Natural resource scarcity, ecological scarcity and sustainable development 20 years on:

What have we learned that is relevant to developing countries?

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Outline

- What is “ecological scarcity” and why is it an “economic problem”?
- Why has ecological scarcity become a “global” problem that is particularly relevant to developing countries?
- Why is “frontier expansion” at the heart of this problem and the key indicator of “unsustainable development”?
  - Big picture overview
  - Specific case study: shrimp farming vs mangrove loss in Thailand
- What needs to be done and how urgently?

References

- For “big picture” overview:
  - Barbier, E.B. 2008. “Poverty, Development, and Ecological Services.” *International Review of Environmental and Resource Economics 2* (In press).
  - Barbier, E.B. 2007. “Frontiers and Sustainable Economic Development.” *Environmental and Resource Economics* 37:271-295.
  - Barbier, E.B. 2005. *Natural Resources and Economic Development,* Cambridge University Press, 410 pp.
- For case study:
  - Barbier, E.B. 2007. “Valuing Ecosystem Services as Productive Inputs” *Economic Policy* 22 (49): 177–229.

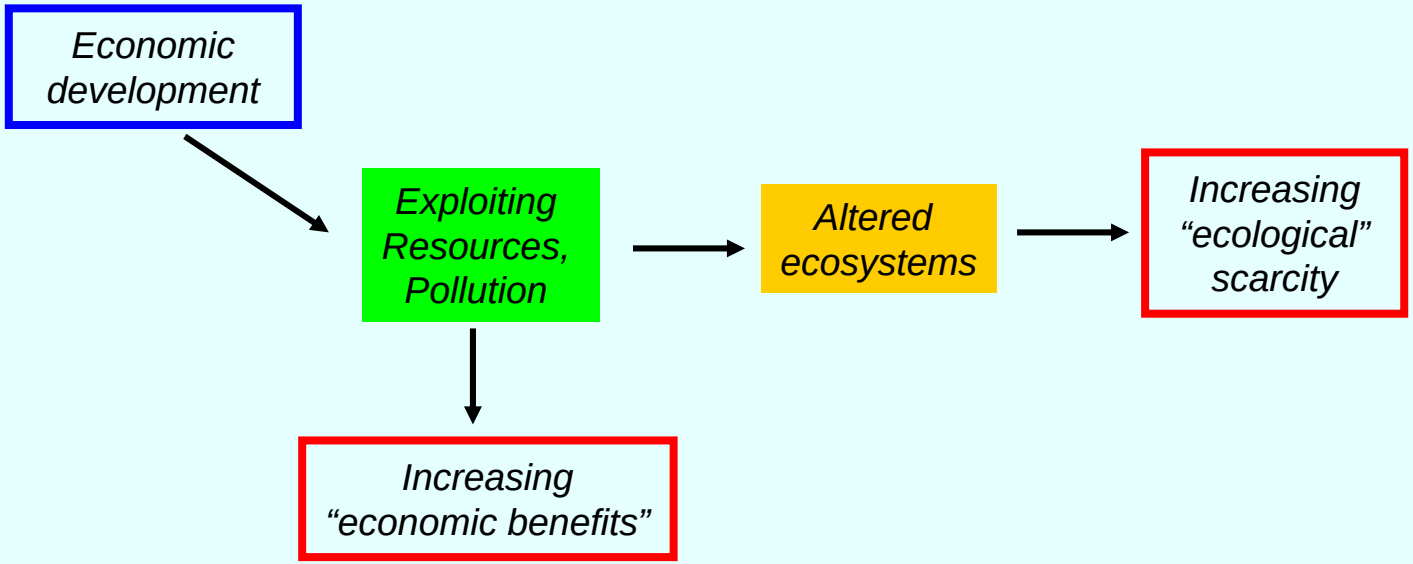
“Ecological scarcity” *is* “an economic problem”

- Sometimes “old” definitions still make some sense:

  “The fundamental scarcity problem...is that as the environment is increasingly being exploited for one set of uses (e.g., to provide sources of raw material and energy, and to assimilate additional waste), the quality of the environment may deteriorate. The consequence is an increasing *relative scarcity* of essential natural services and ecological functions....Although the loss of these essential natural services as a result of environmental degradation is not directly reflected in market outcomes, it nevertheless has a major effect in the form of economic scarcity. In other words, if ‘the environment is regarded as a scarce resource’, then the ‘deterioration of the environment is also an economic problem.’”

Barbier, E.B. 1989. *Economics, Natural Resource Scarcity and Development: Conventional and Alternative Views.* Earthscan Publications, London, pp. 96-7.

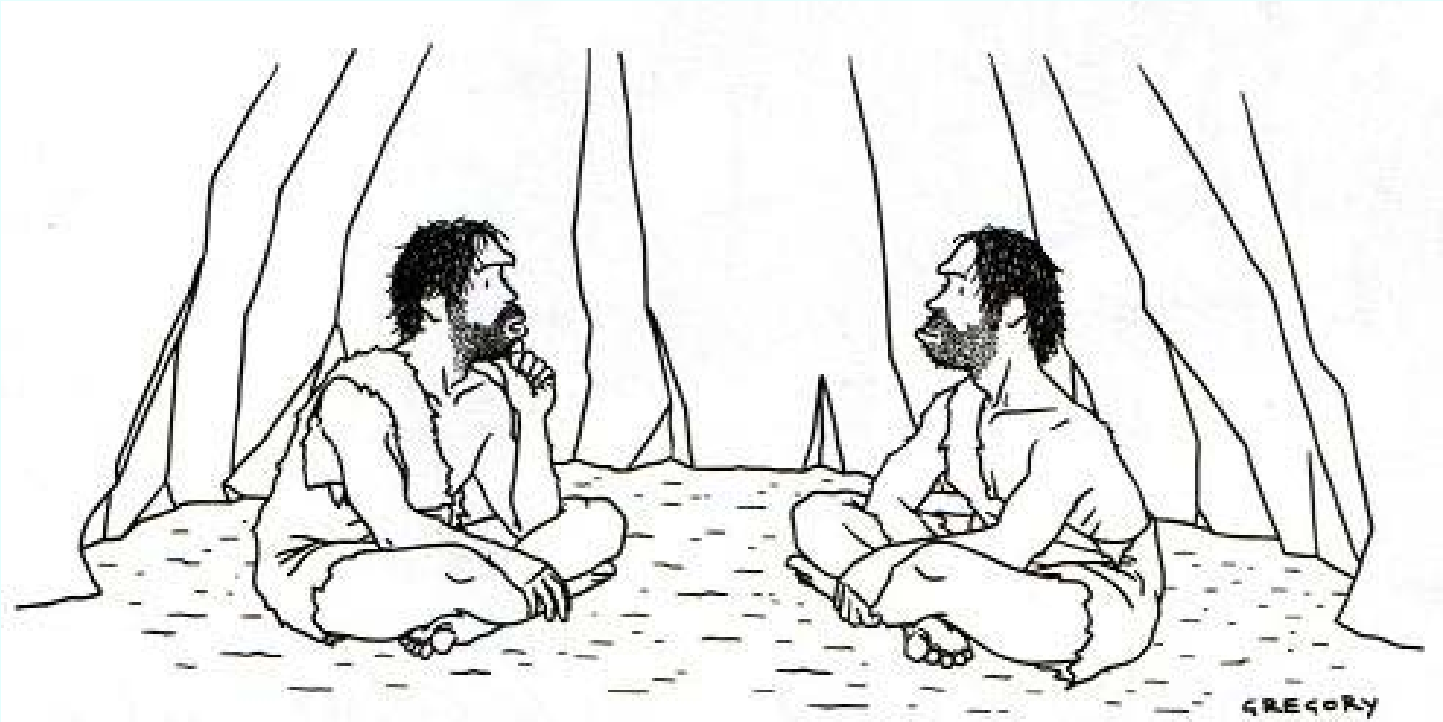
The key trade-offs involved....



Barbier, E.B. 1989. *Economics, Natural Resource Scarcity and Development: Conventional and Alternative Views.* Earthscan Publications, London.

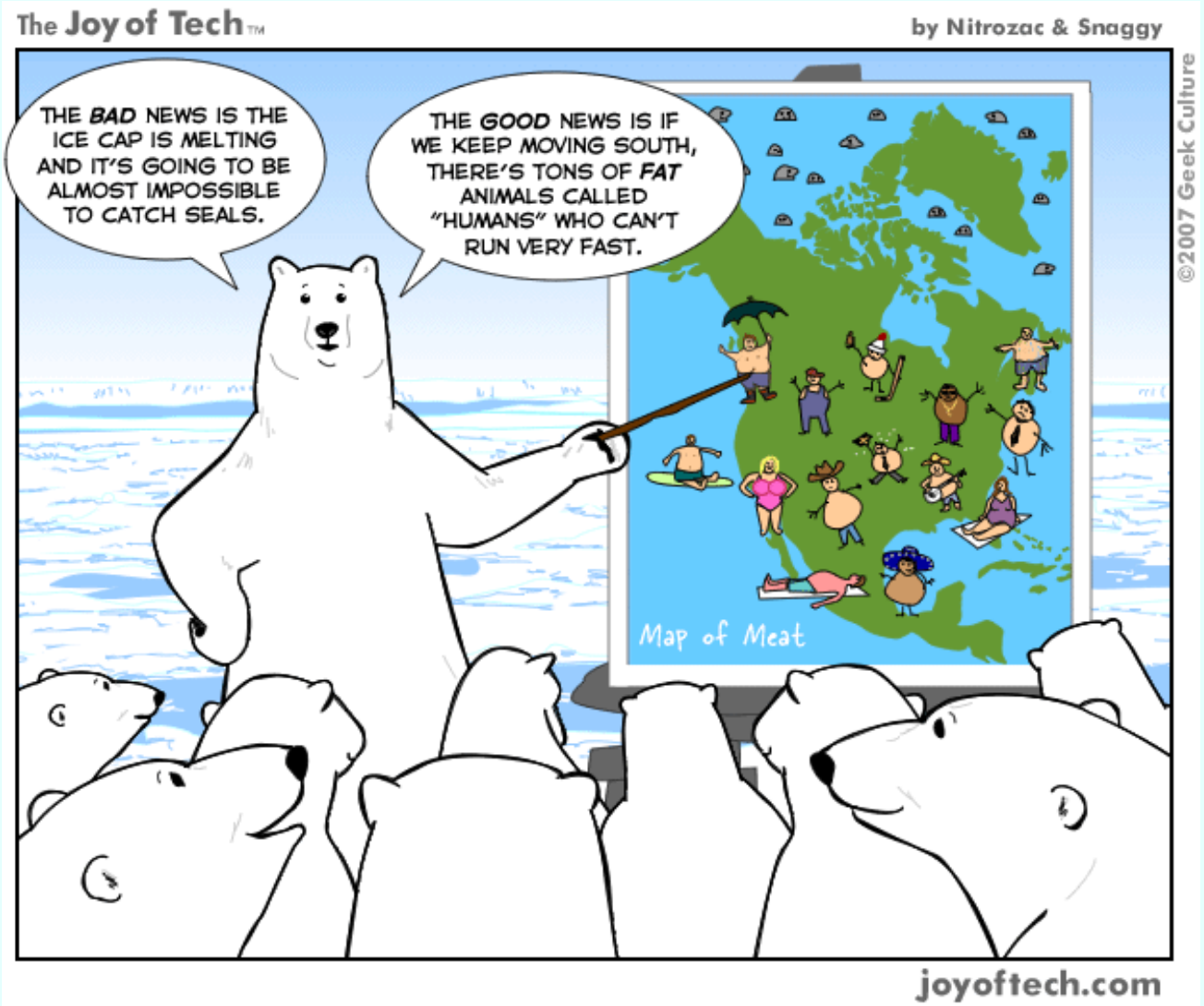
Barbier, E.B. et al. 1994. *Paradise Lost? The Ecological Economics of Biodiversity.* Earhscan Publications, London

Some increased economic benefits may be worth the tradeoff....

