

Global environmental change: an overview

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GEC (global environmental change) is among the most severe challenges facing the mankind today. The unprecedented change in our global environment is currently a major concern to scientists and environment managers. Over the recent decades, changes in the earth system due to population pressure as well as growth in per capita resource exploitation have been alarming. These growing impacts of human activities on the earth and atmosphere at all scales encourage Crutzen and Stoermer (2000) to assign a term 'anthropocene' and suggest the advent of a new geological epoch.

In general, land resources are being used unsustainably and land-use and land-cover changes cause cascading effects on the local as well as global ecology. Food production has increased mainly through intensification of resources. Increased load of nitrogen from fertilizers is ultimately discharged to the water resources. Exceeding its capacity to absorb nutrients, the coastal water supports the growth of algae, which very often are harmful and cause serious concerns to human health. Coastal fisheries are under threat from pollution, overfishing, and habitat degradation. Two major concerns associated with biodiversity – loss of species and the introduction of alien species, particularly pests and pathogens – have created serious concerns. Carbon emissions have increased to an extent that has overloaded sink capacity of terrestrial and aquatic ecosystems. Fresh-water pollution and shortages are experienced in most parts of the world.

Human population and the global economy have been growing rapidly. These two factors have increased resource consumption significantly. While much of the environmental degradation in the developing countries is on account of poverty and population pressures, that in the developed world is due to increase in per capita resource consumption. However, many studies point out that although much of the accelerating economic activity and energy consumption have occurred in the developed countries, the developing world is beginning to play a larger role in the global economy and hence is having increasing impacts on resources and environment.

Scientists warn that our planet is under threat due to excessive resource consumption, which may exceed the threshold level of the earth system, if human population and activities continue to rise at the current pace. Beyond a particular threshold, earth's buffer capacity will give way and the earth system will move to another state that may be irreversible. The palaeo-record shows that in the earth system, abrupt changes and surprises are a common feature (Steffen, Sanderson, Tyson, *et al.* 2004). Such abrupt changes can give rise to catastrophic failures.

Two approaches

Current GEC studies follow either of the two approaches, cumulative or systemic. Turner, Kasperson, Meyer, *et al.* (1990) have described these two approaches in detail. According to them, in the systemic approach, 'global' refers to the spatial scale of operation or functioning of a system. A physical system is 'global' if its attributes at any locale can potentially affect its attributes anywhere else, or even alter the global state of the system. On the other hand, in the cumulative approach, 'global' refers to the area or substantive accumulation of localized change. A change is 'global' if it occurs on a worldwide scale, or represents a significant fraction of the total environmental phenomenon or global resource. This implies that it replicates itself in different parts of the world and accumulation of such changes in the different parts of the world becomes a global phenomenon.

Turner, Kasperson, Meyer, *et al.* (1990) state that the systemic approach dominates much of the discourse on GEC to date. They further point out that place-specific studies allow for a more complete understanding of the way in which global forces are played out in specific places and cultures. This is particularly the case where some components such as fresh water or land resources are concerned.

Global–local interplay

GEC occur at multiple scales and involve complex dynamics at different scales. Cash and Moser (2000) point out that GEC is a cross-scale phenomenon that requires assessment at all scales and integration across scales. The fact that the issues have different implications at different scales further complicates the system. Research shows that cascading effects of human activities interact with each other and with local- and regional-scale changes in multidimensional ways.

The importance of scales and cross-scale dynamics in understanding and addressing GEC is receiving increasing recognition. Challenges involved in integrating research into policy necessitate a thorough understanding of the dynamics between the human actions at different scales, their outputs at these

