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Relevant Issues and Current Dimensions in Global Environmental Change

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1. Introduction

Global environmental change (GEC) includes both systemic changes that operate globally through the major systems of the geosphere-biosphere, and cumulative changes that represent the global accumulation of localized changes. The importance and awareness of GEC has greatly increased since the second UN Conference on Environment and Development (UNCED) in 1992. During the last two decades, GEC research programs around the world have advanced our understanding of the Earth's ever-changing physical, chemical, and biological systems and the growing human influences on these systems. On the basis of current knowledge attention is now focused on the critical unanswered scientific questions that must be resolved to fully understand and usefully predict future's GEC. It is hoped that measurable significant progress would be made in the forthcoming Earth Summit 2012, formerly known as United Nations Conference on Sustainable Development (UNCSD) or Rio+20 scheduled for Rio de Janeiro in June 2012.

Generally, the earth's climate system varies naturally across a range of temporal scales, including seasonal cycles, inter-annual patterns such as the El Niño/La Niña-Southern Oscillation- ENSO, inter-decadal cycles such as the North Atlantic and Pacific Decadal oscillations, and multimillenial-scale changes such as glacial to inter-glacial transitions (Harley et al., 2006). This natural variability is reflected in the evolutionary adaptations of species and large-scale patterns of biogeography. In all, human activities play an important part in virtually all natural systems and are forces for change in the environment at local, regional, and even global scales. Human drivers of GEC include consumption of energy and natural resources, technological and economic choices, culture, and institutions. The effects of these drivers are seen in population growth and movement, changes in consumption, de- or reforestation, land-use change, and toleration or regulation of pollution, and other issues highlighted in section two of this chapter. For instance, the Intergovernmental Panel on Climate Change (IPCC) reports that, if global average temperatures exceed 2°C there will be irreversible impacts on water, ecosystems, food, coastal zones and human health. We have a 50% chance of avoiding a 2°C warming if we stabilize greenhouse gases at 450 ppm CO_2 eq (parts per million carbon dioxide equivalents). Recent evidence suggests even more rapid change, which will greatly, and in some case irreversibly, affect not just people, but also species and ecosystems. The schematic framework on the current state of GEC, representing anthropogenic drivers, impacts of and responses to climate change, and their linkages is presented in Figure 1.

In the light of the above overview on GEC, the rest of this chapter is organized as follows: First, in section 2, a review of relevant issues in GEC is given. Section three elucidates on pathways/indicators of GEC. The fourth section centers on the interrelatedness of natural systems and human as driver of most GEC. Some of the consequences of GEC on natural and human systems are reviewed in section five. Section six dealt on global responses, ranging from positive policy drive and actions through innovations and a change where possible in institutional and environmental governance frameworks while weakening some implementation barriers ravaging existing institutions. Lastly, section seven concludes and foregrounds on the need for more interdisciplinary and integrative perspective on global environmental change issues. It hopes to proffer some definitions and answers to overarching questions in GEC.

