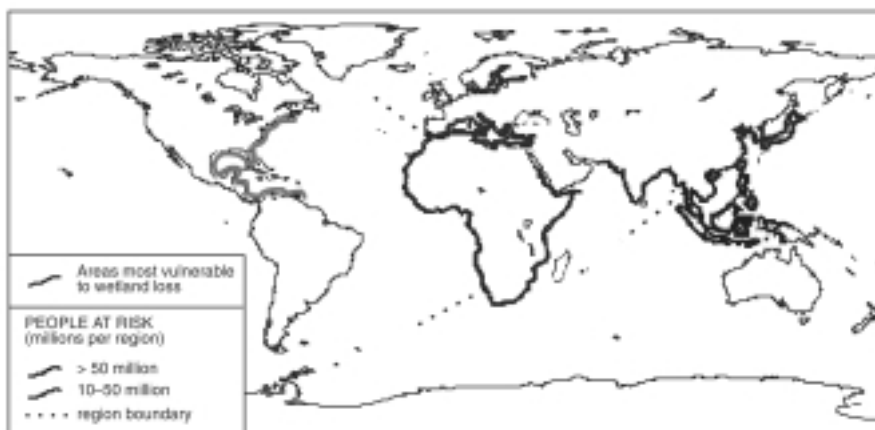
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## Evidence of yearly extreme weather-related losses:1950-99



## People at Risk from a 44 cm Sea-level Rise by the 2080s

Assuming 1990s Level of Flood Protection



Source: R. Nicholls, Middlesex University in the U.K. Meteorological Office. 1997. *Climate Change and Its Impacts: A Global Perspective*.

## Vector (insect)-borne Diseases

Disease	Vector	Population at risk (millions)	Present distribution	Likelihood of altered distribution with warming
Malaria	mosquito	2,100	(sub)tropics	✓✓
Schistosomiasis	water snail	600	(sub)tropics	✓✓
Filariasis	mosquito	900	(sub)tropics	✓
Onchocerciasis (river blindness)	black fly	90	Africa/Latin America	✓
African trypanosomiasis (sleeping sickness)	tsetse fly	50	tropical Africa	✓
Dengue	mosquito	unavailable	tropics	✓✓
Yellow fever	mosquito	unavailable	tropical South America & Africa	✓

Likely            ✓  
Very likely      ✓✓

Source: Modified WHO, as cited in Stone (1995).

## **Co-Benefits: Adaptation to Both Natural and Forced Climate Change**

- **Many sectors vulnerable** (e.g., water resources and agriculture) to natural climate variability, e.g., floods and droughts associated with ENSO events
- **Identify technologies, practices and policies** that can reduce the vulnerability of sectors to natural climate variability, and can increase adaptive capacity as well as resilience to long-term climate change - examples:
  - better infrastructure design (e.g., bridges, roads, buildings)
  - incorporate modern scientific forecasts of ENSO events into sector management decisions
  - integrated multi-sector watershed management and appropriate water pricing policies
  - elimination of inappropriate agricultural subsidies

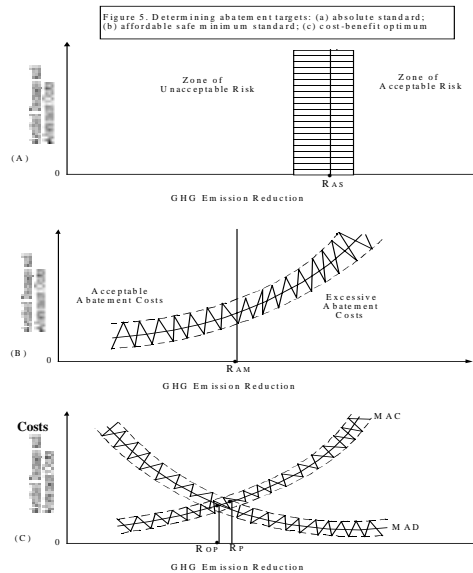
## **Mitigation and Burden Sharing**

**UNFCCC and Kyoto Protocol confirm that developed (Annex 1) countries must take lead in mitigation efforts:**

- **main contributors to GHG emissions**
- **greater financial and technical capability**