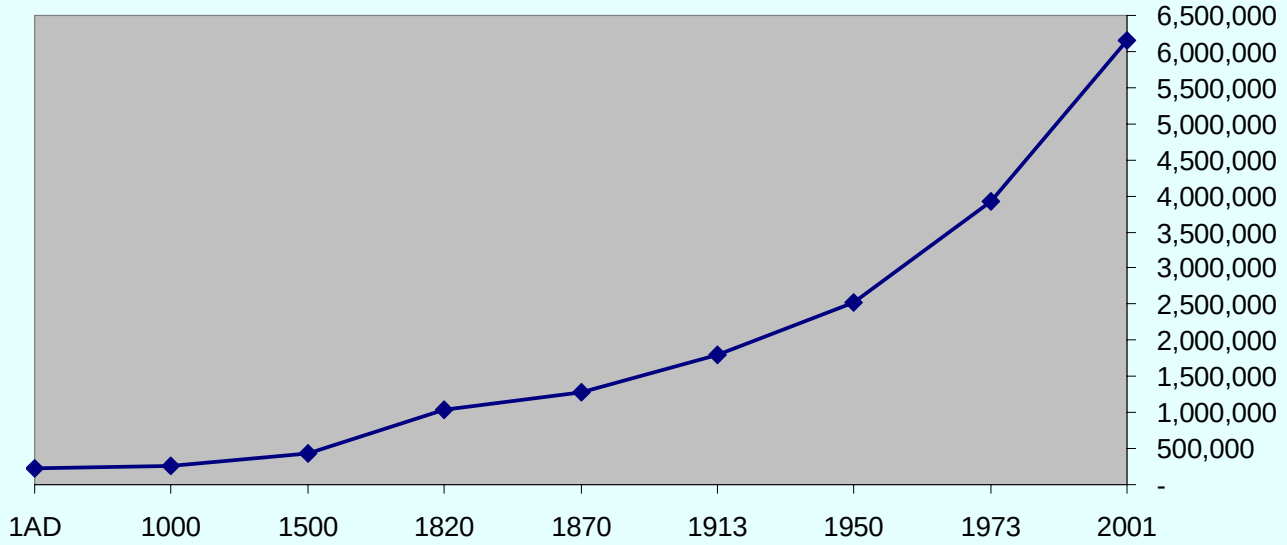


"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."

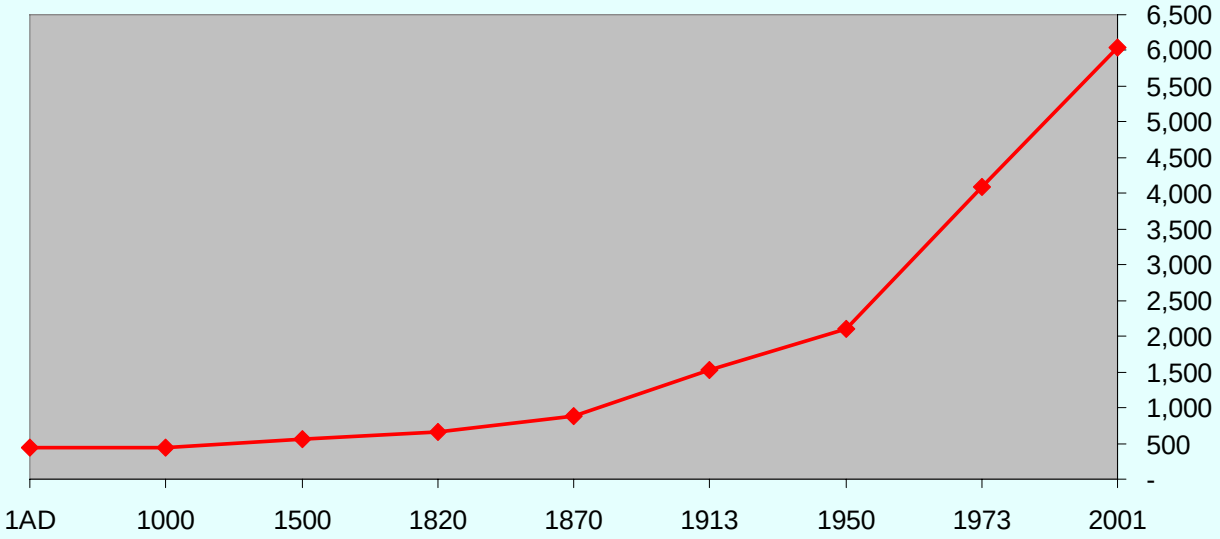
...or will ecological change “bite”?



World Population, 1 AD - 2001



World GDP per capita ($1990)



Unending frontiers?

- But the environmental impact of modern global development has been substantial:

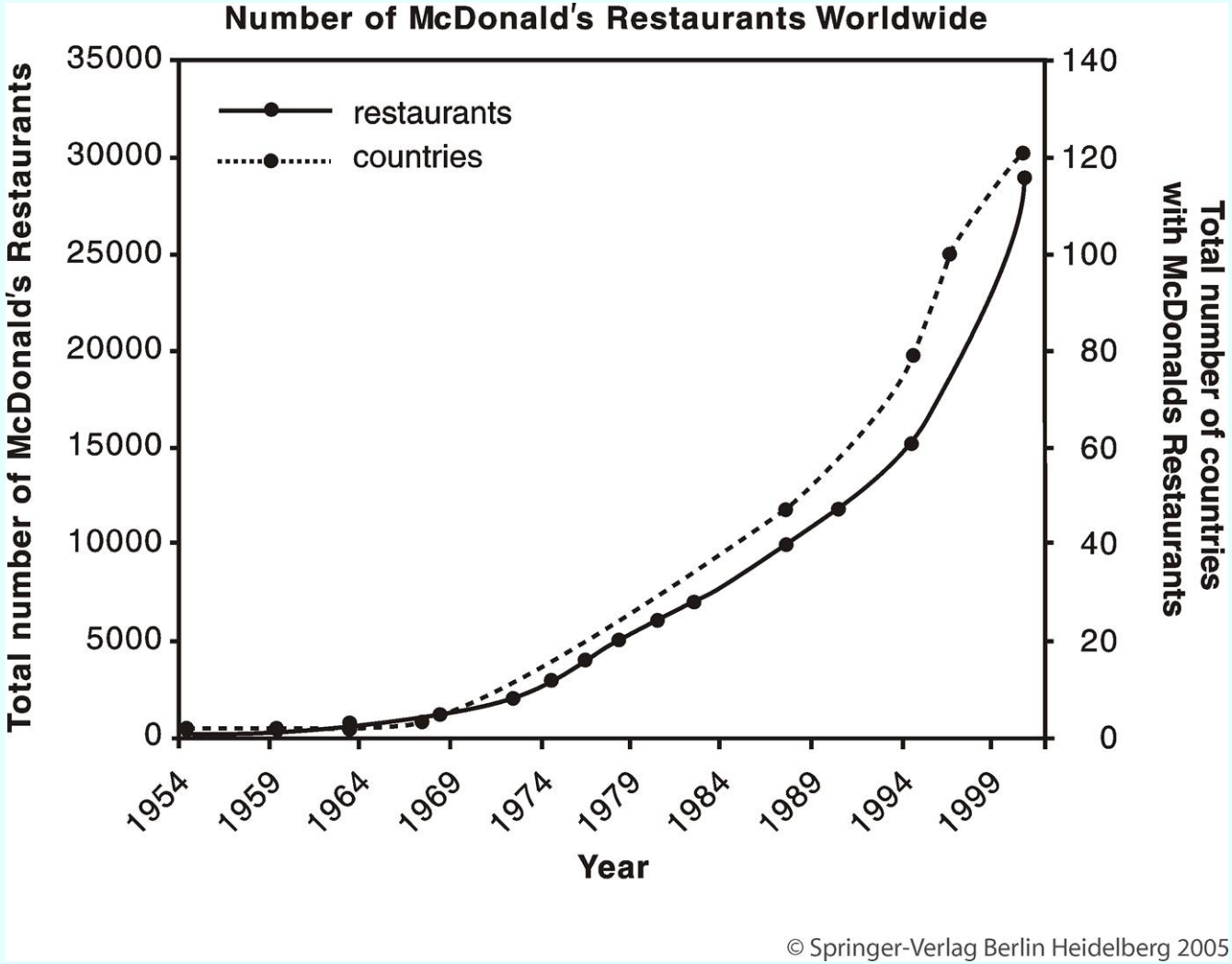
  "The early modern near-doubling of human numbers generated new pressures on the natural world….shared long-term historical processes – settlement frontiers, biological invasions, and the world hunt – imposed shattering changes on regional ecosystems around the world. During the early modern period, there was an irresistible, and seemingly irreversible trend towards more intensive human control and use of the land and the natural environment. As this occurred, those intricate local assemblages of vegetation and fauna that had long flourished with far less human intervention lost complexity, lost diversity, lost numerous species, and sometimes were even eradicated completely….These processes once underway, have continued with little restrained or diversion in the nineteenth and twentieth centuries."

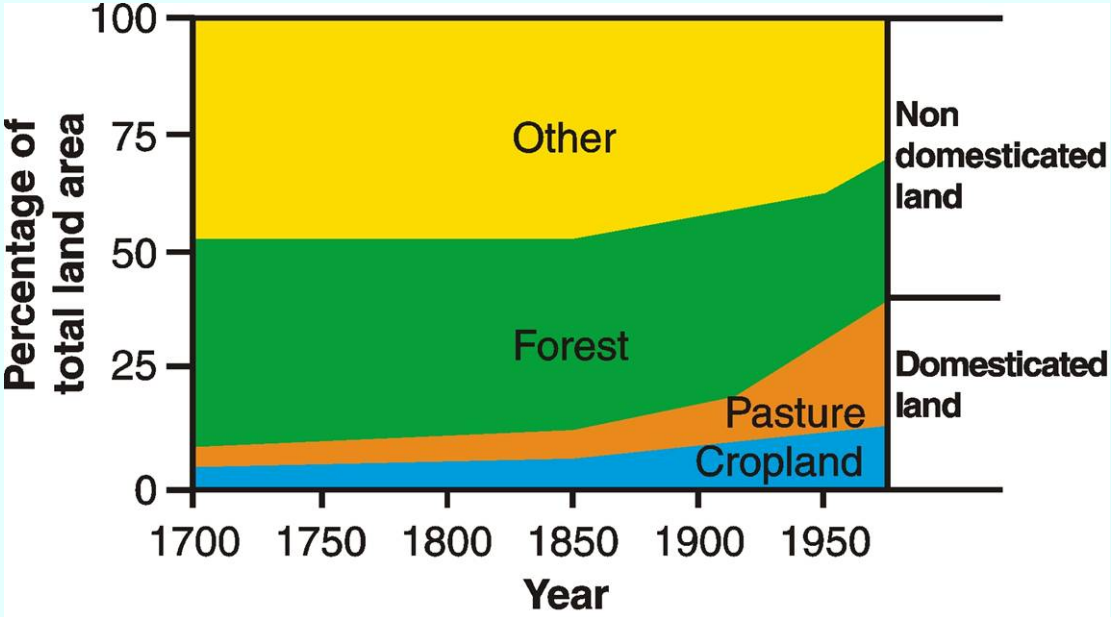
Richards, John F. 2003. *The Unending Frontier: An Environmental History of the Early Modern World.* University of California Press, Berkeley, pp. 617-618.