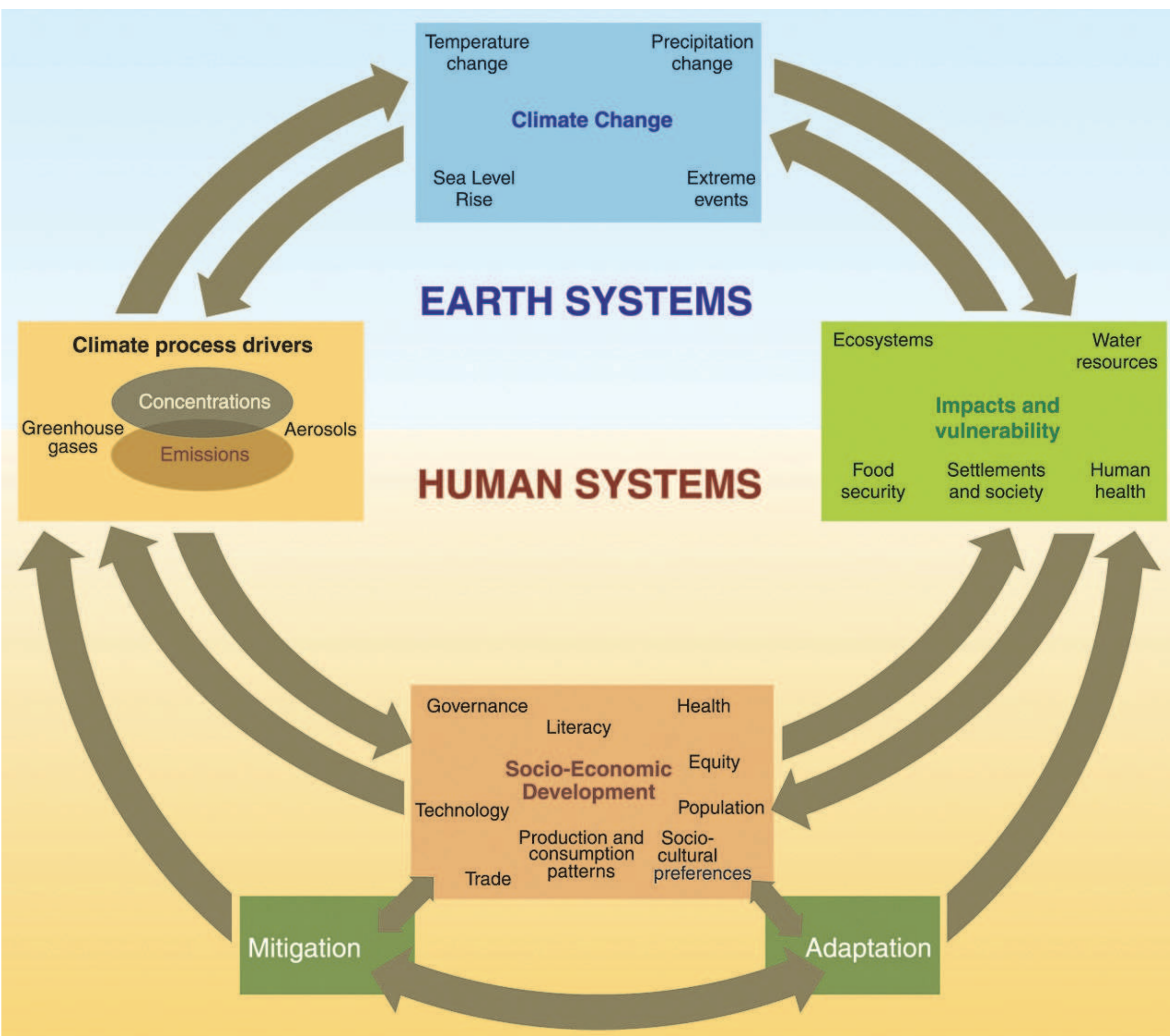

Fig. 1. Schematic framework of anthropogenic climate change drivers, impacts and response. Source: IPCC, 2007.

2. Relevant issues in global environmental change

In the past, several issues have been addressed on GEC. Very striking and concise in my opinion is Vitousek (1994). He concluded that three of the well-documented global changes are: increasing concentrations of carbon dioxide in the atmosphere; alterations in the biogeochemistry of the global nitrogen cycle; and ongoing land use/land cover change, and are perhaps the bedrock of other relevant issues in GEC mentioned in sub-sections 2.0 below. Human activity-now primarily fossil fuel combustion- has increased carbon dioxide concentrations from 280 ppm to 355 ppm since 1800; the increase is unique, at least in the past 160 000 yr, and several lines of evidence demonstrate unequivocally that it is human-caused (Vitousek, 1994; Ebi, 2011). The global nitrogen cycle has been altered by human activity to such an extent that more nitrogen is fixed annually by humanity (primarily for nitrogen fertilizer, also by legume crops and as a byproduct of fossil fuel combustion) than by all natural pathways combined. This added nitrogen alters the chemistry of the atmosphere and of aquatic ecosystems, contributes to eutrophication of the biosphere, and has substantial regional effects on biological diversity in the most affected areas. Finally, human land use/land cover change has transformed one-third to one-half of Earth's ice-free surface. This in and of itself probably represents the most important component of global change now and will for some decades to come; it has profound effects on biological diversity on land and on ecosystems downwind and downstream of affected areas. These three and other equally certain components of global environmental change are the primary causes of anticipated changes in climate, and of ongoing losses of biological diversity (Vitousek, 1994, Sala et al, 2000).

2.1 Climate change

Climate change is one of several large-scale environmental changes to which human activities make a significant contribution, and that, in turn, affects human health and well-being. The Intergovernmental Panel on Climate Change (IPCC) concluded: "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC 2007)." Over the past decade, the fact that emissions of greenhouse gases due to human activities are affecting the world's climate has become clear (Ebi 2011). In addition: "most of the observed increase in globally averaged temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." These changes have begun to affect morbidity and mortality worldwide, with projections suggesting that overall health burdens will increase with increasing climate change. Although all countries are projected to experience increased health risks, those at greatest risk include the urban poor, older adults, children, traditional societies, subsistence farmers, and coastal populations, particularly in low-income countries (Ebi 2011).

The task of understanding climate change and predicting future change would be complex enough if only natural forcing mechanisms were involved. It is significantly more daunting because of the introduction of anthropogenic forcing and even more so considering the limitations in available records.

2.2 Land use

Landscapes are changing worldwide, as natural land covers like forests, grasslands, and deserts are being converted to human-dominated ecosystems, including cities, agriculture, and forestry. Between 2000-2010, approximately 13 million hectares of land (an area the size of Greece) were converted each year to other land cover types (FAO 2010). Developed regions like the US and Europe experienced significant losses of forest and grassland cover over the past few centuries during phases of economic growth and expansion. More recently, developing nations have experienced similar losses over the past 60 years, with significant forest losses in biologically diverse regions like Southeast Asia, South America, and Western Africa.

Land use changes affect the biosphere in several ways. They often reduce native habitat, making it increasingly difficult for species to survive. Some land use changes, such as deforestation and agriculture, remove native vegetation and diminish carbon uptake by photosynthesis as well as hasten soil decomposition, leading to additional greenhouse gas release. Almost 20% of the global CO_2 released to the atmosphere (1.5–2 billion tons of carbon) is thought to come from deforestation.

2.3 Biodiversity

Biodiversity is the diversity of life on Earth and includes the richness (number), evenness (equity of relative abundance), and composition (types) of species, alleles, functional groups, or ecosystems. The period since the emergence of humans has displayed an ongoing biodiversity reduction and an accompanying loss of genetic diversity. Named the Holocene extinction, the reduction is caused primarily by human impacts, particularly habitat destruction.

Currently, global biodiversity is changing at an unprecedented rate and scale in response to human-induced perturbation of the Earth System. Fossil records indicate that the background extinction rate (that is Pre-Industrial value) for most species is 0.1-1 extinctions per million species per year (Braimoh et al., 2010). Over the past years however, the species extinction rate has increased to more than 100 extinctions per million species per year (MA, 2005). There is a strong linkage between biodiversity loss and human-driven ecosystem processes from local to regional scales. Conversely, biodiversity impacts human health in a number of ways, both positively and negatively (Sala et al. 2009), and there is considerable evidence that contemporary biodiversity declines will lead to subsequent declines in ecosystem functioning and ecosystem stability (Naeem et al. 2009).