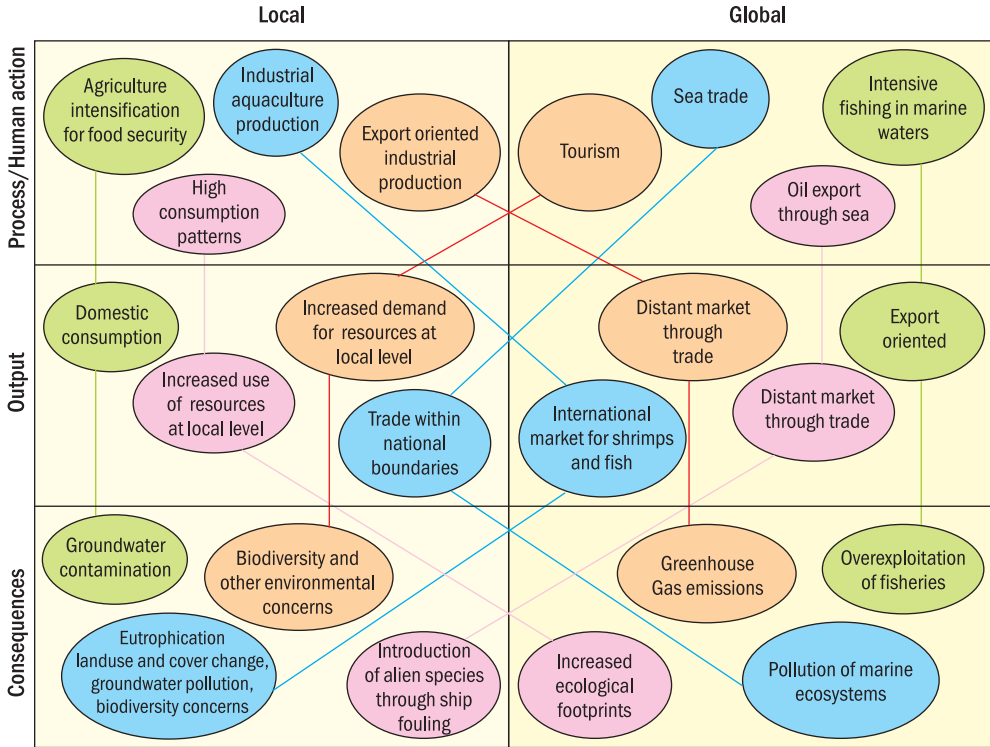


Figure 1 Global–local interplay: cross-scale dynamics

scales, and their implication at different scales. Very often these three events occur at different scales (Figure 1), posing challenges for integration of the information flows into policy. Some actions such as intensification of agricultural products for subsistence may occur and have implications at the local level only. Similarly, intensive fishing in global marine waters may, generally, have implications at the global level. Nevertheless, most actions that are linked to GEC present cross-scale dynamics. For example, tourism is a global phenomenon and beneficiaries are international tourists, but the impacts, such as land-use and land-cover changes, biodiversity loss, etc., are normally borne by local communities. Similarly, while human actions, such as shrimp production, may occur at local level, the output may be exported to the international market (global level) and the impacts are very often borne by the local communities.

Cash and Moser (2000) identify three broad categories of challenges related to scales: (1) matching the scales of the biogeophysical system and the management system: an institutional fit problem; (2) matching the scales of the assessment and the management system: a scale discordance problem; and (3) understanding the linkages between scales, and how they affect decision-making, information flows, and the integration of information into the decision-making process: a cross-scale dynamics problem. Further, Harrington

and Lu (2002) believe that to build an understanding of global sustainability, potential local responses to various aspects of global change need to be considered. While analysing the effect of the local feedlot operations on greenhouse gas emissions, they argue that national-scale approaches can miss significant local variations.

Most of the studies on GEC address environmental problems that exist at global scale and ignore local concerns. Accumulated consequences of several environmental concerns occurring at local levels pose serious threats at the global level. The effort in the present volume is to generate a wider consensus of the issues connected with the GEC using local case studies with cumulative approach. Such assessments at the local level will deepen our understanding of the GEC.

Climate change and beyond

Global environment includes physical, chemical, and biological processes that are necessary for life-supporting services on the earth. Research on GEC till date focuses on climate change. While climate refers to the aggregation of all components of weather, environment is made up of the complex interactions between the physical, chemical, and biological systems. The climate system interacts with other components of the earth's environment to bring about GEC. No studies on a single environmental component will be meaningful for GEC, if viewed in isolation. It is the feedback between various components that assumes greater importance for GEC and, hence, the term GEC involves changes in various components of the environment. Steffen, Sanderson, Tyson, *et al.* (2004) firmly assert that global change should not be confused with climate change. In order to have a meaningful understanding of GEC, other environmental components, such as land-use and land-cover, biodiversity, fisheries, coastal and marine ecosystems, fresh water, etc., and the cascading effects generated due to the changes in these components merit attention along with climate change.

However, current GEC research overlooks environmental issues other than climate change, global warming, and sea-level rise. Even a few research papers that address other issues follow the systemic approach, thus establishing links with the climate change. Nevertheless, several studies underscore the need for inclusion of such components of environment in GEC research. Significant changes that have taken place in our environment at various scales include the following.

- Land-use and land-cover changes
- Changes in biodiversity
- Unsustainable fisheries
- Pollution of coastal and marine environment
- Climate change
- Fresh water scarcity

Using a cumulative approach, this volume presents some case studies on each of these components. The general structure of the volume is such that an overview of a particular component and the issues involved are discussed in the first chapter and the following chapters describe factors causing the change, its impacts on society and/or human health, methods for studying the change, and institutional responses to this change. The volume is a collaborative effort of a multidisciplinary team and uses an interdisciplinary lens to present a kaleidoscopic view of the multiple dimensions of GEC. These dimensions are ecological, social, economic, biomedical, institutional, gender, and methodological. The quest for a greater understanding of the GEC issues and their interconnections is the central objective of the volume.

Section I: Land-use/land-cover change

One of the most alarming manifestations of human activity has been conversion of natural landscapes and agricultural lands. Lambin, Turner, Geist, *et al.* (2001) point out that land-use and land-cover changes are so pervasive that, when aggregated globally, they significantly affect the key aspects of the functioning of the earth system. Land-use and land-cover change is not a recent phenomenon, though it has received much attention in the recent years. Land cover is the biophysical state of the earth's surface and immediate subsurface, whereas land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation, that is, the purpose for which the land is used (Turner, Skole, Sanderson, *et al.* 1995: 20). Land use affects land cover with wide implications. Land-cover changes act as sources or sinks of bio-geochemical flows, the feedback from which may affect the use-cover relationship (Turner, Skole, Sanderson, *et al.* 1995: 20).

Land-use/land-cover change plays a very important role in GEC. It contributes significantly to changes in the biogeochemical cycles and biodiversity loss and has implications to the livelihood issues at societal level. Forest is at the centre of the GEC research. It is both the source and the sink for carbon emissions. The loss of carbon to the atmosphere through the burning of slash is a major source of carbon. Similarly, forests play a vital role in carbon sequestration. Increasing loss of agricultural lands has impacts on food security, and food scarcity has now become an issue of global concern. Food scarcity is expected to give rise to increased food prices, which, in turn, is likely to create political and social instability (López, Aide, and Thomlinson 2001).