# Some Applications of Sustainomics to Identify Practical Options

## Avoiding “dangerous anthropogenic intervention with climate system”



Source: Adapted from IPCC 1996c, Figure 5.10

## **SD and Macro/Sectoral Policies**

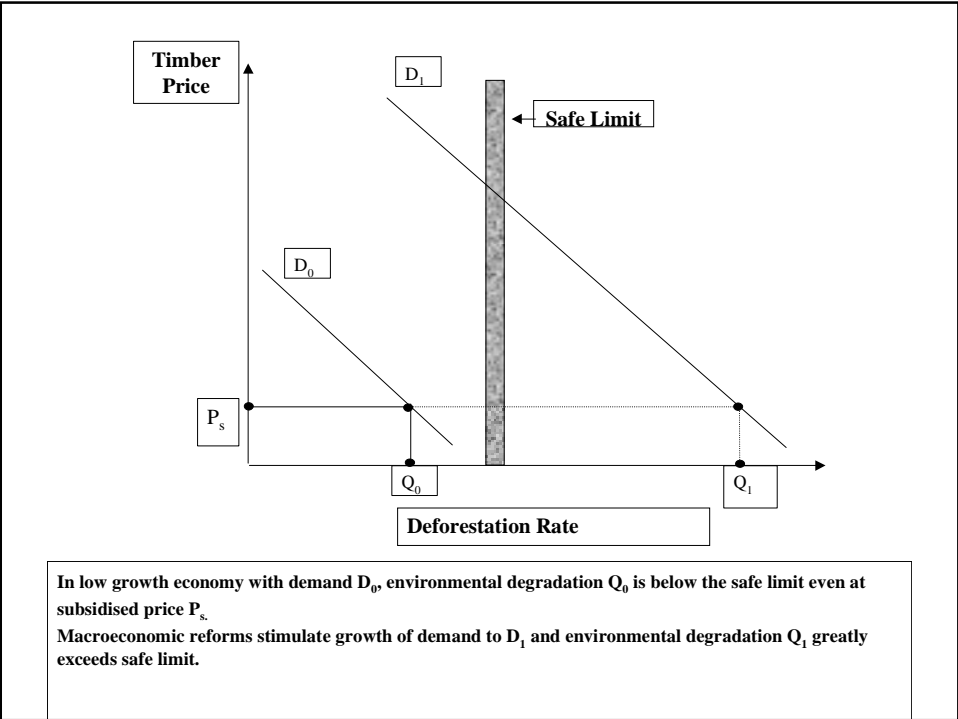
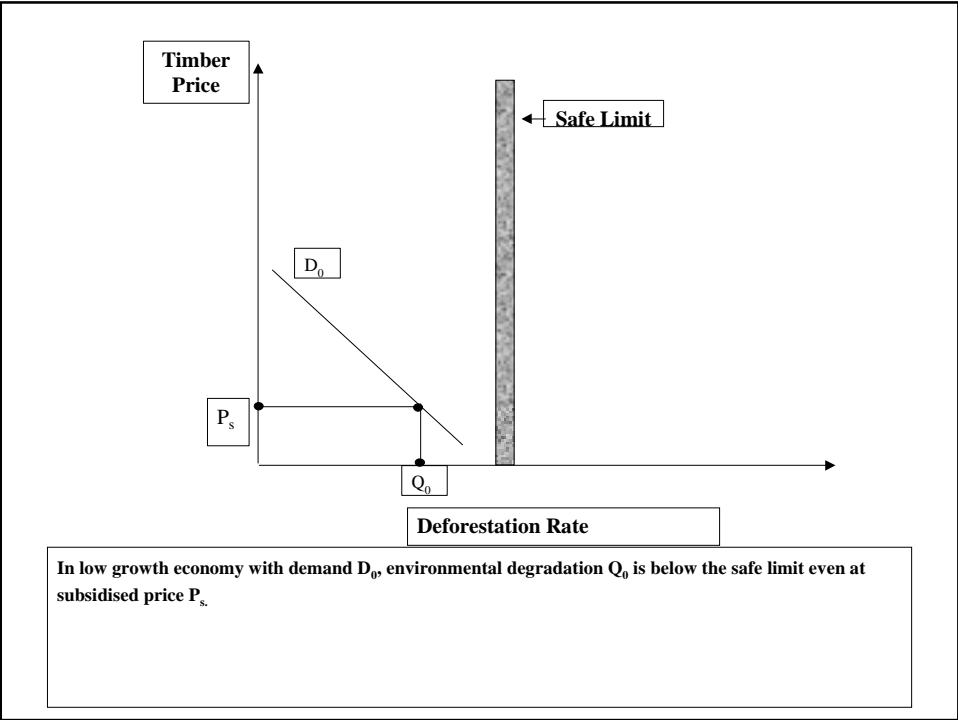
- Macro/sectoral (economywide) policies are designed mainly to revive economies, boost growth, alleviate poverty, etc.
- They can have good social and environmental impacts -- e.g., economywide liberalization and market-based reforms will improve efficiency of natural resource use.
- However, growth can combine with economic imperfections to cause social and environmental damage.