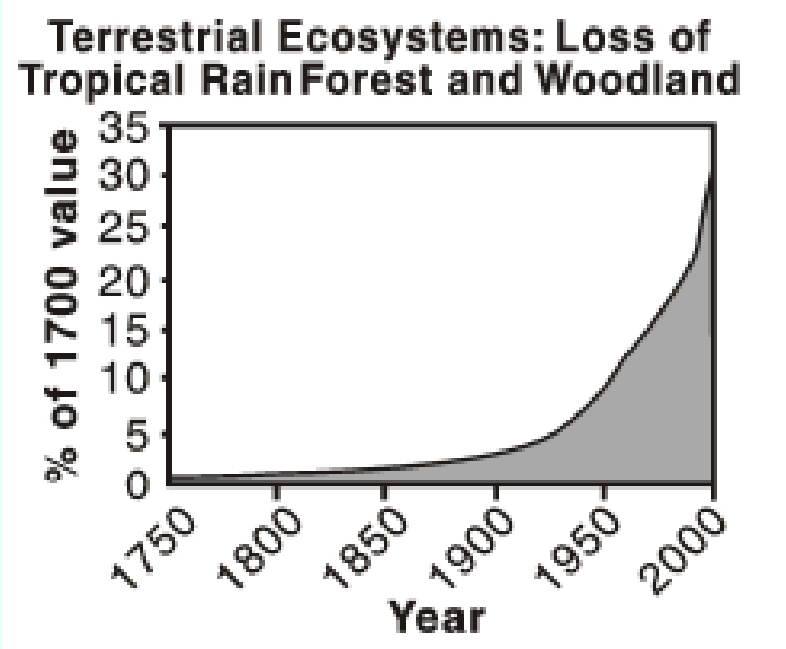
Table 3
Magnitudes of Global Environmental Change, 1890s to 1990s

Variable	Coefficient of Increase, 1890s–1990s
Human population	4
Urban proportion of human population	3
World Economy	14
Total urban population	14
Industrial output	40
Energy use	13–14
Coal production	7
Water use	9
Irrigated area	5
Cropland	2
Forest area	0.8 (20% decrease)
Bird and mammal species	0.99 (1% decrease)
Fin whale population	0.03 (97% decrease)
Marine fish catch	35
Cattle population	4
Pig population	9
Carbon dioxide emissions	17
Air pollution	2–10
Carbon dioxide emissions	17
Sulfur dioxide emissions	13
Lead emissions	8

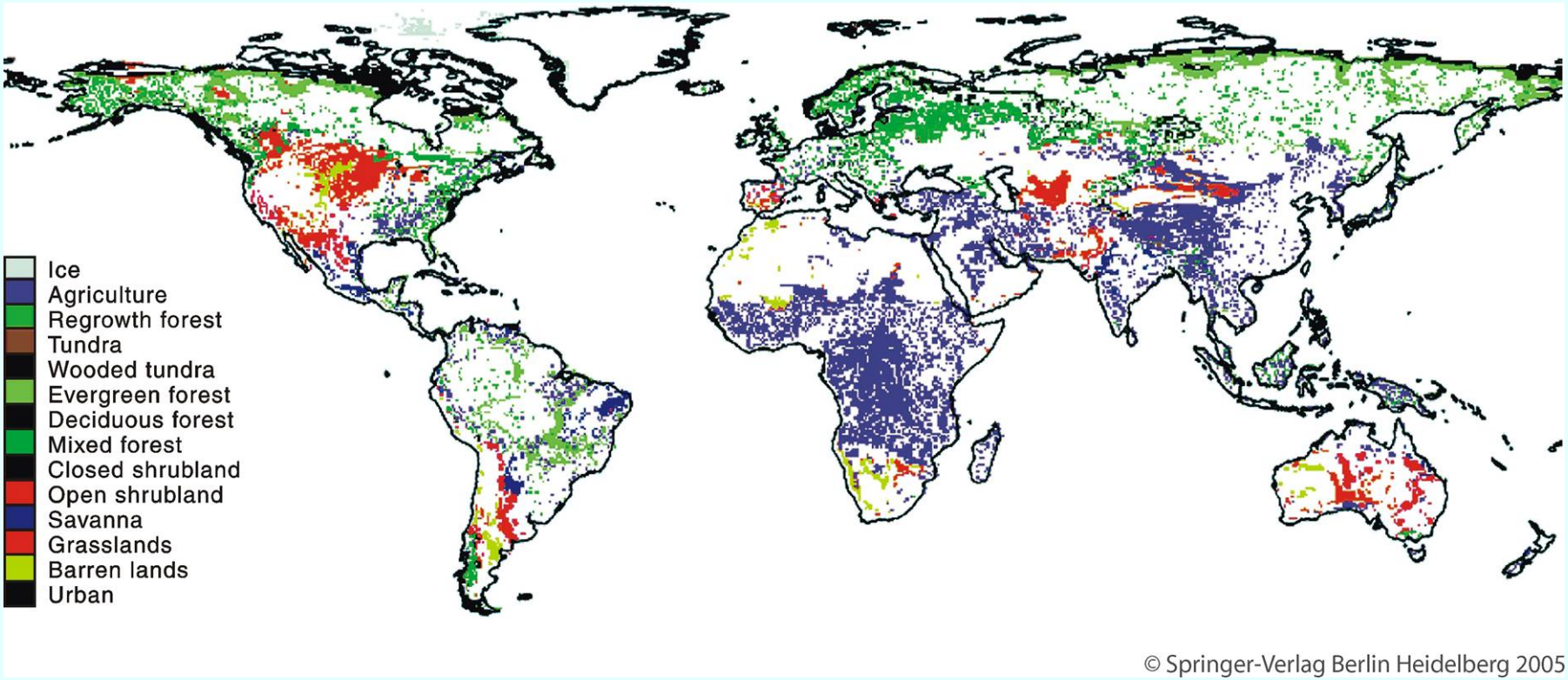
Source: adapted from McNeill (2000): pp. 360–361.







Projected global land-cover change, 1990-2090



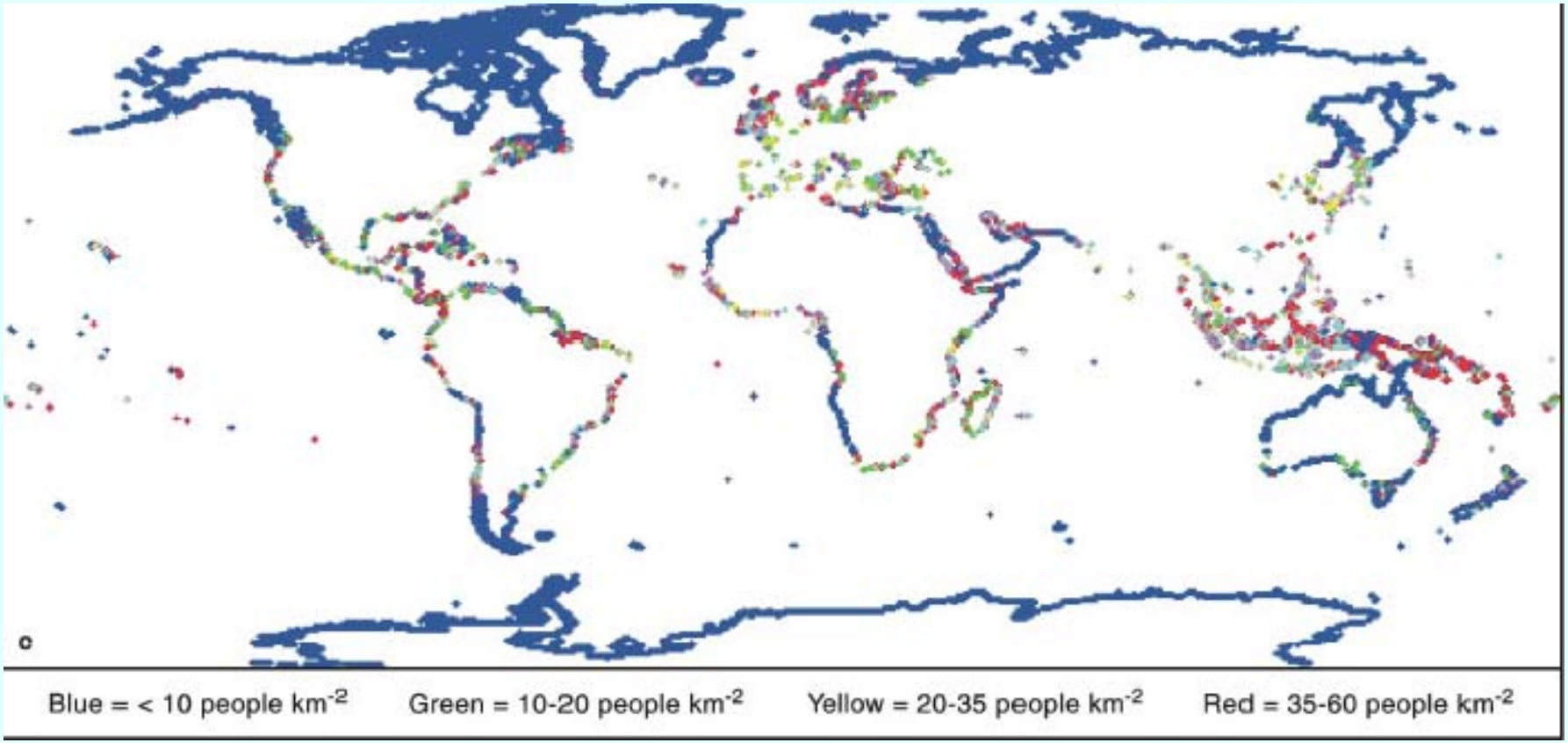
Demand for Cultivated Land in 2050 in Developing Regions

Region	Cultivated crop land in 1990 (1000 ha)	% of production increase from new land	Additional cultivated land required in 2050 (1000 ha)	% of new lands from forest and wetland conversion
Africa	252,583	29	241,703	61
Asia[a]	456,225	10	85,782	73
Latin America[b]	189,885	28	96,710	70
All developing countries	899,795	21	424,194	66

[a] Excludes China.

[b] Includes the Caribbean.

Global areas of relatively pristine coastal regions



Concentration of populations on fragile lands

- Since 1950, the estimated population on fragile lands in developing economies has doubled.
- Currently one quarter of the people in developing countries – almost 1.3 billion – survive on fragile lands. More than 1.2 billion people on fragile lands are in the developing regions of Latin America, Africa and Asia.
- The developing country populations on fragile lands include 518 million living in arid regions with no access to irrigation systems, 430 million on soils unsuitable for agriculture, 216 million on land with steep slopes and more than 130 million in fragile forest systems.
- These populations living on fragile land in developing countries account for many of the people in extreme poverty, living on less than $1 per day.

Barbier, E.B. 2005. “Natural Resource-Based Economic Development in History.” *World Economics* 6(3):103-152.