International research on GEC requires a thorough understanding of land-use and land-cover changes. Linking land-use and land-cover changes with anthropogenic activities will help in improving our understanding of the subject. Human actions serve as proximate sources of change. World population growth coupled with economic development and continuous need for improved infrastructure gives rise to increasing demands for land-based resources.

Increasing human population has undoubtedly driven global changes in land-cover. However, land-cover change attains global significance through the cumulative addition of locally specific changes (Ramankutty, Foley, and Olejniczak 2002).

Further, Turner, Skole, Sanderson, *et al.* (1995: 48) suggest that land-use/land-cover classification should involve at least three dimensions: manipulation of land characteristics, land users' purposes or objectives, and the broader biophysical and socio-economic circumstances or underlying conditions. In their opinion, the purpose is important to distinguish such critical attributes as subsistence versus market orientations that usually respond differently to changing conditions. An understanding of social, political, and economic factors that influence land use is necessary to understand the complex dynamics of GEC.

In Section I, Untawale presents an overview of the coastal landforms in India, current status, impacts of climate change on coastal land, and strategies for protection of coastal land in the first chapter. In Chapter 2, factors affecting land-use changes in the coastal wetlands of Goa have been analysed with particular emphasis on institutional factors. In Chapter 3, on the other hand, Kazi and Siqueira discuss tourism-induced land-use and land-cover changes with focus on the consequences of these changes to Goan society. In order to better inform the wider target audience of the book, Girap presents the methodology most commonly used for interpreting LUCC (land use and cover changes) in the following chapter (Chapter 4). A chapter on sand mining and its impact on local ecology including LUCC has been presented by Sonak, Pangam, Sonak, *et al.*, with an aim of introducing consequences of 'sand mining' to the research community (Chapter 5). The literature is otherwise deficient in papers on sand mining. A review of institutions and history of forest management has been carried out by Acharya and Pokharel in the last chapter of this part (Chapter 6).

Section II: Changes in biodiversity

Biodiversity is defined as 'the variety and variability among living organisms and the ecological complexes in which they occur.' Biodiversity changes can have numerous far-reaching consequences to earth's life-support system. Ecological services, such as nutrient cycling, food production, medicines, carbon sequestration, etc., can be seriously impaired due to the changes in biodiversity. Two major challenges concerning biodiversity today are loss of species and introduction of alien species.

Paleo-studies show that the average life of a species is 5–10 million years. With 5–10 million living species, the extinction rate should be one per year. The current rate appears to be well in excess of the normal. Over the last 400 years, there were 611 documented extinctions, but this record excluded many creatures including most invertebrates that account for 95% of all animals. Today, there are over 5000 threatened species listed, but only a very small proportion of recognized species has been evaluated (Atlas 2001: 345).

Introduction of alien species poses serious threats, particularly if the species are pathogenic and/or highly competitive. Invasion of pests and pathogens is either an intended or unintended consequence of human decisions involving the use of exotic species in production and consumption; conversion and fragmentation of habitats; or the movement of goods and people. Human activities such as marine trade related ship fouling, ballast water exchange, and culture of exotic aquatic/terrestrial species are the prime causes of the introduction of alien species.

The first chapter in Section II (Chapter 7) deals with an overview of issues related to biodiversity monitoring and management. Various approaches to biodiversity management have been described, and a need for integrated approaches has been emphasized by Stoll-Kleemann and Bertzky in this chapter. Differential impacts of global change on different countries and population have been well documented. Rural population of the developing countries depends on the forest resources for traditional health remedies. In Chapter 8, Rodrigues draws our attention to the impacts of biodiversity loss – more specifically, the loss of medicinal plants – on the health of the rural population of India. The links between people and nature are made more explicit in Chapter 9 by Borkar. Further, the concept of protected areas is well accepted in modern biodiversity management approaches. Kerkar (Chapter 10) documents forest areas in Goa protected by traditional societies under the label of sacred groves. While the above chapters focus on the loss of biodiversity, Anil in Chapter 11 and Jay in Chapter 12 discuss the recent threat to biodiversity, that is, bioinvasion. Anil provides an overview of the factors that influence alien species and Jay presents institutional mechanisms relating to biosecurity. A new methodology to statistically measure biodiversity changes has been proposed by Rao and Antony in Chapter 13 and further developed by Rao, Antony, and Nairy in Chapter 14.

Section III: Unsustainable fisheries

Global marine fish production has increased in the past few decades. However, the capacity of the aquatic ecosystems to produce fish is reduced on account of increase in fishing efforts, increase in fishing intensity, and unsustainable practices and loss of nursing grounds. Overfishing was formally recognized as a problem in the early 1900s (World Resources 2000: 76). Seventy-five per cent of all fish stocks for which information is available are in urgent need of better management (Burke, Kura, Kassem, *et al.* 2001: 7). Of these, 28% are already depleted or in the danger of depletion, and 47% are being fished at their biological limit and therefore are vulnerable to depletion (Burke, Kura, Kassem, *et al.* 2001: 7). Pauly *et al.* (1998) have noticed ‘fishing down the web’, which implies that as highly priced fish on the higher level of food web are depleted, fish catch is dominated by other species, which are normally on the lower level on the food web.