Generally, observed changes in climate have already adversely affected biodiversity at the species and ecosystem level, and further changes in biodiversity are inevitable with further changes in climate (CBD 2009). While human actions have significantly contributed to the loss of biodiversity, in some cases, human actions have promoted biodiversity. Conservation strategies, such as creating parks to protect biodiversity hotspots, have been effective but insufficient (Bruner et al. 2001). For example, although biodiversity is often greater inside than outside parks, species extinctions continue. Specifically, biodiversity and ecosystem services are greater in restored than in degraded ecosystems but lower in restored than in intact remnant ecosystems (Benayas et al. 2009). Despite the positive effects of conservation and restoration efforts, biodiversity declines have not slowed (Butchart et al. 2010). Thus, further investigation is needed to determine new conservation and restoration strategies.

Global agreements such as the Convention on Biological Diversity, give "sovereign national rights over biological resources" (not property). The agreements commit countries to "conserve biodiversity", "develop resources for sustainability" and "share the benefits" resulting from their use. Sovereignty principles can rely upon what is better known as Access and Benefit Sharing Agreements (ABAs). The Convention on Biodiversity implies informed consent between the source country and the collector, to establish which resource will be used and for what, and to settle on a fair agreement on benefit sharing. Theoretical and empirical studies have identified a vast number of natural processes that can potentially maintain biodiversity. Biodiversity can be maintained by moderately intense disturbances that reduce dominance by species that would otherwise competitively exclude subordinate species. For example, selective grazing by bison can promote plant diversity in grasslands (Collins et al. 1998).

Now, it may be possible to predict future changes in biodiversity, ecosystem functioning, and ecosystem stability by considering how global ecosystem changes are currently influencing stabilizing species interactions. In this direction, the United Nations is currently developing an Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to monitor biodiversity and ecosystem services worldwide (Marris 2010). The IPBES will be modelled after the Intergovernmental Panel on Climate Change (IPCC), and there is great potential for ecologists to borrow strategies that have been successfully employed by climatologists. Another global effort in this direction (conservation of biodiversity) recently culminated in the United Nations designating 2011-2020 as the United Nations Decade on Biodiversity during the Aichi COP 10 meeting in 2010- the International Year of Biodiversity.

3. Pathways and indicators of global environmental change

Changes are occurring throughout the Earth System and are evident in the oceans, on the land and in the atmosphere. These changes are increasingly driven by human activities. There is the need to understand how these ecosystems react to global change so as to understand the consequences for their functioning and to manage ecosystems resources sustainably. Sala et al., (2000) recognize five major drivers of biodiversity loss, namely land use, climate, nitrogen deposition, biotic exchange and atmospheric carbon dioxide, and opined that the importance of these drivers varies from one ecosystem to the other. Here, I present and elucidate the pressures on three major pathways of global environmental change.

3.1 Terrestrial

Land-use change (especially deforestation) and climate change generally have the greatest impact for terrestrial ecosystems, whereas biotic exchange is more important for freshwater ecosystems. As earlier mentioned, human activity–now primarily fossil fuel combustion–has increased carbon dioxide concentrations from 280 ppm to 355 ppm since 1800; the increase is unique, at least in the past 160 000 yr, and several lines of evidence demonstrate unequivocally that it is human-caused (Vitousek, 1994). This increase is likely to have climatic consequences–and certainly it has direct effects on biota in all Earth's terrestrial ecosystems. Land use and land cover change has aroused increasing attention of scientists worldwide since 1990. Recognizing the importance of this change to other global environmental change and sustainable development issues, the International Geosphere-Biosphere Programme (IGBP) and the Human Dimensions of Global Environmental Change Programme (IHDP) initiated a joint core project Land Use and Land Cover Change (LUCC) and published a Science/Research Plan for the project. This precipitated into a number of IGBP core projects, of which one is Global Change and Terrestrial Ecosystems (GCTE). Despite these achievements, agricultural activities have continued to be significant emitters of global greenhouse gases (GHGs) and as such agricultural activity is a major driver of anthropogenic climate change. Emissions from agricultural sources were 14% of global GHG emissions in 2000 with developing countries accounting for three quarters of agriculture emissions in the case of rice (WRI, 2006; Stern, 2007).

Also, changes in vegetation structure influence the magnitude and spatial pattern of the carbon sink and, in combination with changing climate, also freshwater availability (runoff). The potential for terrestrial ecosystems to absorb significant amounts of CO_2, thus slowing the buildup of CO_2 in the atmosphere and reducing the rate of climate change, is a key issue in the debate on CO_2 emission controls. As more land is converted to agriculture, there is less area in natural ecosystems that can act as carbon sinks, thereby reducing the potential sink strength of the terrestrial biosphere.

3.2 Aquatic

The ocean is a vital component of the metabolism of the Earth and plays a key role in global change. In 1987 the World Commission on Environment and Development (Brundtland Commission) warned in the final report, Our Common Future, that water was being polluted and water supplies were overused in many parts of the world. The ocean is the source of most of the world's precipitation (rainfall and snowfall), but people's freshwater needs are met almost entirely by precipitation on land (see Figure 2), with a small though increasing amount by desalination. Due to changes in the state of the ocean, precipitation patterns are altering, affecting human well-being. Asides from this, ocean changes are also affecting marine living resources and other socio-economic benefits on which many communities depend, and anthropogenically induced global climate change has profound implications for marine ecosystems and the economic and social systems that depend upon them (Harley et al., 2006).