Distribution of World's Population and Rural Poor on Fragile Land

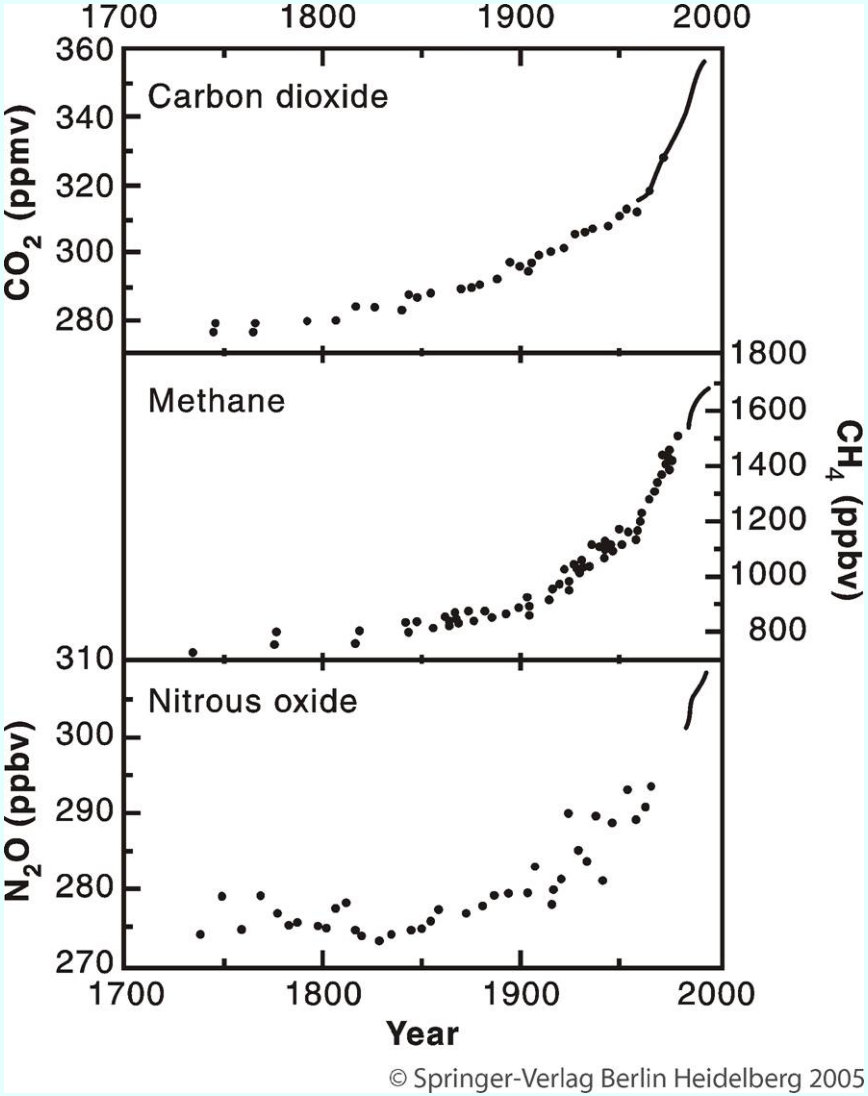
(a) Distribution of World's Population

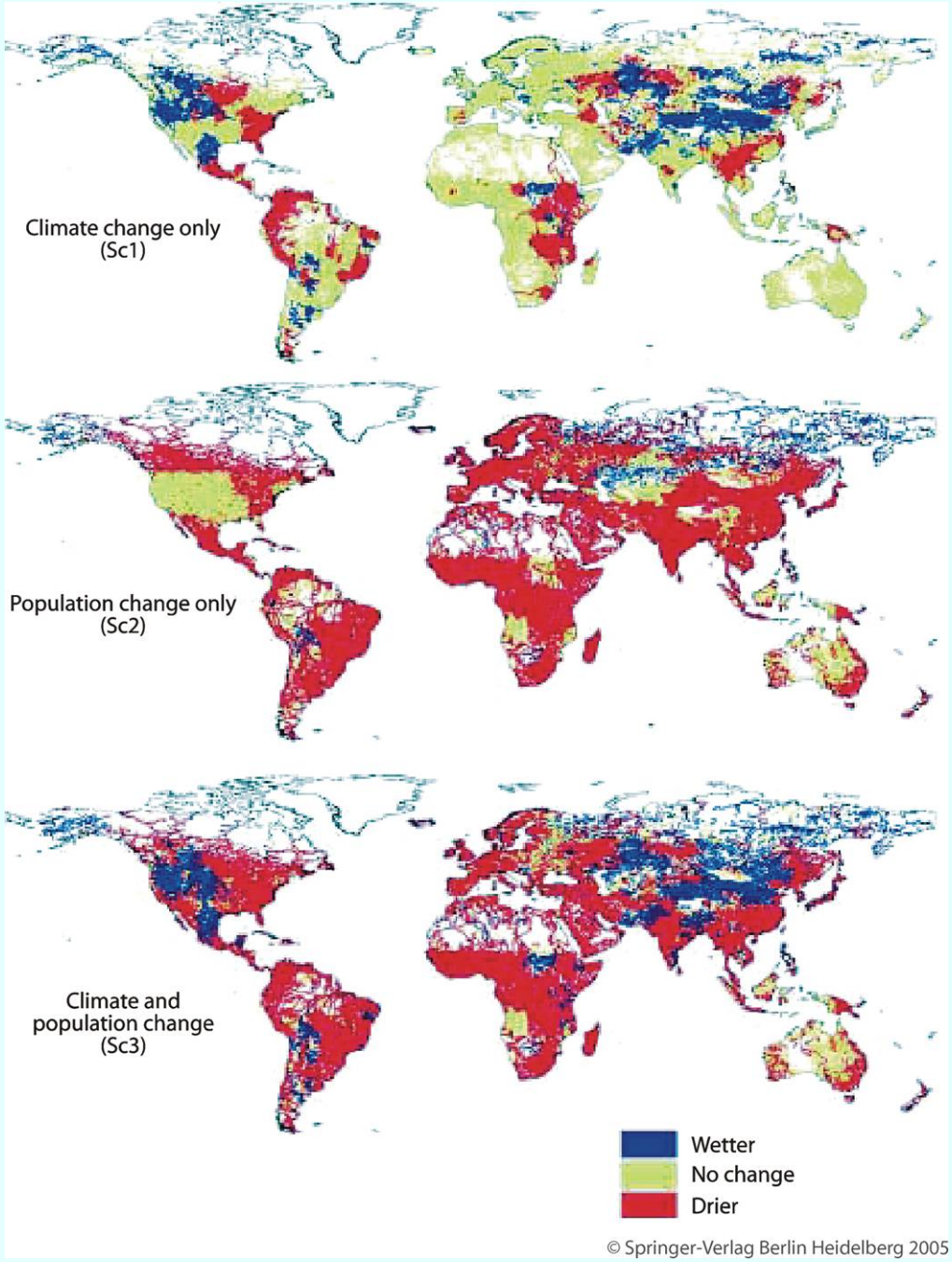
		Population in fragile lands	
Region	**Population in 2000 (millions)**	**Number (millions)**	**Share of total (%)**
Latin America and the Caribbean	515.3	68	13.1
Middle East and North Africa	293.0	110	37.6
Sub-Saharan Africa	658.4	258	39.3
South Asia	1,354.5	330	24.4
East Asia and Pacific	1,856.5	469	25.3
Eastern Europe and Central Asia	474.7	58	12.1
OECD Group[a]	850.4	94	11.1
Other	27.3	2	6.9
Total	**6,030.1**	**1,389**	**23.0**
Total Developing Economies[b]	**5,179.7**	**1,295**	**25.0**
Total Latin America, Africa and Asian Developing Economies[c]	**4,677.7**	**1,235**	**26.4**

(b) Distribution of Rural Poor in Developing Regions

		Rural poor on fragile lands	
Region	**Rural poor on favored lands (millions)**	**Number (millions)**	**Share of total (percent)**
Central and South America	24	47	66
West Asia and North Africa	11	35	76
Sub-Saharan Africa	65	175	73
Asia	219	374	63
Total	**319**	**613**	**66**