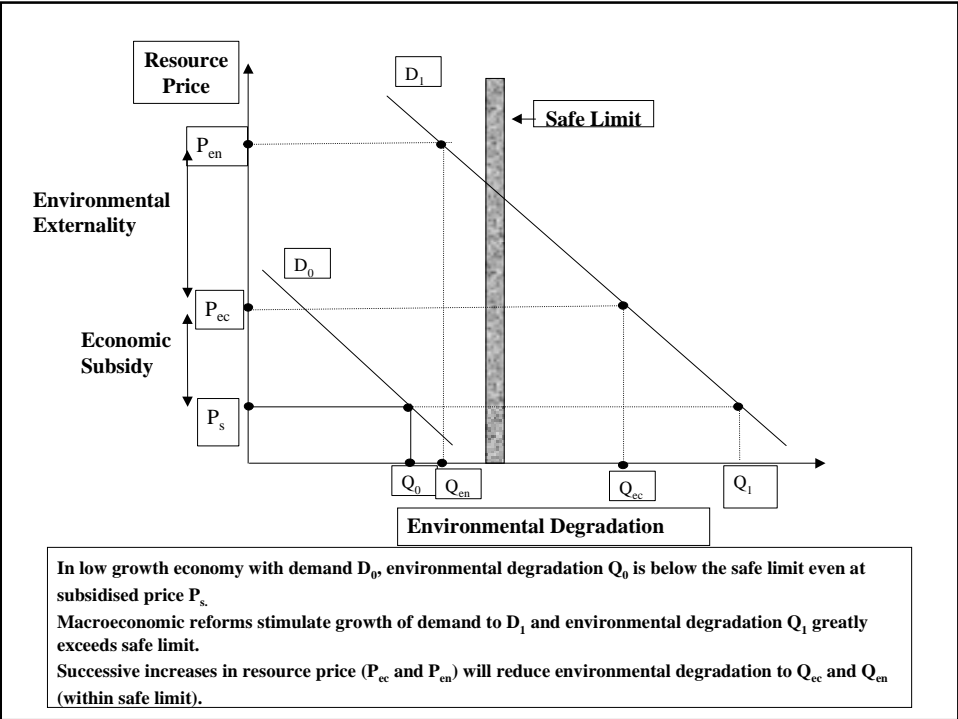
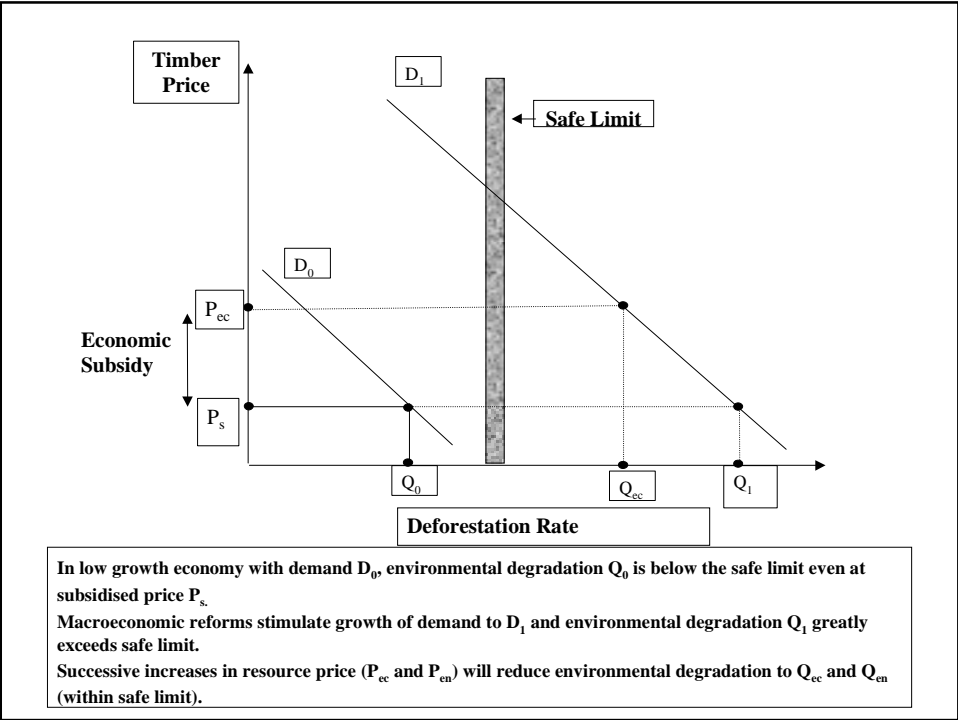
### Problem