Human pressures at global to basin scales are substantially modifying the global water cycle, with some major adverse impacts on its interconnected aquatic ecosystems- freshwater and marine - and therefore on the well-being of people who depend on the services that they provide. Like other ecosystems, marine and coastal areas are already adversely impacted by many stresses, which will be exacerbated by climate change (e.g., sea level rise) (see figure 3). At the same time, coastal ecosystems ranging from Polar Regions to Small Island developing States are essential to our capacity to respond to projected climate change impacts.

In recent years, a major observed pressure on the aquatic ecosystem is Ocean acidification caused by decrease in the pH and increase in acidity of the Earth's oceans as a result of uptake of anthropogenic carbon dioxide (CO_2) from the atmosphere. Past, present and future predicted average surface ocean pH is shown in Table 1. Dissolving CO_2 in seawater increases the hydrogen ion (H^+) concentration in the ocean, and thus decreases ocean pH. Caldeira and Wickett (2003) placed the rate and magnitude of modern ocean acidification changes in the context of probable historical changes during the last 300 million years.

Furthermore, in terms of resources, aquatic ecosystems continue to be heavily degraded, putting many ecosystem services at risk, including the sustainability of food supplies and biodiversity. Global marine and freshwater fisheries show large scale declines, caused mostly by persistent overfishing. Freshwater stocks also suffer from habitat degradation and altered thermal regimes related to climate change and water impoundment. A continuing challenge for the management of water resources and aquatic ecosystems is to balance environmental and developmental needs. It requires a sustained combination of technology, legal and institutional frameworks, and, where feasible, market-based approaches.

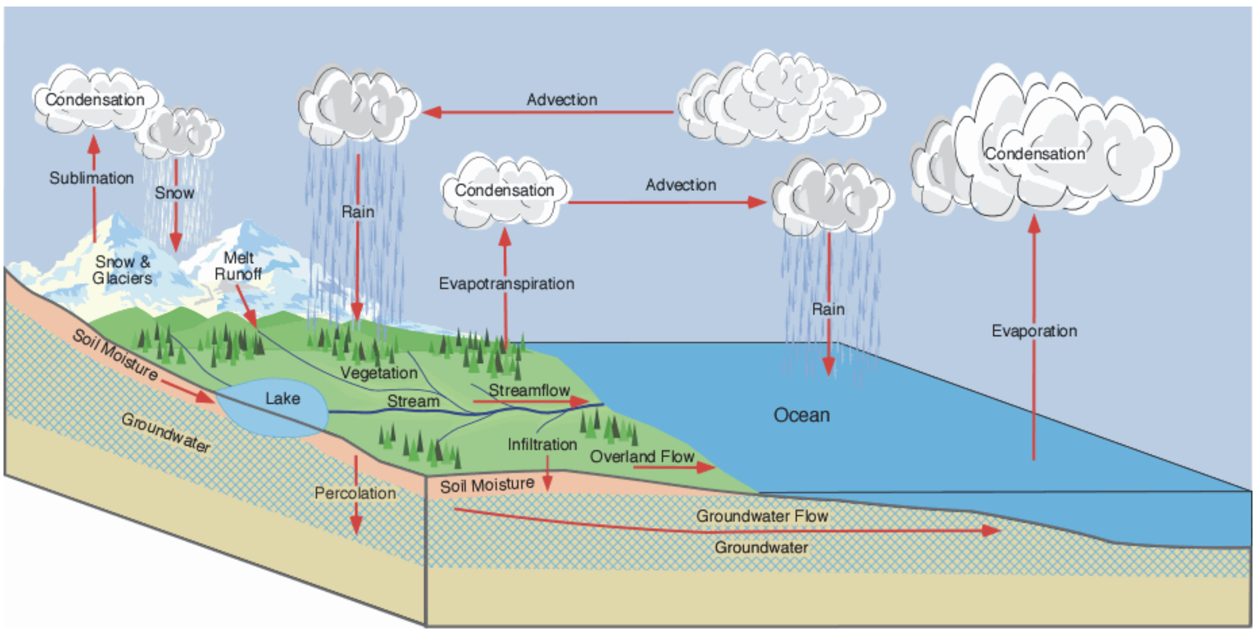

Fig. 2. Hydrologic cycle (Adapted from Pidwirny, 2006).