Increasing atmospheric pollutants





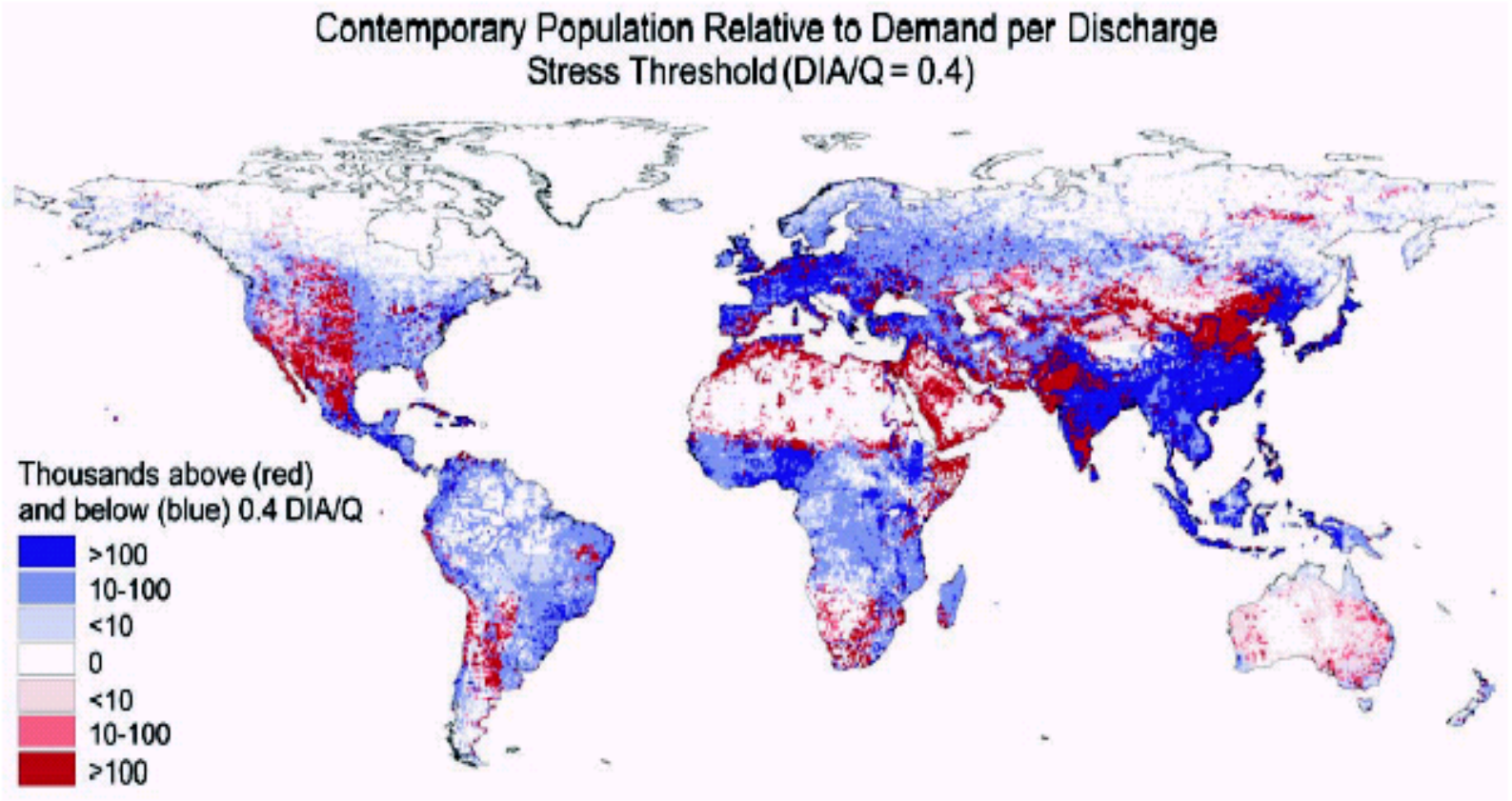
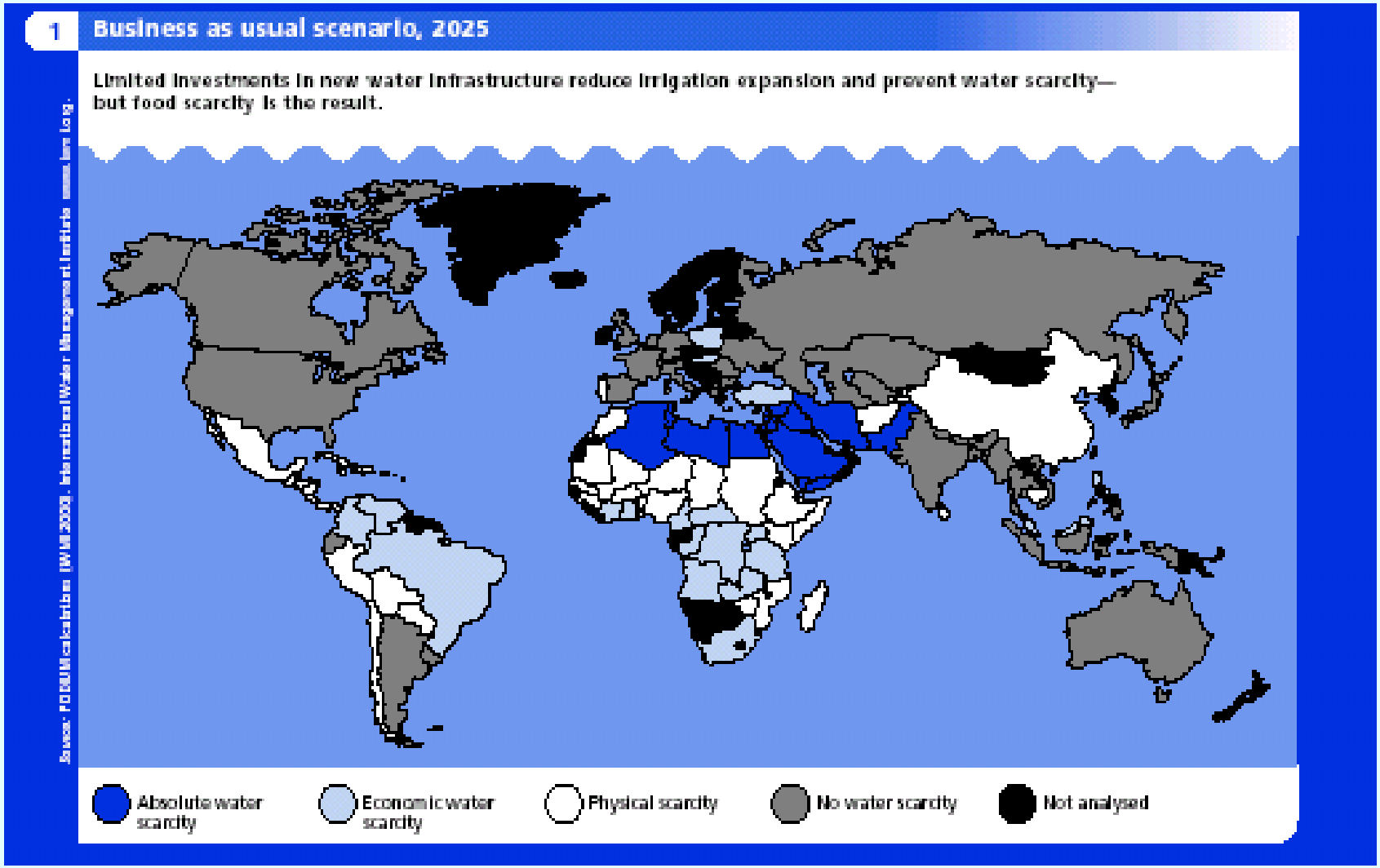


Fig. 1. The global distribution of population in 1985 with respect to the relative water stress threshold of DIA/Q = 0.4 indicating severe water scarcity (*10*). A 30′ spatial resolution is used. This mapping reflects a mean global runoff of ~40,000 km^3 year^{-1} and aggregate water withdrawals of 3100 km^3 year^{-1}. These estimates are highly dependent on contemporary water use statistics, which reflect a degree of uncertainty. Recent reviews (*5*, *36*) show year 2000 global water withdrawals from assessments made even as late as 1987 to vary by >1300 km^3 year^{-1}. National-level water use statistics (*18*) for some countries are decades old. Runoff estimates for some regions may also be biased (*9*,*13*). Results should be viewed with appropriate caution.

Source: Charles J. Vörösmarty, Pamela Green, Joseph Salisbury and Richard B. Lammers. 2000. "Global Water Resources: Vulnerability from Climate Change and Population Growth." *Science* 289 (14 July):284-288.



Source: William J. Cosgrove and Frank R. Rijsberman. 2000. *World Water Vision: Making Water Everybody's Business.* World Water Council and Earthscan Publications, London.

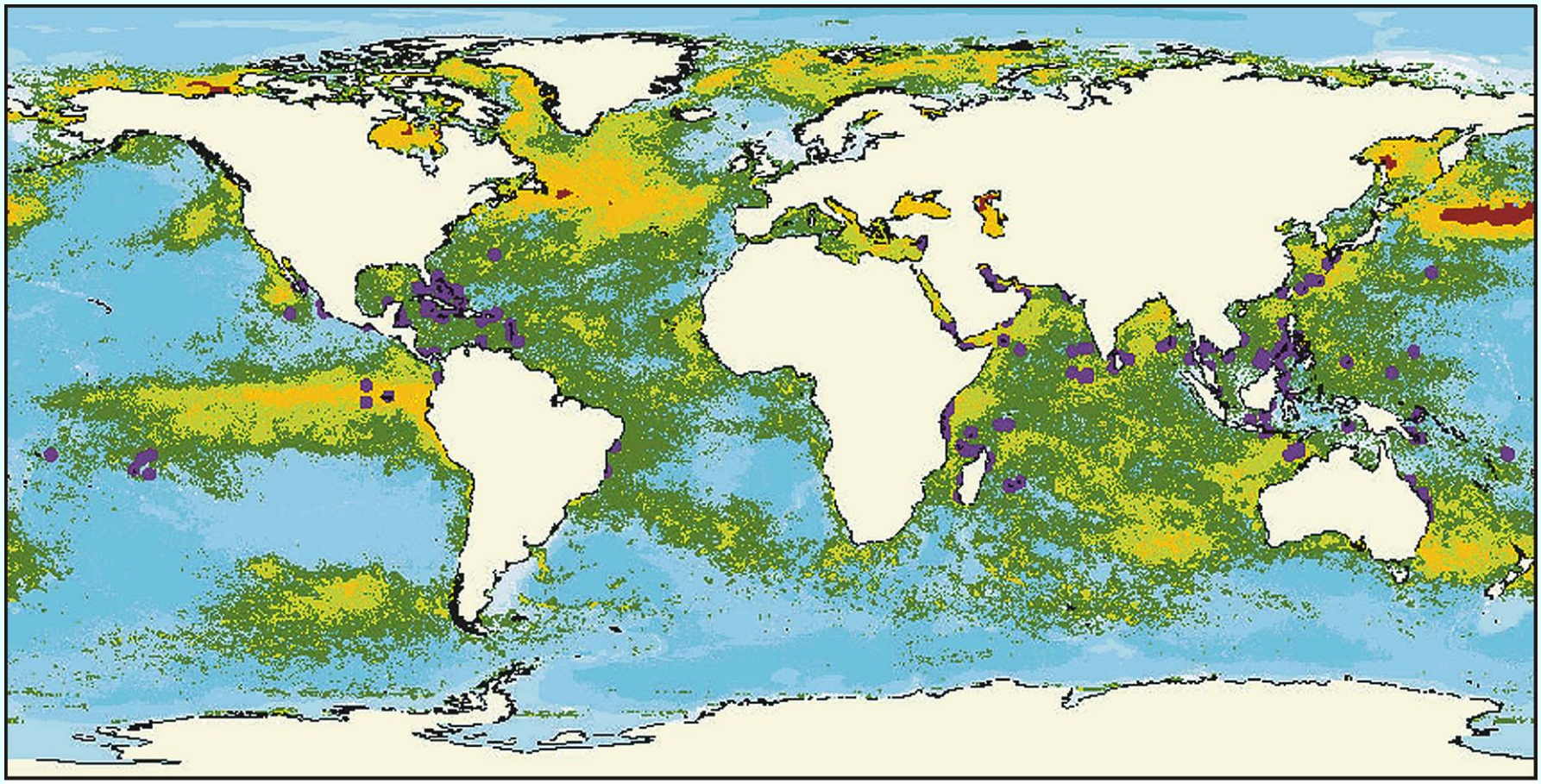
Developing Countries and Regions with Critical Water Ratios

Region/Country	Total Water Withdrawal (km^3)			Total Withdrawal as a Percentage of Renewable Water Supply (%)		
	1995	2010	2025	1995	2010	2025
Huaihe	77.9	93.7	108.3	83	100	115
Haihe	59.2	62.1	62.9	140	147	149
Huanghe	64.0	71.1	79.5	89	99	111
Changjian	212.6	238.5	259.1	23	26	29
Songliao	51.5	59.2	67.6	26	30	34
Inland	89.5	98.9	111.2	299	330	371
Southwest	8.3	9.7	12.3	1	1	2
ZhuJiang	77.1	84.9	96.9	19	21	24
Southeast	38.8	41.4	47.7	27	29	33
China total	**678.8**	**4,356**	**845.5**	**26**	**29**	**33**
Sahyadri Gats	14.9	18.7	20.8	14	17	19
Eastern Gats	10.5	13.7	11.6	67	87	74
Cauvery	11.8	12.8	13.1	82	89	91
Godavari	30.2	33.3	38.8	27	30	35
Krishna	46.2	51.4	57.5	51	57	63
Indian-Coastal-Drain	34.8	46.9	43.6	108	145	135
Chotanagpur	7.2	10.9	14.3	17	26	34
Brahmari	25.5	27.2	31.0	24	22	26
Luni River Basin	41.9	43.1	50.8	148	140	166
Mahi-Tapti-Narmada	31.4	34.3	36.3	36	39	42
Brahmaputra	5.5	7.2	9.2	1	1	1
Indus	159.1	178.7	198.6	72	81	90
Ganges	255.3	271.9	289.3	50	54	57
India total	**674.4**	**750.0**	**814.8**	**30**	**33**	**35**
Pakistan	**267.3**	**291.2**	**309.3**	**90**	**98**	**105**
Philippines	**47.0**	**58.2**	**70.0**	**24**	**29**	**35**
South Korea	**25.8**	**34.9**	**35.9**	**56**	**75**	**78**
Mexico	**78.6**	**86.2**	**94.2**	**24**	**26**	**29**
Egypt	**54.3**	**60.4**	**65.6**	**89**	**99**	**108**
Other West Asia/North Africa[a/]	**143.2**	**156.0**	**171.5**	**116**	**125**	**139**