Fisheries form a crucial part of most national government agendas, at least, of developing countries. Traditionally, fish has served as a source of income as well as food for the poor and low-income group people. Fishing provides livelihood opportunities and nutrition to the traditional coastal communities. However, globalization has placed new pressures on this sector. Access to distant market and growing international demand have encouraged the entry of the corporate sector with mechanized crafts into the fishing industry. This gives rise to conflicts between traditional fishers and industrial fishers. Small-scale marginalized fishers are generally at a disadvantage compared to industrial fishers. In addition to overharvesting, fish resources also face challenges from coastal and marine pollution. Pollutants from toxins released by algal blooms, TBTs (tributyltins), and PCBs (polychlorinated biphenyls) can accumulate in fish. A more serious concern, from strictly anthropocentric perspective, is the problem of biomagnification and risk to human health from consumption of polluted fish.

In this section, an overview of marine exploitation has been presented by Kropp, Eisenack, and Scheffran. They develop a model that could help predict future development in fisheries (Chapter 15). Ansari, Achuthankutty, and Dalal focus on overexploitation of fisheries in Goa in Chapter 16. Sonak, Rubinoff, and Sonak, using a case study of fishing ban in Goa, present conflicts between different institutions in fisheries management and those between traditional and industrial fishers (Chapter 17). Potential effects on human health from consumption of fish exposed to marine pollution have been presented by Ashiazawa, Hicks, and De Rosa in Chapter 18.

Section IV: Coastal and marine pollution

Pollution from land-based activities

Land-based activities are the major source of coastal pollution. Human activities, such as intensification of agriculture, aquaculture, domestic sewage of coastal population, waterfront location of industries and power plants, tourism, use of marine water for trade, etc., are primarily responsible for coastal and marine pollution. Large amounts of nitrogen compounds discharged by humans, largely as fertilizers, cannot be assimilated easily by soil micro-flora. Significant amounts of nitrogen accumulate in vegetation, soils, and groundwater, some of it being released into the coastal zone and to the atmosphere. Unable to metabolize excess nitrogen, the coastal waters show signs of eutrophication, giving rise to algal blooms, some of them harmful, thus causing serious concerns to human health. These concerns are likely to be overwhelmed by the growing populations as well as increase in economic activities and coastal megacities. Of the 20 megacities in the world, 17 are located along the coast.

Identification of drivers behind changes in coastal and marine areas and indicators using a PSR (pressure, state, response) framework has been in focus

of Chapter 19. Conceptual frameworks connecting human activities to the coastal ecosystems have been presented in this chapter. Estimation of waste assimilative capacity of Ennore estuary in the north Chennai region has been presented by Chaudhury, Jebakumar, Jena, *et al.* in Chapter 20, whereas, eutrophication of coastal waters in the Rodrigo de Freitas lagoon in Brazil has been studied by Cardoso da Silva in the following chapter (Chapter 21). Coastal eutrophication gives rise to harmful algal blooms. Algal blooms and their consequences to society, particularly to human health, have been discussed by Bhat, Prabha Devi, and D'Souza, *et al.* in Chapter 22.

Tributyltin in marine environment

TBT marine environment has been a serious concern since past few years due to the persistent and bioaccumulative nature of TBT compounds. TBT, after its release into the aquatic environment, shows a great tendency to be accumulated onto particulate matters, sediments being the final sink. The high toxicity of TBT together with its tendency to be accumulated in marine organisms can produce heavy damage in marine organisms, particularly in molluscs and gastropods. The bioaccumulation of TBT in several marine organisms has been largely documented (Hong, Takahashi, Min, *et al.* 2002). The first evidence of environmental damage by TBT released by antifouling paints appeared in aquaculture farms in Arcachon (France) where, from 1975 to 1982, oyster production was severely reduced due to a lack of reproduction and the appearance of shell calcification anomalies in adult oysters leading to high economic losses (Alzieu, Sanjuan, Deltreil, *et al.* 1986). Decline in gastropod population has been registered worldwide as a consequence of the induction of the imposex effect by TBT, which essentially is the superimposition of male sexual characteristics on female organisms. High occurrence of imposex has been evidenced in the North Sea, the Atlantic Ocean, and the Mediterranean Sea in Europe as well as along the coasts of the USA, Japan, India, Australia, Chile, etc. Some recent studies documenting these impacts have been conducted by Birchenough, Barnes, Evans, *et al.* (2002); Chiavarini, Massanisso, Nicolai, *et al.* (2003); De Metrio, Corriero, Desantis, *et al.* (2003); Evans and Nicholson (2000); Ramon and Amor (2001); and Rees, Brady, and Fabris (2001). The problem of environmental impacts of TBT was brought to the notice of the MEPC (Marine Environment Protection Committee) of IMO (International Marine Organization) in 1988. In 1996, the MEPC approved of resolution, which includes complete prohibition of organotin compounds in anti-fouling systems by 2008. Signature of about 25 nations, whose combined flagged fleet equals 25% of the world fleet, is necessary for the convention to come into force. However, concerns have been raised that the hostility towards the use of TBT appears to be based on a biased assessment of its environmental impact and a need for cost-benefit analysis is suggested (Abbott, Abel, Arnold, *et al.* 2000). It is suggested that the environmental

impacts of not using TBT, such as acceleration of greenhouse gases, introduction of alien species through fouling of ship hull, reduced safety to humans through increased corrosion and fouling, and unforeseen environmental impacts of alternatives, have not been given adequate consideration. Little thought has been given to a technical solution to control TBT inputs to the environment. Long-term biocidal properties of the existing alternatives are largely untested as also their environmental impacts (Evans 1999). There is no safe alternative that has global approval. There is concern that organic booster biocides in the antifouling paints, which will replace TBT-based coatings, could cause serious environmental damage (Evans, Birchenough, and Brancato 2000). It is argued that the ban on TBT-based antifoulants is desirable but, in view of these uncertainties, it should be delayed until alternatives that have been proved to be less harmful to the environment are available (Evans, Birchenough, and Brancato 2000). A safer and efficient antifouling alternative and a reliable monitoring/inspection system appear to be an urgent need. Given the environmental impacts of TBT coupled with the fact that no alternative with global approval is available and that reliable inspection system is yet to be developed, research need to be focused on these aspects.