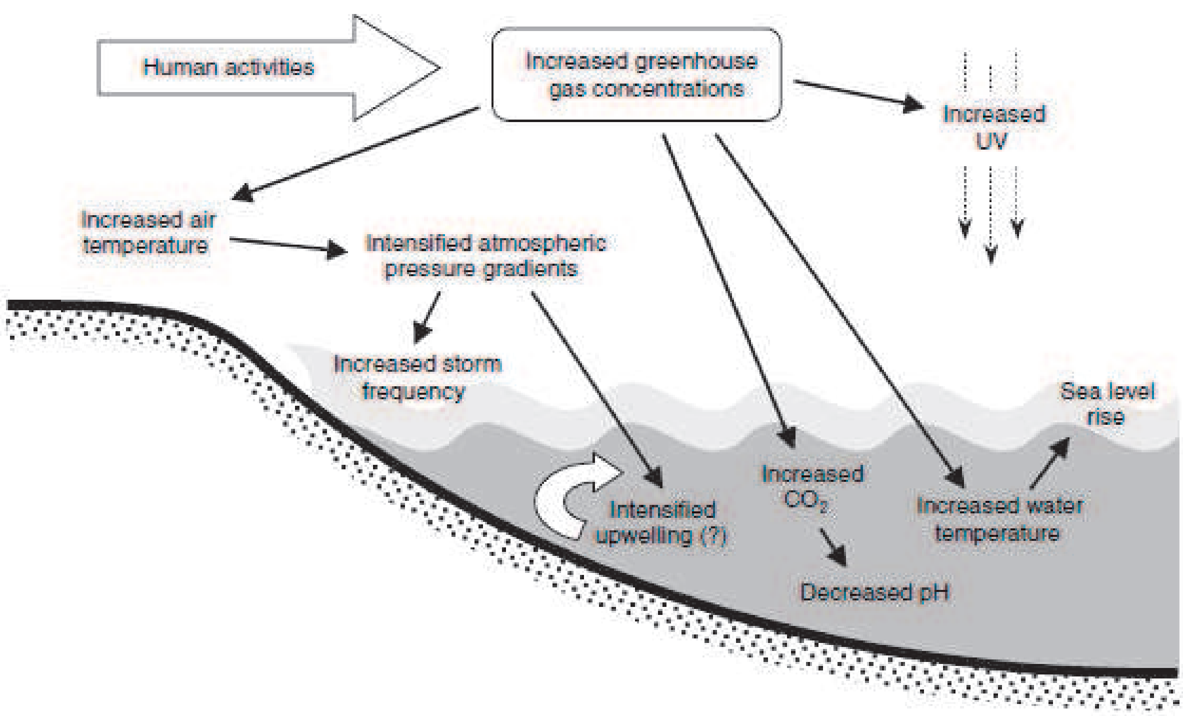

Fig. 3. Important abiotic changes associated with climate change. Human activities such as fossil fuel burning and deforestation lead to higher concentration of greenhouse gases in the atmosphere, which in turn leads to a suit of physical and chemical changes in coastal ocean. (Adapted from Harley et al., 2006).

Time	pH	pH change	Source	H^+ concentration change relative to pre-industrial
Pre-industrial (18th century)	8.179	0.000	*Analyzed field* Key et al (2004)	0%
Recent past (1990s)	8.104	-0.075	*Field* Key et al (2004)	+18.9%
Present levels	~8.069	-0.11	*Field* Hall-Spencer et al (2008)	+28.8%
2050 (2×CO2 = 560 ppm)	7.949	-0.230	*Model* Orr et al (2005)	+69.8%
2100 (IS92a) (IPCC 2001)	7.824	-0.355	*Model* Orr et al (2005)	+126.5%

Table 1. Average surface ocean pH (Adapted from Orr et al 2005).

3.3 Atmospheric

In the last two centuries, human have released ever greater quantities of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other greenhouse gases, into the Earth's atmosphere (Woodward and Buckingham, 2008). Scientists have found that the four most important variable greenhouse gases, whose atmospheric concentrations can be influenced by human activities, are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs). Greenhouse gases basketed under the Kyoto Protocol and their main generators are shown in Table 2. Historically, CO_2 has been the most important, but those other atmospheric trace gases are also radiatively active, in that they can affect Earth's heat budget and thereby contribute to a greenhouse warming of the lower atmosphere. CO_2 has risen from pre-industrial concentration of 280 ppm to current values in excess of 380 ppm, and is currently rising by 1.9 ppm per year (Woodward and Buckingham, 2008). There is a growing concensus among climate researchers that these greenhouse gases are causing the Earth's temperature to rise. Scientists have measured a temperature rise of 0.76 ℃ (with confidence intervals of 0.56 to 0.92 ℃) between 1850 and 2005, as a result of increased radiative forcing from the increases in atmospheric greenhouse gases (IPCC 2007).

Greenhouse Gas	Main Sources
Carbon dioxide (CO_2)	Fossil fuel combustion (e.g. road transport, energy industries, other industries, residential, commercial and public sector); forest clearing
Methane (CH_4)	Agriculture, landfill, gas leakage, coal mines
Nitrous oxide (N_2O)	Agriculture, industrial processes, road transport, others
Perfluorocarbons (PFCs)	Industry (e.g. aluminium production, semi-conductor industry)
Hydrofluorocarbons (HFCs)	Refrigeration gases, industry (as perfluorocarbons)
Sulphur hexafluoride ($SF/_6$)	Electrical transmissions and distribution systems, circuit breakers, magnesium production

Source: UNFCC, 2003

Table 2. Greenhouse gases basketed under the Kyoto Protocol and their main generators (Note: greenhouse gases produced by air transport are exempted from the Protocol).

Current developments in atmospheric chemistry are revealing the close links between chemistry, radiation, dynamics, and climate. Examples include the powerful role played by aerosol formation in both the boundary layer and the upper troposphere, chemical initiation of subvisible cirrus in the region of the tropopause, the control exerted by water vapor and temperature on the sharply nonlinear partitioning of halogen and hydrogen radicals in the lower stratosphere, and the importance of stratosphere-troposphere exchange on the composition and meteorology of the upper troposphere and lower stratosphere.

4. Human dimensions of global environmental change

According to Jager (2002), research on the human dimensions of global environmental change is concerned with the human causes of change, the consequences of such changes for individuals and societal groups, and the ways in which humans respond to the changes. The human causes include emissions of pollutants into the atmosphere, especially carbon dioxide, chlorofluorocarbons and acidifying substances, as well as land-use and land-cover changes.

It is now established wisdom that humans are the prime drivers of change on Earth, and it is this recognition that underpins the discussion of the Anthropocene. Social, economic, and cultural systems are changing in a world that is more populated, urban, and interconnected than ever. Such large-scale changes increase the resilience of some groups while increasing the vulnerability of others.

With the impetus of global change research, study of large-scale ecosystems has become a rapidly maturing field of science and has shown major successes over the past decade. Improved fundamental understanding of marine and terrestrial ecosystems and hydrology has already led to practical applications in weather and climate modeling, air quality, and better management and natural hazards responses for water, forest, fisheries, and rangeland resources. The development of spatially resolved global-scale ecosystem models has occurred only during the past five years. Computing capability and remote sensing technology have further driven change in the nature of the field. The capability has emerged not only to model at global scales but also to exploit data at these scales.