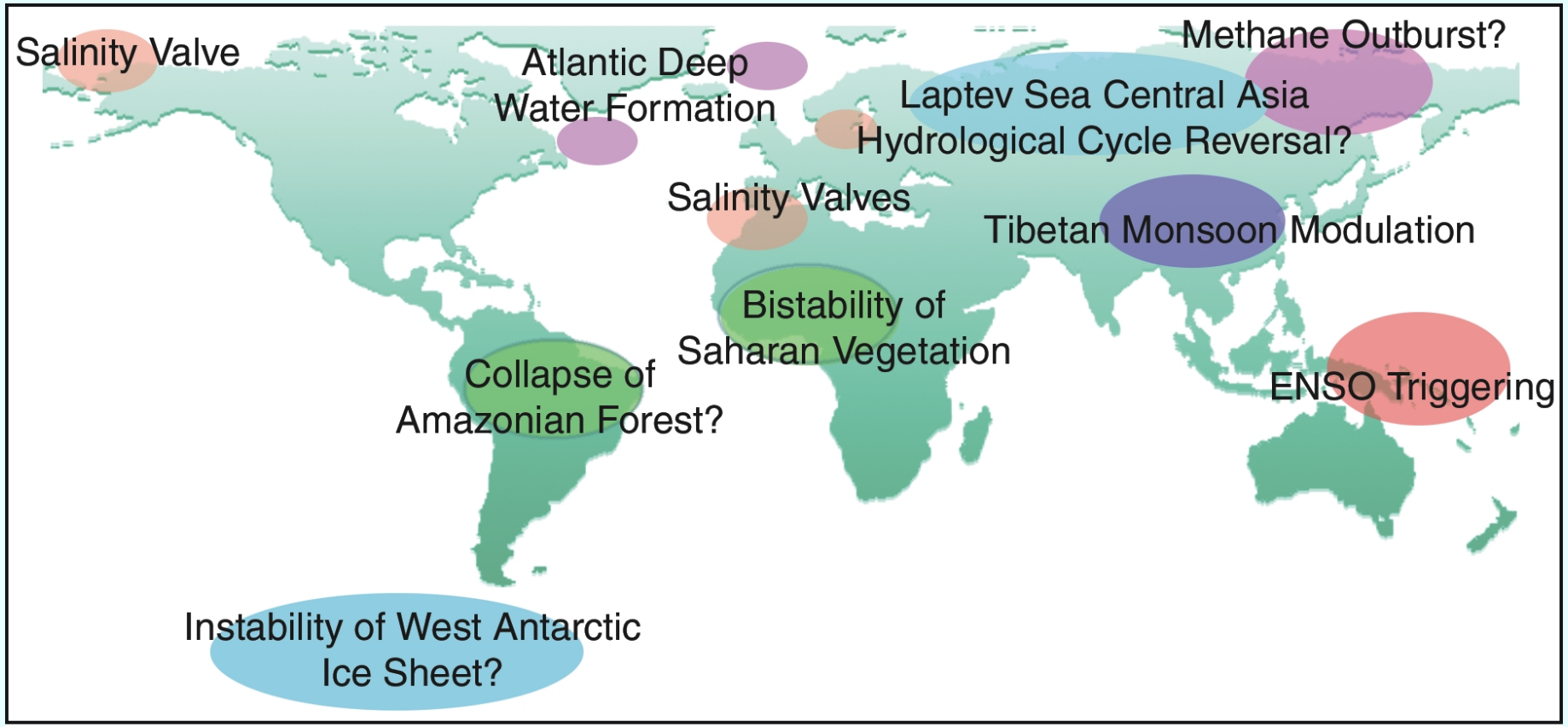
Notes: a/ Excluding Turkey.

Source: Adapted from Rosegrant *et al.* (2002), Table B.3.

Rising surface water temperature and coral reefs



Major changes in earth system?



Why the focus on “frontiers”….?

- Exploitation of “frontiers” is a critical part of the puzzle of “unsustainable” economic development in many of the poorest nations of the world.
- The term “frontier” usually refers to an area of unusually abundant natural resources and land relative to labor and capital, and the process of “frontier expansion” or “frontier-based development” refers to finding and exploiting or converting these relative abundant resources for production purposes.
- This perspective is especially important, as it suggests that the process of economic development is not just about allocating scare resources but also about obtaining and exploiting “new frontiers” of natural resources.
- This is particularly the case if the concept of a “frontier” also extends “vertically downwards” to include mineral resources and extractive activities “rather than be horizontally extensive as in the case of land and agriculture.”
- When viewed in this way, “frontier resource expansion” has clearly been an important aspect of economic development for most of global history.

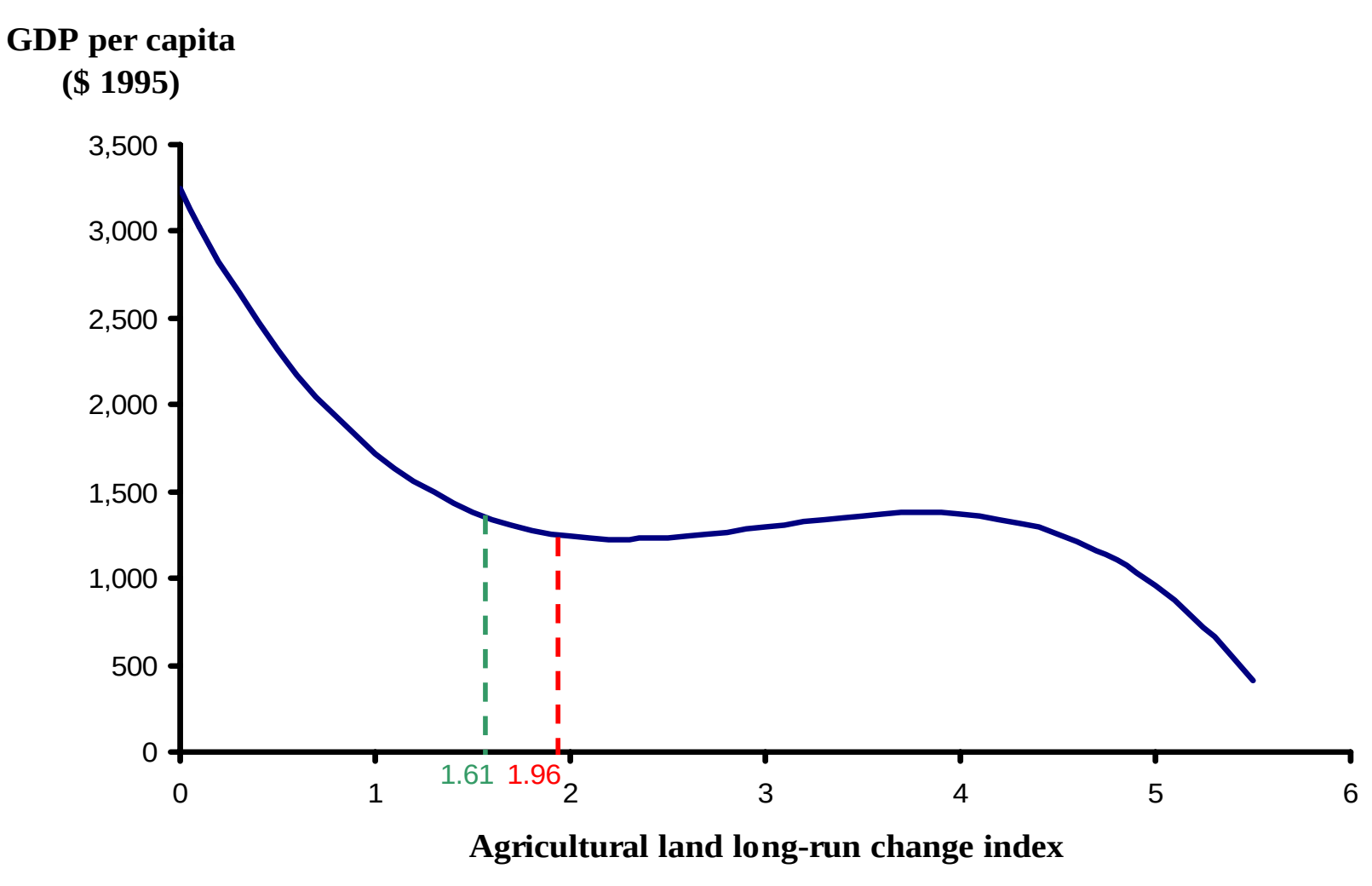
…because frontier exploitation appears to matter!

- Although historically “frontier expansion” may have been associated with successful resource-based development, this is less likely in the case of most developing countries today.
- The main reason is that the current process of “frontier expansion” in many poor countries has two unique structural features:
  - the key “frontier” activity occurring in these countries is land conversion leading to agricultural expansion
  - this frontier *land* expansion is serving mainly as an outlet for the subsistence and near-subsistence needs of the rural poor.
- Such frontier land expansion does not generate substantial rents, and any resulting agricultural output is consumed mainly locally.
- In the case of frontier resource-extractive activities (e.g. timber harvesting, mining, ranching and commercial plantations) that do yield more significant rents, the rent-seeking behavior associated with these activities will mean that these rents will be re-invested into further exploitation of frontier resources rather than in other sectors of the economy.