With the above background, this volume presents a set of papers that illustrate several issues concerning TBT in antifouling paint. Bhosle documents the accumulation of butyltin compounds in biofilm and marine organisms along the West Coast of India in Chapter 23. Effect of TBT on oyster industry has been demonstrated by Alzieu (Chapter 24). Willemsen, Wegener, Massanisso, *et al.* in the following chapter (Chapter 25) evaluate the risk of organotin compounds to the seafood consumers. Mukherjee and Ramesh, on the other hand, point out the implications of the ban on TBT on the shipping industry (Chapter 26). Giriyan and Pangam present a review of antifouling strategies that exist as alternatives to TBT in Chapter 27.

Section V: Climate change

There is no doubt that the global carbon system is out of balance. A major source of carbon in the earth system is combustion of fossil fuels. In the last few decades, mankind has used vast quantities of fossil fuels that take millions of years to build. Changes in the land cover significantly modify the concentration of atmospheric constituents. The climate system responds to the human-driven land-cover change by changing the amounts of absorbed and reflected solar radiation owing to changes in the reflectance of the earth's surface (Steffen, Sanderson, Tyson, *et al.* 2004). Such effects are known to be important for climate locally and regionally and may be significant globally.

Intergovernmental Panel on Climate Change (IPCC 2001b) report describes the following changes that have occurred and are likely to occur in the climate system.

- The global average surface temperature has increased over the 20th century by about 0.6 °C.
- Temperatures have risen during the past four decades in the lowest 8 kilometres of the atmosphere.
- Global average sea level has risen and ocean heat content has increased.
- Changes have also occurred in other important aspects of climate, such as changes in precipitation and rainfall. However, the IPCC (2001b) report also notes that some important aspects of climate, such as the Antarctic sea ice extent, the frequency of tornadoes, thunder days, or hail events appear not to have changed.

Differential impacts of climate change and food security have attracted much attention over the past few decades. Developing countries with high population and a higher rate of population increase are likely to suffer substantially from the changing climate in terms of food security and livelihood. Poor people in the developing countries are likely to be more affected due to their dependency on climate-sensitive sectors such as agriculture, forestry, and fisheries. They are also more vulnerable to disasters and extreme events arising on account of climate change. Tropical cyclones coupled with the sea-level rise will create devastating impacts in terms of loss of life and property in low-lying coastal areas.

In Chapter 28, Shaw describes the basic concept of human security and exemplifies linkages between environment, disaster and development, and community-level adaptations. Food security concerns in developing countries, such as India, have been discussed by Shinkre in the following chapter (Chapter 29). Samarappuli and Wijesuriya attempt to assess the prospects of growing rubber to combat adverse impacts of climate change in Chapter 30. In Chapter 31, Wijesuriya, Thattil, and Herath apply Bayesian theory to quantify causal maps and present results of participatory studies to identify causes for abandoning rubber cultivation. Climate change impacts on mosquito-borne diseases have been well studied and documented in Chapter 32 by De Alwis, Rajamanthrie, Senanayake, *et al.*

Section VI: Fresh water depletion

Hydrological poverty is a grave concern to most parts of the world today. It is predicted that the number of people (currently 2.2 billion) living under moderate or severe water stress will rise to 4.0 billion by 2025 (Steffen, Sanderson, Tyson, *et al.* 2004). Climate change may decrease water availability in some water-stressed regions and increase it in others. In Africa, Asia, and South America, climate change is predicted to exacerbate water stress significantly.

Climate change is unlikely to impact municipal and industrial demands but may substantially affect irrigation withdrawals (IPCC 2001a). About 70% of the world's current freshwater resource is used for agriculture, but that number

approaches 90% in China and India, with extensive irrigation (Steffen, Sanderson, Tyson, *et al.* 2004). In southern and eastern Asia, agriculture is monsoon based, and on account of lack of financial and technological resources, there is little scope to adjust farming practices should monsoon cycles change. For Indian experts, monsoon variability, therefore, stands in the centre of their concern and research (Biermann 2001).

Non-climatic changes may have a greater impact on water resources. Anthropogenic impacts on fresh water are typically confined within individual basins and aquifers, but widespread shortages caused by excessive withdrawal or pollution may lead to a globally critical situation (Turner, Kasperson, Meyer, *et al.* 1990). Depletion and degradation of water resources are two major threats to freshwater systems. Climate-related stresses in coastal areas include loss and salinization of agricultural land as a result of change in sea level and changing frequency and intensity of tropical cyclones (IPCC 2001a). Coastal aquifers are more vulnerable to seawater intrusion.