Such capability is increasingly important for developing our economy, protecting our environment, safeguarding our health, and negotiating international agreements to ensure the sustainable development of the global community of nations. As earlier mentioned, if global average temperatures exceed 2°C there will be irreversible impacts on water, ecosystems, food, coastal zones and human health (IPCC 2007). We have a 50% chance of avoiding a 2°C warming if we stabilize greenhouse gases at 450 ppm CO_2 eq (parts per million carbon dioxide equivalents). This means we must start radically reducing emissions now and stay on a low emissions pathway to avoid increasing the amount of CO_2 in the atmosphere. The good management of ecosystems such as wetlands and forests remains an effective mitigation option given the high sequestration potential of natural systems. The permanence of carbon sinks is also tied to the maintenance or enhancement of the resilience of ecosystems (CBD 2009).

5. Consequences for natural and human systems and responses

There are consequences for natural and human systems in GEC events. Studies have focused, for example, on global environmental change impacts on agriculture and human health and on particular locations, such as the coastal zone. Rising sea levels; increased temperatures; increased risk of droughts, floods and fires; stronger storms and increased storm damage; changing landscapes; forced environmental migrations and food insecurity are but a few of the issues linked to a changing climate. However, while a large proportion of climate change impacts will be negative, some will be positive too. For certain societies these will include, among others, increased agricultural growing periods and lower winter mortalities (warmer winters), although it is generally accepted that the negatives will significantly outweigh the positives (Nelson et al, 2009). The Stern Review suggests that all countries will be affected by climate change, but it is the poorest countries that will suffer earliest and most. Unabated climate change may risks raising average temperatures by over 5°C from pre-industrial levels. Such changes would transform the physical geography of our planet, as well as the human geography- how and where we live our lives (Stern Review, 2007). Some examples of these consequences are elucidated.

5.1 Food security

Food security is the ability of people to have access to sufficient, nutritious food. Global environmental change (GEC), including land degradation, loss of biodiversity, changes in hydrology, and changes in climate patterns resulting from enhanced anthropogenic emission of greenhouse gas emissions, will have serious consequences for food security, particularly for more vulnerable groups (Ericksen et al. 2009). Growing demands for food in turn affect the global environment because the food system is a source of greenhouse gas emissions and nutrient loading, and it dominates the human use of land and water. The speed, scale and consequences of human-induced environmental change are beyond previous human experience, and thus science has a renewed responsibility to support policy formation with regard to food systems (Carpenter et al., 2009; Steffen et al., 2003). Most research linking global environmental change and food security focuses solely on agriculture: either the impact of climate change on agricultural production, or the impact of agriculture on the environment, e.g. on land use, greenhouse gas emissions, pollution and/ or biodiversity (Ericksen et al. 2009).

Although, we currently grow enough food to feed the global human population, a population rising to 9 billion by 2050, combined with climate changes, will strain the capacity of some regions to feed people, thereby raising the risks of food insecurity (Godfray et al. 2010). Thus, the effects of global environmental change (GEC) are increasingly making the practical achievement of food security more difficult in some of the world's poorest communities. It is important to note that while technical fixes are important, they will not alone solve the food security challenges. Adapting to the additional threats to food security arising from major environmental changes requires an integrated food system approach, not just a focus on agricultural practices. In this line, Ericksen et al (2009) further highlighted on six key issues that has emerged for future research: (i) adapting food systems to global environmental change requires more than just technological solutions to increase agricultural yields; (ii) tradeoffs across multiple scales among food system outcomes are a pervasive feature of globalized food systems; (iii) within food systems, there are some key underexplored areas that are both sensitive to environmental change but also crucial to understanding its implications for food security and adaptation strategies; (iv) scenarios specifically designed to investigate the wider issues that underpin food security and the environmental consequences of different adaptation options are lacking; (v) price variability and volatility often threaten food security; and (vi) more attention needs to be paid to the governance of food systems.

5.2 Human security

The concept of human security came to prominence through the 1994 Human Development Report, which defined human security as a ''concern with human life and dignity'' (UNDP 1994, 22), and which adopted a comprehensive approach by identifying economic, food, health, environmental, personal, community, and political components to human security. In the 21st century three key issues facing humankind are environmental degradation, impoverishment, and the insecurity that can result from either of these two. A review of environment and security work indicates that there is an ongoing need for conceptual and theoretical discussions on the nature of the relationship between environment and security. It is also important to build upon early empirical work that focused on environment and conflict and to provide additional empirical studies on environmental change and its relationship to a broader conception of security. At the same time expanded research networks and improved communication among researchers, policy makers, and NGOs are required in order to develop integrated research projects on environmental change and human security.

5.3 Human health

It is well established that human health is linked to environmental conditions, and that changes in the natural environment may have subtle, or dramatic, effects on health. Timely knowledge of these effects may support our public health infrastructure in devising and implementing strategies to compensate or respond to these effects.

Ecosystems, human health and economy are all sensitive to changes in climate- including both the magnitude and rate of climate change. Climate change is likely to affect human health and well-being through a variety of mechanisms. For example, it can adversely affect the availability of freshwater, food production, and the distribution and seasonal transmission of vector-borne infectious diseases such as malaria, dengue fever and schistosomiasis. The additional stress of climate change will interact in different ways across regions. It can be expected to reduce the ability of some environmental systems to provide, on a sustained basis, key goods and services needed for successful economic and social development, including adequate food, clean air and water, energy, safe shelter and low levels of diseases (IPCC 2001).