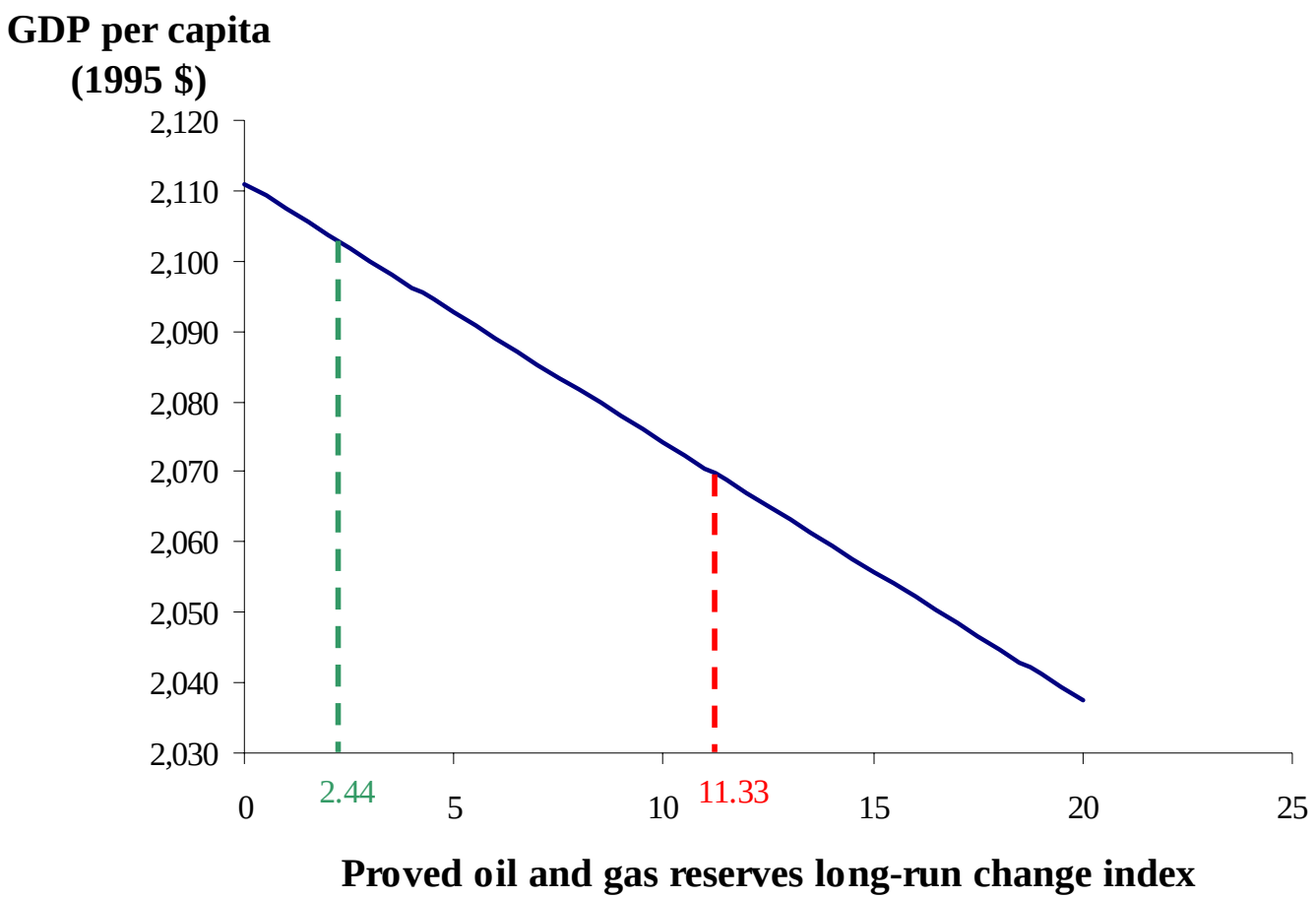
Economic implications

- The outcome is that whether one is talking about exploitation of “horizontal” or “vertical” frontiers, and whether the exploitation is the basis for commercial or subsistence activity, the frontier economy will remain a largely isolated enclave within the larger developing economy.
- The resulting land expansion and resource exploitation becomes symptomatic of a pattern of economy-wide resource-based development that:
  - generates little additional economic rents beyond short-term “windfall” profits
  - what rents are generated from lucrative activities are not reinvested in more productive and dynamic sectors, such as manufacturing.
- This would suggest that low and middle-income countries that have experienced persistent expansion of agricultural land and other natural resource “reserves” over the long term are likely to have performed less well than countries that have been less reliant on frontier conversion.

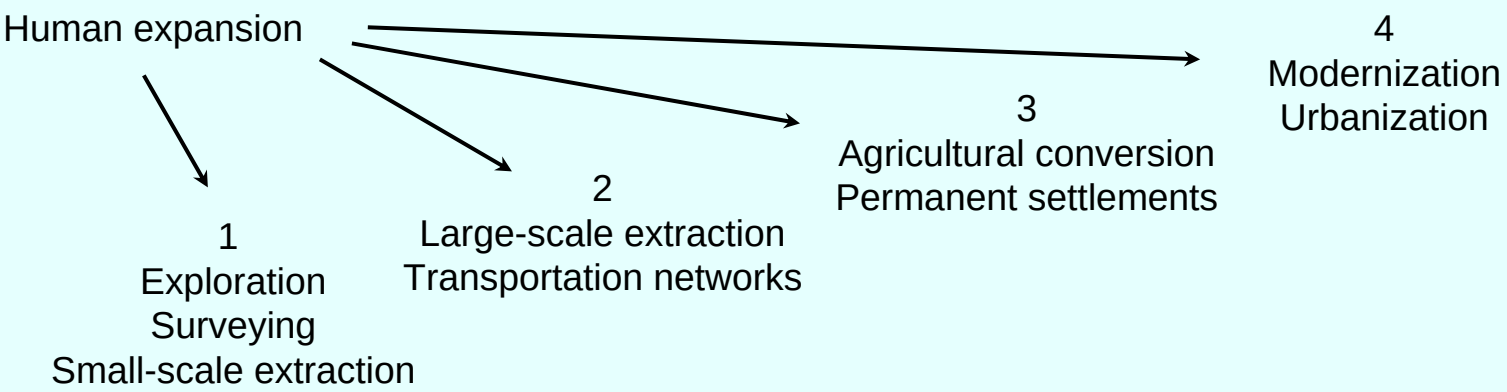
Agricultural land expansion and GDP per capita in low and middle-income countries, 1961-2000



Oil and natural gas proved reserve expansion and GDP per capita in low and middle-income countries, 1980-2004



Terrestrial ecosystems

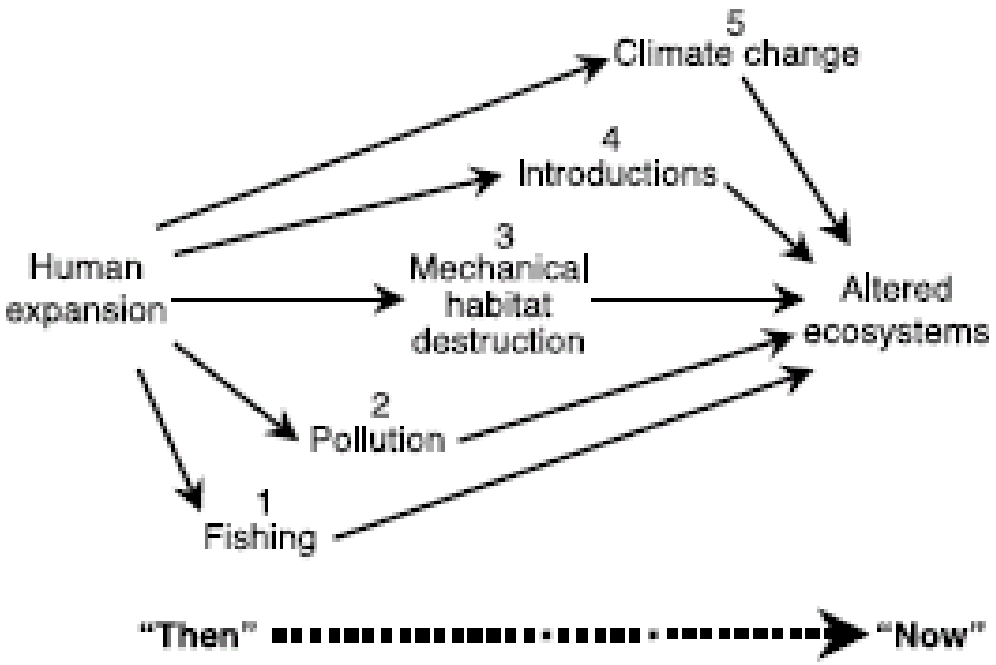


Low → High

Altered ecosystems
Population density
Economic activity/development
Pollution/resource-intensity

Coastal ecosystems

Fig. 3. Historical sequence of human disturbances affecting coastal ecosystems. Fishing (step 1) always preceded other human disturbance in all cases examined. This is the basis for our hypothesis of the primacy of overfishing in the deterioration of coastal ecosystems worldwide. Subsequent steps 2 through 5 have not been observed in every example and may vary in order.



Jackson, J. et al. 2001. "Historical over-fishing and the recent collapse of coastal ecosystems." *Science* 293:629-638.

Marine ecosystems

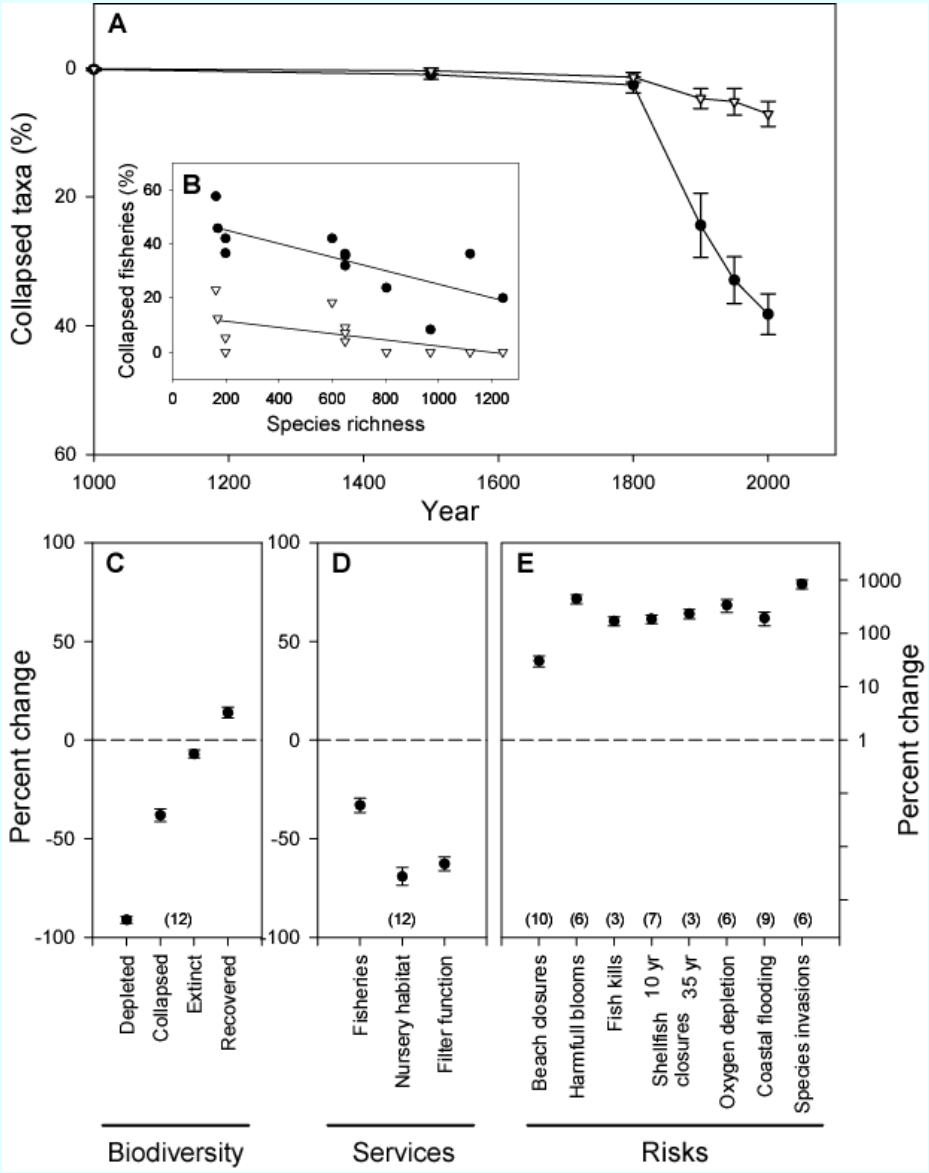
"A dramatic depletion of large predators triggered fisheries to target species of lower trophic levels in a process called 'fishing down marine food webs' (Pauly et al. 1998). More recently, fisheries exploitation has spread from coastal areas to the open ocean and a general decline in fish biomass has been reported; as a consequence, many marine species are of serious conservation concern."

Morato, T. et al. 2006. "Fishing down the deep." *Fish and Fisheries* 7:23-33.

Pauly, D. et al. 1998. "Fishing down marine food webs." *Science* 279:860-863.

Worm, B. et al. 2006. "Impact of Biodiversity Loss on Ocean Ecosystem Services." *Science* 314:787-790.

Biodiversity Loss and Ocean Ecosystem Services



Worm, B. et al. 2006. “Impact of Biodiversity Loss on Ocean Ecosystem Services.” *Science* 314:787-790.