Mapping of seawater intrusion using modified GALDIT indicator model has been presented by Chachadi in Chapter 33. In Chapter 34, Choudri and Chachadi present a case study of Goa to link water withdrawal with human activities, such as mining. Further, several issues related to water shortage due to mining activities in Goa and its differential impacts on women have been discussed by Cooper, Mehra, and Joshi in the following chapter (Chapter 35). Institutional dimensions of water use and water scarcity are presented by Narain in the last chapter (Chapter 36).

Global environmental change: complex dynamics of the interrelated systems

While some studies are being conducted worldwide on various components of GEC, the need of the hour is an understanding of the earth system as a whole. GEC studies need both multidisciplinary and interdisciplinary approaches. Multidisciplinary refers to benefiting from two or more branches of learning and interdisciplinary refers to a more active involvement of several separate academic disciplines. The terms trans-disciplinary and cross-disciplinary also are often used to describe collaborative efforts between different disciplines. Steffen, Sanderson, Tyson, *et al.* (2004) emphasize that the biggest challenge is to develop a substantive science of integration, which transcends disciplinary boundaries across the natural and social sciences, as earth system science is ultimately concerned with issues that lie well beyond any single field of study (Steffen, Sanderson, Tyson, *et al.* 2004). Turner, Kasperson, Meyer, *et al.* (1990) suggest that the 'geocentric' focus of natural scientists should be supplemented by an 'anthropocentric' perspective that evaluates physical changes primarily in terms of their importance to society. According to them, the anthropocentric perspective gives importance to any worldwide change of significance to society,

which are normally cumulative ones. Turner, Kasperson, Meyer, *et al.* (1990) further observe that a holistic perspective that integrates the geocentric and anthropocentric perspectives may prove to be most valuable for global change studies.

Global change does not operate in isolation but rather interacts with an almost bewildering array of natural variability modes and also with other human-driven effects at many scales (Steffen, Sanderson, Tyson, *et al.* 2004). Bio-physical feedbacks (Figure 2) play a critical role in long-term dynamics of global change. For example, large areas of land have been lost due to human activities. Moreover, it is predicted that increasing scarcity of water for agriculture will, to a large extent, determine the extent of land-use and land-cover changes in case of agricultural lands. Changes in land use, on the other hand, may have considerable impacts on water demands (Turner, Skole, Sanderson, *et al.* 1995: 20). Water shortages may be influenced by land-cover changes, deforestation, and global warming. Changes in land use can also change the downstream water quality. Study of feedbacks on land-use and land-cover changes and water resources assume importance. A clear understanding of not only how water policies and water availability affect land-use and land-cover changes but also the impacts of land-use and land-cover changes on water resources is required to ensure sustainability of land and water resources.

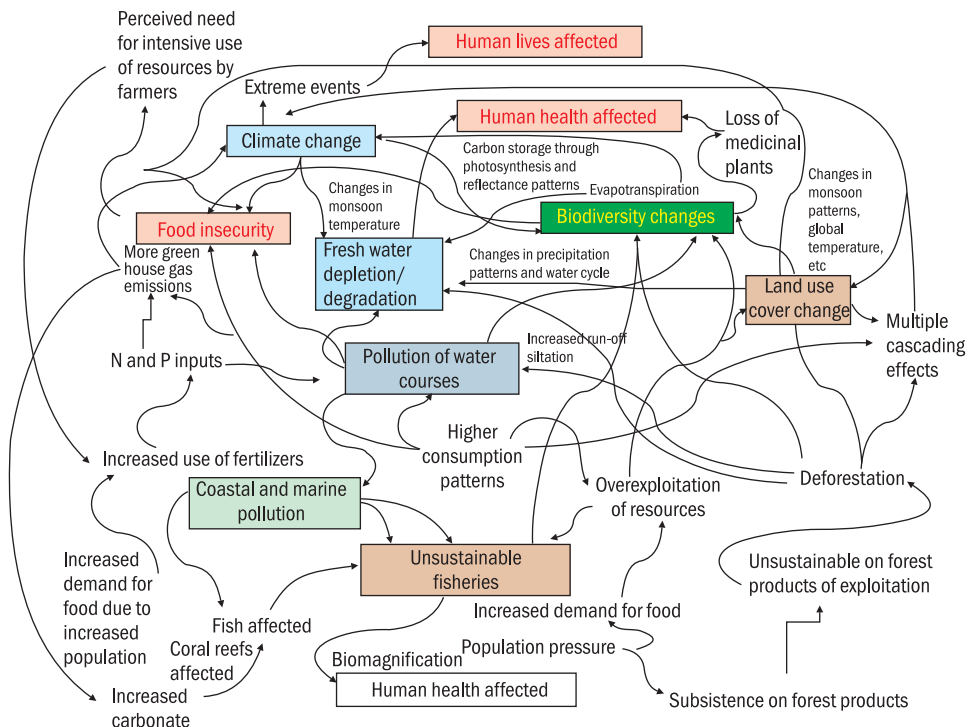


Figure 2 Complex dynamics of global environmental change

Land-use and land-cover changes may also have significant impacts on biodiversity, nutrient recycling, soil biology, including micro-flora, climate, and pollution of water resources, particularly in coastal areas. Alternatively, biodiversity or the biota is an important component in the functioning of the earth system. For example, the type of vegetation present on the land surface influences the amount of water transpired back to the atmosphere and the absorption or reflection of the sun's radiation. The vegetation's rooting patterns and activity are also important controllers of both carbon and water storage and of fluxes between the land and the atmosphere (Steffen, Sanderson, Tyson, *et al.* 2004).