In this chapter, current state of knowledge of the associations between weather/climate factors and health outcome(s) for the population(s) concerned, either directly or through multiple pathways is as outlined in Figure 4. The figure shows not only the pathways by which health can be affected by climate change, but also shows the concurrent direct-acting and modifying (conditioning) influences of environmental, social and health system factors.

5.4 Natural disturbances

Changing climate has the potential to increase risks from sea level rise, extreme storm events, and drought. About 25% of the world's population lives with 100 km of the coast. In 2007, the IPCC projected an 18-59 cm sea level rise by 2100, but many scientists argue that this range is too low, and that sea level rise could be as great as 1-6 m (Kopp et al 2009; Jevrejeva *et al.* 2010). People living in low lying regions, such as Bangladesh and Pacific island nations (e.g., Tuvalu and the Maldives) are already experiencing the effects of salt water incursion in their agricultural fields and fresh water supplies. Arctic Inuit communities are battling the loss of coastal villages as a result of increased storm surges from sea level rise.

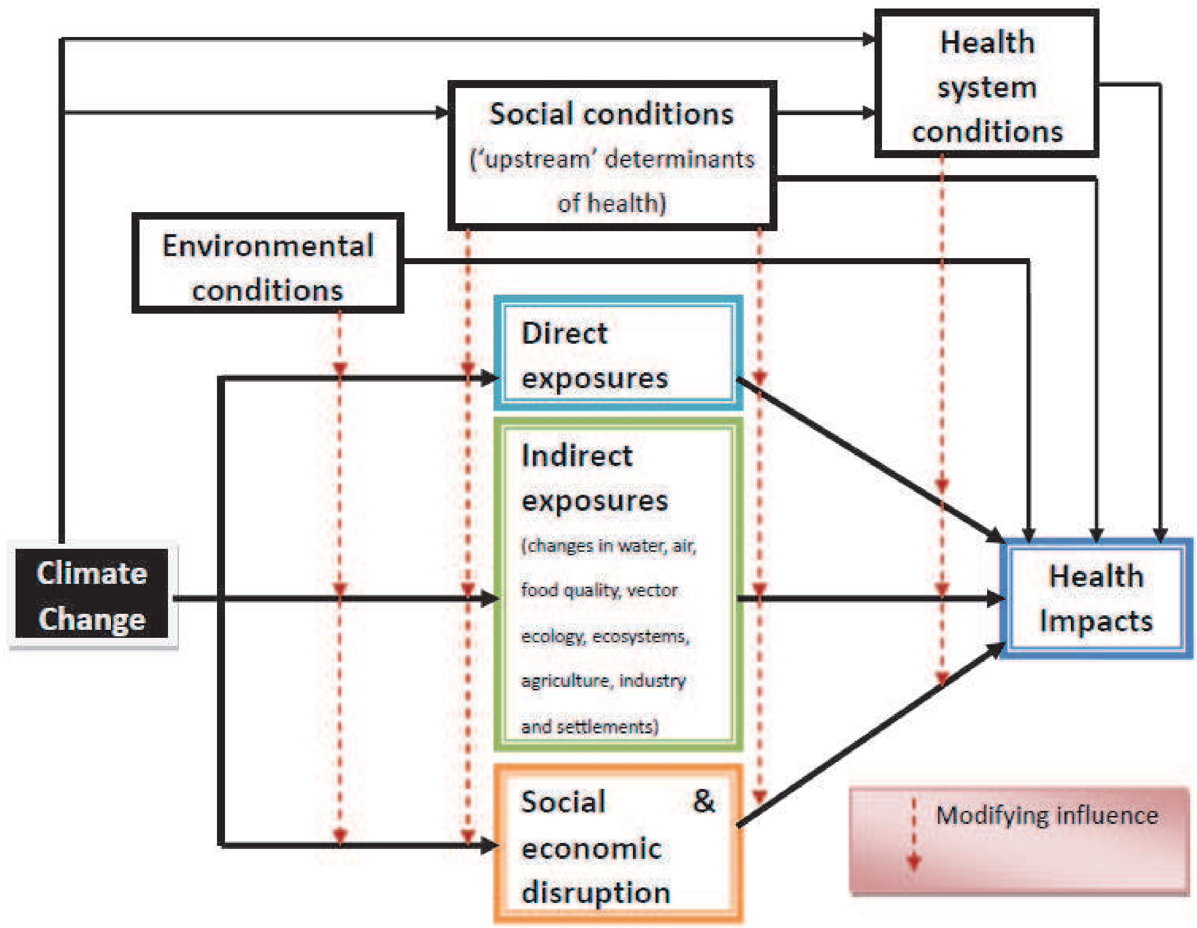

Fig. 4. Schematic diagram of pathways by which climate change affects health, and concurrent direct-acting and modifying (conditioning) influences of environmental, social and health-system factors (Modified from Confalonieri et al 2007).

Extreme precipitation events may become more common in mid-to-high latitude regions, consistent with the prediction that warmer air temperatures, as a result of climate warming, will increase the moisture content of the atmosphere (IPCC 2007). Besides catastrophic flooding and associated property damage, extreme storms are a concern for infrastructure, with cities now faced with the prospect of significant costs associated with roads, dams, and levees being washed out by floods. Regions such as the Sahel are particularly vulnerable to increases in rainfall variability and extremes; the timing of rainfall is as important as the amount of rainfall for agriculture in the Sahel. Extreme rainfall events in semi-arid regions are also likely to lead to increased soil erosion; analysis of interannual variability in rainfall and atmospheric dust content in the Sahel indicates that episodic rainfall events play an important role in generating the erodible material that is necessary for the development of dust storms (Brooks and Legrand, 2001). Atmospheric dust is a major cause of respiratory problems in regions such as the Sahel (Shinn, 2001), and a shift towards higher rainfall variability and intensity might therefore have a negative impact on health.