Summary of the concern

- The costs of increasing ecological scarcity, in terms of loss of valuable ecosystem “services”, are more evident today.
- There is increasing concern, among the public and (some) policymakers, that these losses are mounting, not diminishing:
  - Processes of “frontier expansion” are more rapid than ever.
  - Contributing to worsening global income distribution.
  - The risks of catastrophic events seem to be rising.
- The long-term expansion of human activities, on land and sea, seems to be at the heart of the problem of altering ecosystems.
- Developing countries and poor populations are the most vulnerable to the rising costs associated with ecological scarcity.

Mangrove Deforestation

- Many mangrove ecosystems throughout the world and particularly in Asian countries are threatened by rapid deforestation.
- At least 35% of the area of mangrove forests has been lost in the past two decades, losses that exceed those for tropical forests and coral reefs.
  - In Asia, 36% of mangrove area has been deforested, at the rate of 1.52% per year.
- Aquaculture accounts for 52% of mangrove loss globally, with shrimp farming alone accounting for 38% of mangrove deforestation.
  - In Asia, aquaculture contributes 58% to mangrove loss with shrimp farming accounting for 41% of total deforestation

Valiela, I. et al. 2001. 'Mangrove Forests: One of the World's Threatened Major Tropical Environments.' *BioScience* 51(10), 807-815.

Shrimp farm expansion and mangrove loss in Thailand

- Over 1961-96, Thailand has lost around 2,050 km^2 of mangrove forests, or about 56% of the original area, mainly due to shrimp aquaculture and other coastal developments.
- Estimates of the amount of mangrove conversion due to shrimp farming vary, but recent studies suggest that up to 50-65% of Thailand's mangroves have been lost to shrimp farm conversion since 1975.
- Shrimp farming is highly profitable and important economically:
  - Since the late 1990s, the total value of export earnings for shrimp in Thailand has been around US$ 1 billion to US$ 2 billion annually.
  - Thailand has been the world's largest producer of cultured shrimp since 1991.

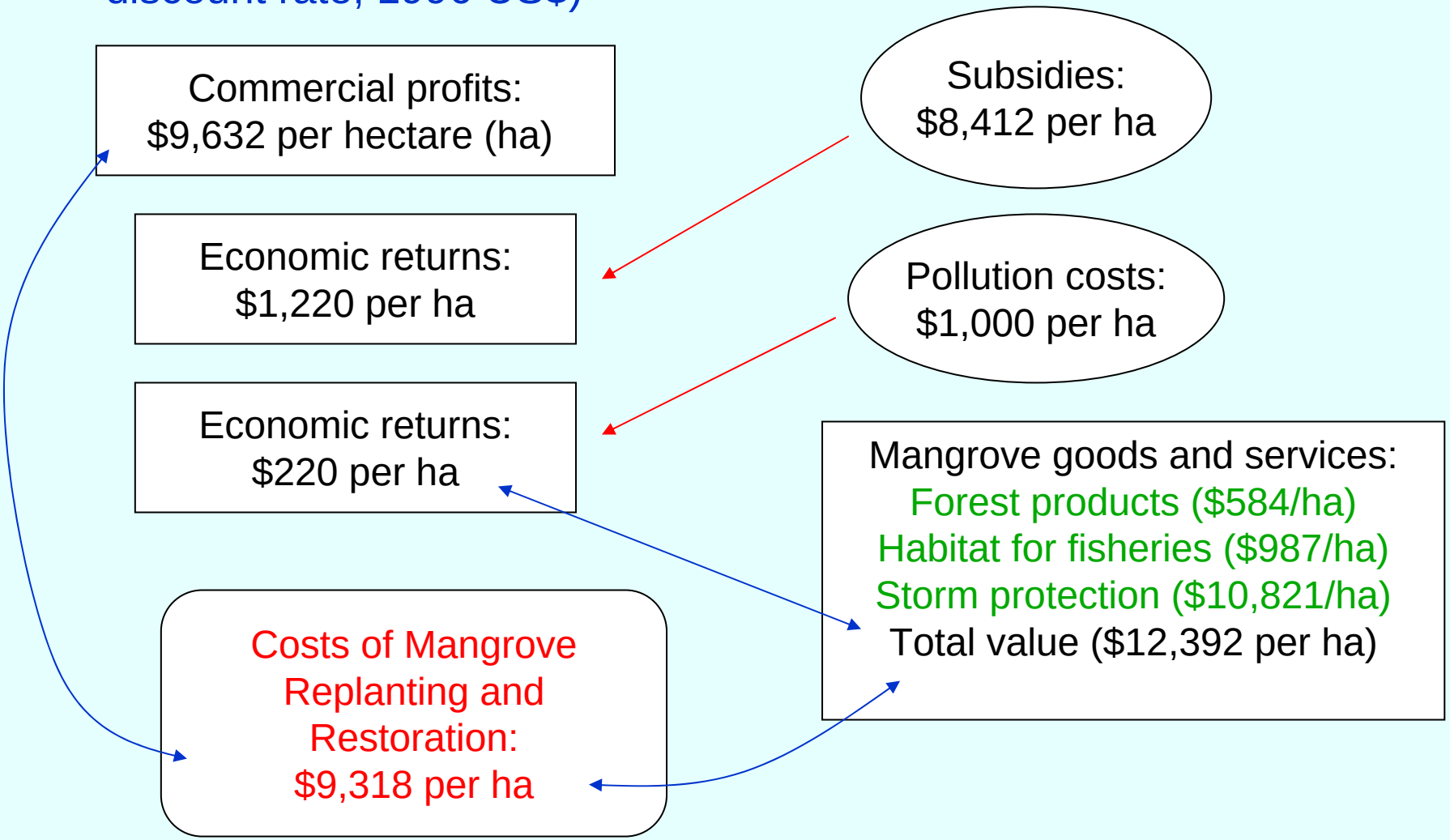
Barbier, E.B and S. Sathirathai, ed. 2004. *Shrimp Farm Expansion and Mangrove Loss in Thailand.* Edward Elgar, London.

Abandoned shrimp farm and polluted sludge waste discharged from shrimp pond next to mangroves, Southwest coast of Thailand.

Valuing the tradeoffs

Barbier, E.B. 2007. “Valuing Ecosystem Services as Productive Inputs” *Economic Policy* 22 (49): 177–229.

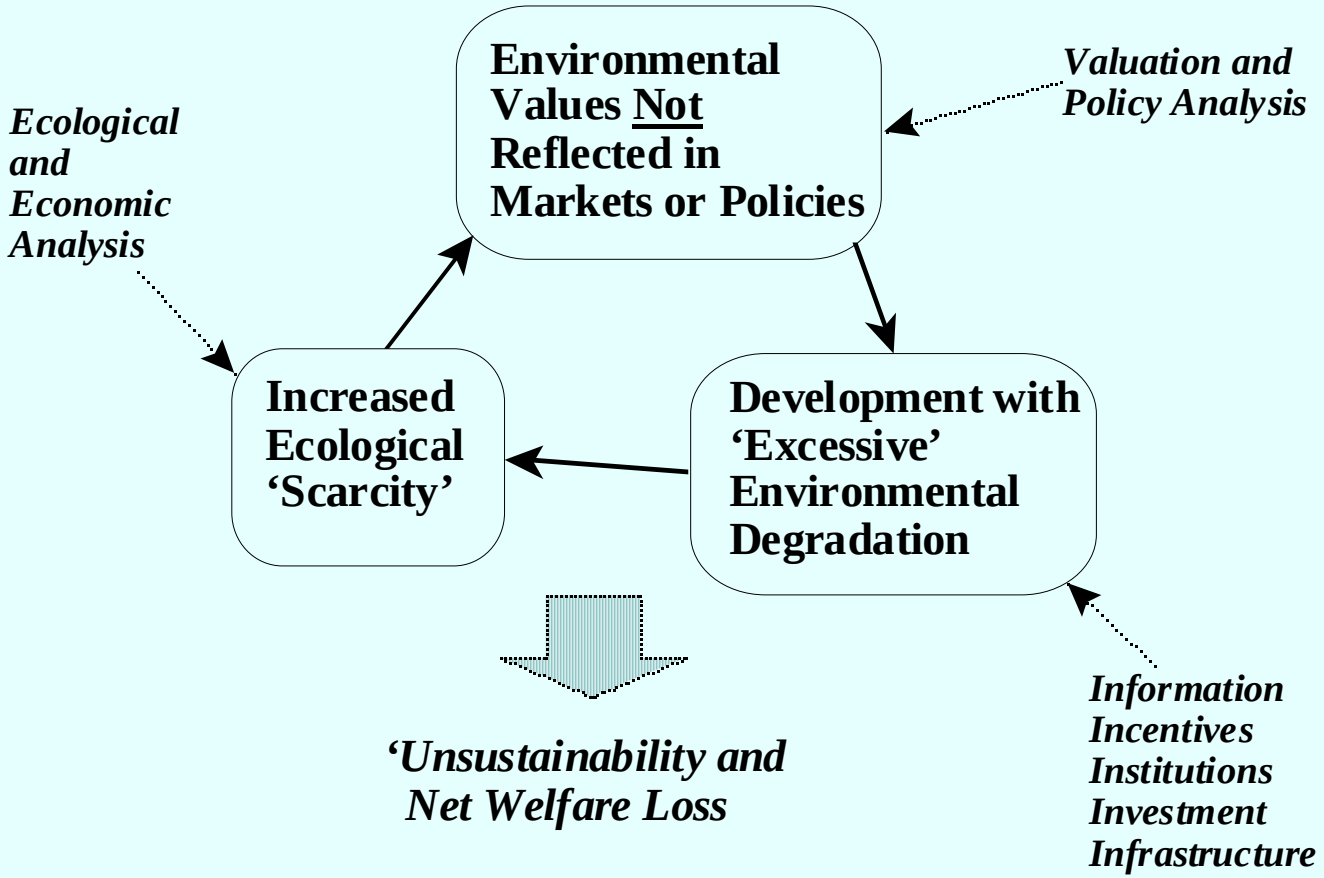
- Economic Benefits of Shrimp Farming (NPV, 10% discount rate, 1996 US$)
- Environmental Impacts of Pollution and Mangrove Loss



Lessons learned

- More studies are needed to assess the “coastal protection” value of mangroves and other natural barriers (sea grass beds, sand dunes and coral reefs).
- Destruction of these ecosystems for coastal development can no longer be viewed as “costless”. E.g.:
  - Mangrove areas cannot be given away as “free land” for shrimp farming and other coastal developments.
  - Shrimp farm and other developments should have legal requirements to replant mangroves and to finance the costs.
  - Dynamite fishing of coral reefs, mining of sand dunes, clear-cutting mangroves for wood chips should be banned and the bans enforced.
  - Coastal pollution from shrimp farms, tourism infrastructure and other developments should be monitored, regulated and taxed.
- There is an urgent need to address the *de facto* “open access” management of mangrove resources.
  - In most countries, the present law and formal institutional structures of mangrove resource management do not allow coastal communities to establish and enforce their local rules effectively.

Reversing the process of unsustainable development



...and there is a cost “to doing nothing”!

Final remarks

- Economists are becoming more interested in ecological change because the economic consequences are becoming less “long term” and more immediate.
- Processes of “frontier-based” development are accelerating; many poor countries have little choice because of the dire poverty, population and development problems they face.
- Industrialized countries have more choices; they should lead the way with resource-conservation development strategies, market-based incentives and technologies.
- Rising ecological scarcity indicates that we do not have much time; comparatively few of the world’s major ecosystems remain intact or undisturbed.
- The next 25 years are critical: it is essential that economists, ecologists and natural scientists work together to help analyze the complex economic-ecological problems and formulate solutions.
- Will policy makers listen?