- Economic expansion often interacts unfavourably with pre-existing imperfections, to cause social and environmental harm.
  - Policy distortions
  - Market failures
  - Institutional constraints

### Remedy

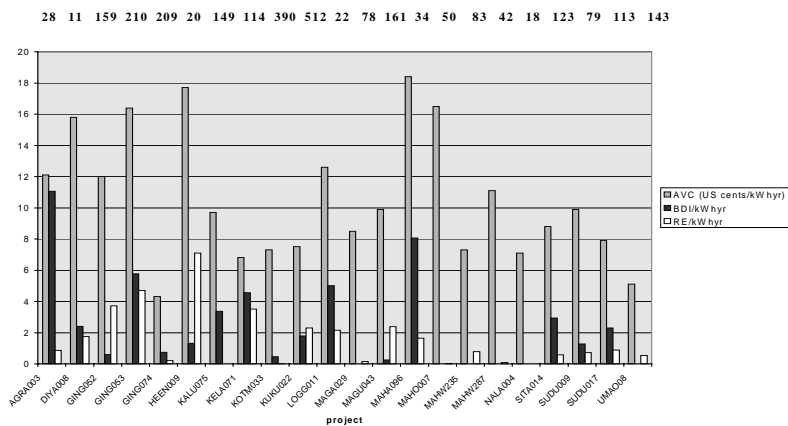
- Introduce complementary measures to remove imperfections and reduce the vulnerability of society and the environment directly -- without reversing economywide reforms and affecting economic growth prospects.





### MCA of Hydroelectric Projects

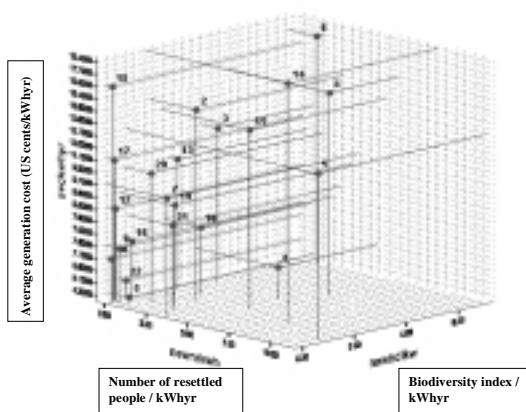
**Figure 11. Average generation costs (AVC), biodiversity index (BDI), and number of resettled people (RE) by hydroelectric project. All indices are per kWh per year. Numbers of people resettled and the biodiversity index are scaled for convenience (by the multipliers  $10^{-5}$  and  $10^{-9}$  respectively). The values at the top of the graph indicate the annual energy generation in gigawatt hours (GWh).**



Source: CEB (1987); CEB (1988); Meier and Munasinghe (1994)

### Three dimensional MCA of sustainable development indicators for various hydropower options.

Source: Morimoto, Munasinghe and Meier [2000]



## **Developing Country Strategies**

- **Develop Fast (reduce vulnerability)**
- **Adapt (reduce impact damage)**
- **Mitigate (earn FX through JI etc.)**
- **Combine above options**

## **Concluding Thoughts on Climate Change and Sustainable Development**

- **CC policies must be integrated with SD strategies**
- **Adaptation and vulnerability reduction is critical for developing countries (avoid adverse CC and globalisation impacts )**
- **Mitigation is the main obligation of industrial countries**

**The way forward towards Sustainable Development is by making existing development patterns more sustainable -- using the Sustainomics approach for balanced consideration of economic, environmental and social elements. In particular, maintaining and accumulating Manufactured, Natural and Human capital is vital.**

### **Some Issues to be Explored in the Case Studies**

1. Designing models and sub-models that better balance and integrate the economic, social and environmental aspects;
2. Incorporating approaches based on both optimality and durability, identifying the circumstances under which these viewpoints would be appropriate, and reconciling potential conflicts;
3. Linking the global/transnational, macroeconomic/regional/sectoral, and local/project impacts;
4. Developing methods to identify win-win situations, where development could be made more sustainable, unambiguously;
5. Developing methods to resolve situations involving trade-offs among different objectives of sustainable development;
6. Exploring the linkages among poverty, equity and climate change;
7. Testing assessment methods and associated indicators of sustainable development at the global/transnational, macroeconomic/regional/sectoral, and local/project.

**Postscript: Learning from the past**

**“The law locks up both man and woman  
Who steals the goose from off the common  
And lets the greater felon loose  
Who steals the common from the goose.”**

**19<sup>th</sup> Century Verse,  
England.**