6. Global response

"The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response" (Stern Review, 2007). Human perceptions of the natural environment, and the way we use the environment, are socially constructed. The human responses are mitigation and adaptation. However, environmental problems must be addressed from a broader perspective that includes issues of impoverishment and issues of (in) equity, and recognizing the fact that "Space Matters". In the context of global environmental change, it is important to consider the various spatial levels at which both environment and security concerns can be addressed. It is believed that these needs can be best met through an international research program that focuses both on guiding future research and assisting in policy development (at all levels).

Given the severity of global environmental change impacts, various adaptation and mitigation measures are being used in the fight against climate change. The effective targeting of these measures across different sectors such as water, agriculture, tourism, infrastructure development and others requires the use of both practical and innovative strategies. Adaptation measures fall within a broad range, among others, from expanded water harvesting, storage and conservation techniques to the diversification of tourism activities. An example of an adaptation strategy to prevent damage from climate change is shore protection (e.g., dikes, bulkheads, beach nourishment), which can prevent sea level rise from inundating low-lying coastal property, eroding beaches, or worsen flooding. If the costs or environmental impacts of shore protection are high compared with the property being protected, an alternative adaptation strategy would be a planned retreat, in which structures are relocated inland as shores retreat. Also, with current climate fluctuations, a good example of adaptation and coping strategies include farmers planting different crops for different seasons, and wildlife migrating to more suitable habitats as the seasons change.

Mitigation measures include "climate friendly" technological innovations; alternative fuels; sustainable land management practices to name but a few (Nelson et al, 2009). Also, the resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies. Conservation and management strategies that maintain and restore biodiversity can be expected to reduce some of the negative impacts from climate change; however, there are rates and magnitude of climate change for which natural adaptation will become increasingly difficult (CBD 2009).

Furthermore, from the highlights of Stern Review, emerging schemes that allow people to trade reductions in CO_2 have demonstrated that there are many opportunities to cut emissions for less than $25 a tonne. In other words, reducing emissions will make us better off. According to one measure, the benefits over time of actions to shift the world onto a low-carbon path could be in the order of $2.5 trillion each year. The shift to a low-carbon economy will also bring huge opportunities. Markets for low-carbon technologies will be worth at least $500bn, and perhaps much more, by 2050 if the world acts on the scale required. Tackling climate change is the pro-growth strategy; ignoring it will ultimately undermine economic growth (Stern Review, 2007).

Lastly, international policy responses to the global challenges described above have been many and varied. Most of them are based on several UN Conventions such as the UN Conference on Environment and Development, Framework Convention on Climate Change (UNFCC), Convention on Biological Diversity (CBD) or the large number of agreements tied to the UN Convention on the Law of the Sea. At the same time, institutional and organizational weaknesses in some countries and the complex interaction among myriad authorities responsible for ecosystems (including marine and coastal) and environmental management make the implementation of policies a difficult task (Agboola and Braimoh, 2009). Changes in institutional and environmental governance frameworks are sometimes required to create the enabling conditions for effective management of ecosystems, while in other cases existing institutions could meet these needs but face significant implementation barriers (MA, 2005). A lot of commitments to sustainable development have been made at past UN conferences, including Agenda 21 (1992), the Rio Declaration on Environment and Development (1992) and the Johannesburg Plan of Implementation (2002).

In all these, there is the need to examine how far we have come in achieving these commitments before we can channel a better way to moving forward.

7. Conclusion

This chapter dealt on some relevant issues and current dimensions in GEC. It presents certainties as explained by some GEC indicators and predictions, and future uncertainties that may require strategic interventions. In all of these, it foregrounds the need for a broader perspective in tackling the myriads of global environmental challenges. Although, research on the human dimensions of global change concerns human activities that alter the Earth's environment, the driving forces of those activities, the consequences of environmental change for societies and economies, and human responses to the experience or expectation of global change; such research is essential both to understand global change and to inform public policy. This review suggests the need for a more interdisciplinary and integrative perspective on environmental change issues. A more integrated understanding of the complex interactions of human societies and the Earth system is essential if we are to identify vulnerable systems and pursue options that take advantage of opportunities and enhance resilience.

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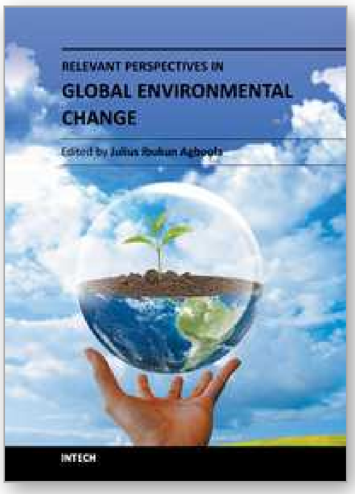

Relevant Perspectives in Global Environmental Change

Edited by Dr. Julius Agboola

ISBN 978-953-307-709-3
Hard cover, 154 pages
Publisher InTech
Published online 22, December, 2011
Published in print edition December, 2011

Over the years, environmental change has sharpened significant dynamic evolution and knowledge in organizational structures of organisms, from cellular/molecular to macro-organism level including our society. Changes in social and ecological systems due to environmental change will hopefully result in a shift towards sustainability, with legislative and government entities responding to diverse policy and management issues concerning the building, management and restoration of social-ecological systems on a regional and global scale. Solutions are particularly needed at the regional level, where physical features of the landscape, biological systems and human institutions interact. The purpose of this book is to disseminate both theoretical and applied studies on interactions between human and natural systems from multidisciplinary research perspectives on global environmental change. It combines interdisciplinary approaches, long-term research and a practical solution to the increasing intensity of problems related to environmental change, and is intended for a broad target audience ranging from students to specialists.