Land and oceans act as sinks for the waste CO₂ (carbon dioxide) emitted by humans. The world's oceans absorb CO₂ equivalent to about 35% of the emissions from fossil fuel combustion (Barrett and Scott 2003). Plants absorb CO₂ during photosynthesis and store it in their tissues. This helps to reduce the accumulation of CO₂ in the atmosphere and mitigate climate change. Phytoplanktons from water also absorb CO₂ through photosynthesis. The nature of the phytoplankton species involved in the carbon fixing may hold a key to the rate of, and potential for, carbon storage (Steffen, Sanderson, Tyson, *et al.* 2004). The terrestrial biota plays a vital role in maintaining carbon concentration. However, the build-up of CO₂ in the earth system has been so rapid that the sink capacity of the oceans as well as land has reduced and is inadequate to accommodate further emission. Forest, as source and sink for carbon, has been very much at the centre of the discourse on global change. Feedbacks on deforestation as well as land-use and land-cover change and climate change have received attention for the past several decades.

Changes in marine ecosystems as a result of human activities are no less significant. Land-use changes affect water courses through soil erosion, run-off, and siltation. Land-based activities are primarily responsible for coastal and marine pollution. This may affect marine and coastal biodiversity creating cascading effects. Eutrophication resulting from coastal and marine pollution poses threats to fisheries and further serious concerns to human health through biomagnification effects. Further, apart from being a major protein source for humans, fish generate a number of ecosystem services that are important for human welfare. With the current trend of fisheries exploitation, a number of ecosystem services generated by fish populations are at risk, with consequences for biodiversity, ecosystem functioning, and ultimately human welfare (Holmlund and Hammer 1999). Climate change and global warming are expected to affect marine biodiversity significantly. Furthermore, increasing atmospheric CO₂ is changing the carbonate chemistry in the surface waters of the ocean, making it more difficult for the reef organisms to form their hard shells.

Precipitation recycling or the water cycle is yet another important connection between the climate change and land-use and land-cover changes. Changes in the precipitation patterns and evapotranspiration are two major effects of climate change. Sea-level rise and salinity intrusion are projected to have

considerable impacts on fresh water, particularly groundwater. GIWA (Global International Water Assessment) focuses on five major threats in relation to water: shortage of fresh water, overfishing, pollution, habitat destruction, and global climate change (Hempel and Daler 2004).

Integrated information

There is little doubt now that global change is a reality and that it will affect life-supporting systems of the earth. Food security (land), water resources, air, and biota are the most important systems that will be affected. These threats coupled with the complex dynamics of GEC warrant a need for integrated assessment. However, despite the recognition of the need for an integrated approach and of importance of including other components of the environment, a few such studies exist in reality. Parry (2004), after analysing the content of the GEC journal, observes that about half of the research papers during the period 1990–93 were on global warming and, despite the efforts to reduce this proportion, the amount has actually increased. This implies that many topics are not getting the exposure that they deserve. Parry (2004) further notes that species extinction, land-use change, land degradation, water supply and quality, and new technology hazards were not being addressed in GEC, and these are still underrepresented. Hence, this volume attempts to bring together case studies that address other aspects of GEC. These case studies reflect concerns regarding environmental threats that may not be mere consequences of climate change, but stem from various other causes, most often, of local origin. Nevertheless, they are focus of study of several international programmes.

Effective environmental policies can be crafted only if integrated information from various perspectives is available. The approach in the present volume has been to integrate such perspectives. The ultimate goal is to contribute to the development of an integrated, broader scientific perspective that will foster inter/multidisciplinary research and promote studies on various environmental issues occurring at local level. This volume is expected to cultivate interest on local case studies among the international community working on GEC issues and to further the understanding regarding the necessity for integration of research on local case studies into global issues. It is hoped that concerns about other components of environment and issues occurring at the local level will emerge in the research agenda on GEC.

In sum, the main objectives of this volume are threefold.

- 1 Local-level case studies that cumulatively make significant impacts at global level
- 2 Concerns related to various components of GEC beyond climate change
- 3 Integrated efforts that transcend disciplinary boundaries and underscore the need to study 'Multiple dimensions of global environmental change'.

References

- Abbott A, Abel P D, Arnold D W, Milne A. 2000
Cost-benefit analysis of the use of TBT: the case for a treatment approach
Science of the Total Environment **258**: 5–19
- Alzieu J, Sanjuan J, Deltreil J P, Borel M. 1986
Tin contamination in Arcachon Bay: effects on oyster shell anomalies
Marine Pollution Bulletin **17**: 494
- Atlas. 2001
Cassell's Atlas of Evolution
London: Casell & Co., Wellington House. 368 pp.
- Barrett J and Scott A. 2003
The application of the ecological footprint: a case of passenger transport in Merseyside
Local Environment **8** (2): 167–183
- Biermann. 2001
Big science, small impacts in the South? The influence of global environmental assessments on expert communities in India
Global Environmental Change **11**: 297–309
- Birchenough A C, Barnesa N, Evans S M, Hinz H, Krönke I, Moss C. 2002
A review and assessment of tributyltin contamination in the North Sea, based on surveys of butyltin tissue burdens and imposex/ intersex in four species of neogastropods
Marine Pollution Bulletin **44** (6): 534–543
- Burke L, Kura Y, Kassem K, Revenga C, Spalding M, McAllister D. 2001
Pilot Analysis of Global Ecosystems: coastal ecosystems
Washington, DC: World Resources Institute
- Cash D W and Moser S C. 2000
Linking global and local scales: designing dynamic assessment and management processes
Global Environmental Change **10**: 109–120
- Chiavarini S, Massanisso P, Nicolai P, Nobili C, Morabito R. 2003
Butyltin concentration levels and imposex occurrence in snails from the Sicilian coasts (Italy)
Chemosphere **50**: 311–319
- Crutzen P and Stoermer E. 2000
The anthropocene
IGBP Global Change Newsletter **41**: 17–18

De Metro G, Corriero A, Desantis S, Zubani D, Cirillo F, Deflorio M, Bridges C R, Eicker J, de la Serna J M, Megalofonou P, Kime D E. 2003

Evidence of a high percentage of intersex in the Mediterranean swordfish (*Xiphias gladius* L.)

Marine Pollution Bulletin 46 (3): 358–361

Evans S M. 1999

TBT or not TBT? That is the question

Biofouling 14 (2): 117–129

Evans S M and Nicholson J. 2000

The use of imposex to assess tributyltin contamination in coastal waters and open seas

The Science of the Total Environment 258: 73–80

Evans S M, Birchenough A C, and Brancato M S. 2000

The TBT ban: out of the frying pan into the fire?

Marine Pollution Bulletin 40 (3): 204–211

Harrington L M B and Lu M. 2002

Beef feedlots in southwestern Kansas: local change, perceptions, and the global change context

Global Environmental Change 12: 273–282

Hempel G and Daler D. 2004

Why a GIWA?

Ambio 33 (1–2): 2–6

Holmlund C M and Hammer M. 1999

Ecosystem services generated by fish populations

Ecological Economics 29: 253–268

Hong H, Takahashi S, Min B, Tanabe S. 2002

Butyltin residues in blue mussels (*Mytilus edulis*) and arkshells (*Scapharca broughtonii*) collected from Korean coastal waters

Environmental Pollution 117 (3): 475–486

IPCC (Intergovernmental Panel on Climate Change). 2001a

Climate change 2001: impacts, adaptation, and vulnerability technical summary
[A Report of Working Group II of the IPCC]

IPCC (Intergovernmental Panel on Climate Change). 2001b

Climate change 2001: summary for policymakers
[A Report of Working Group I of the IPCC]

Lambin E F, Turner B L, Geist H J, Agbola S B, Angelsen A, Bruce J W, Coomes O T, Dirzo R, Fischer G, Folke C, George P S, Homewood K, Imbernon J, Leemans R, Li X, Moran E F, Mortimore M, Ramakrishnan P S, Richards J F, Skanes H, Steffen W, Stone G D, Svedin U, Veldkamp T A, Vogel C, and Xu J. 2001

The causes of land-use and land-cover change: moving beyond the myths
Global Environmental Change 11: 261–269

López T del Mar, Aide T M, and Thomlinson J R. 2001

Urban expansion and the loss of prime agricultural lands in Puerto Rico
Ambio 30 (1): 49–54

Parry M. 2004

Global environmental change since 1993
Global Environmental Change 14: 195

Pauly *et al.* 1998

Fishing down marine food webs
Science 279: 860–863

Ramankutty N, Foley J A, and Olejniczak N J. 2002

People on the land: changes in global population and croplands during the 20th century
Ambio 31 (3): 251–257

Ramon M and Amor M J. 2001

Increasing imposex in populations of *Bolinus brandaris* (Gastropoda: Muricidae) in the north-western Mediterranean
Marine Environmental Research 52: 463–475

Rees C M, Brady B A, and Fabris G J. 2001

Incidence of imposex in *Thais orbita* from Port Phillip Bay (Victoria, Australia), following 10 years of regulation on use of TBT
Marine Pollution Bulletin 42 (10): 873–878

Steffen W, Sanderson A, Tyson P D, Jäger J, Matson P A, Moore III B, Oldfield F, Richardson K, Schellnhuber H J, Turner II B L, Wasson R J. 2004

Global Change and the Earth System: a planet under pressure executive
[Summary]

Sweden: IGBP Secretariat

Turner II B L, Kasperson R E, Meyer W B, Dow K M, Golding D, Kasperson J X, Mitchell R C, Ratick S J. 1990

Two types of global environmental change: definitional and spatial-scale issues in their human dimensions
Global Environmental Change: 14–22

Turner II B L, Skole D, Sanderson S, Fisher G, Fresco L, Leemans R. 1995
Land-use and Land-cover Change Science/Research Plan
[IGBP Report no 35 and HDP report no 7]
Stockholm and Geneva: IGBP and HDP. 132 pp.

World Resources. 2000
World Resources 2000–2001: people and ecosystems: the fraying web of life
Washington DC: World Resources Institute. 389 pp.

Bibliography

Darwin R and Kennedy D. 2000
Economic effects of CO₂ fertilization of crops: transforming changes in yield into changes in supply
Environmental Modeling and Assessment 5 (3): 157–168

Reilly J, Tubiello F N, McCarl B, Melillo J. 2001
Impacts of climate change and variability on agriculture
In *US National Assessment Foundation Document*
[National Assessment Synthesis Team]
Washington, DC: US Global Change Research Programme

Uusivuori J, Lehto E, and Palo M. 2002
Population, income and ecological conditions as determinants of forest area variation in the tropics
Global Environmental Change 12: 313–323

Wilkie D, Morelli G, Rotberg F, Shaw E. 1999
Wetter isn't better: global warming and food security in the Congo Basin
Global Environmental Change 9: 323–328