Impact of Climate Change on Ecosystem Services

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Abstract

Climate change is one of the most important global environmental challenges in the history of mankind. The change in climate is mainly caused by increasing concentration of Green House Gases in the atmosphere. Climate of the planet earth is always in a state of change as a natural process influenced by both natural variability and induced environmental changes due to anthropogenic reasons. Moreover Climate change according to Inter Governmental Panel on Climate Change (IPCC) refers to 'a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer. Climate change will likely put at risk many of nature's benefits, or ecosystem services, that humans derive from our lands and waters. Climate-mediated loss or disruption of ecosystem functions are very likely to have repercussions for society's dependence on ecosystems for wild-caught and farmed food, recreation, nutrient cycling, waste processing, protection from natural hazards, climate regulation, and other services. Ecosystem services do not vary independently of one another, and as a result, one general strategy for responding to harmful reductions in one ecosystem service is to boost another ecosystem service, or to reduce interacting stressors. Better management of supporting services in general may provide substantial adaptive capacity for the negative impacts of climate change on other services. Policies and incentives aimed at getting people to behave differently, or change the location and type of livelihoods they engage in, are urgently required. Therefore, to understand the gaps in our scientific understanding of how ecosystem services will respond to climate change is need to be emphasized.

Keywords: Climate change, $CO_{2,}$ ecosystem, green house gasses

1. Introduction

Climate change is one of the most important global environmental challenges in the history of mankind. The change in climate is mainly caused by increasing concentration of Green House Gases in the atmosphere. In 1980s, scientific evidences linking GHGs emission due to human activities causing global climate change, started to concern everybody. Subsequently, United Nations General Assembly in 1992 formed the Intergovernmental Negotiating Committee for Framework Convention on Climate Change (UNFCCC) which finally adopted the framework for addressing climate change concerns.

Climate change according to Inter Governmental Panel on Climate Change (IPCC) refers to 'a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer. However, UNFCCC, in its Article 1, defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes.

2. Climate Change Situation

Climate of the planet earth is always in a state of change as a natural process influenced by both natural variability and induced environmental changes due to anthropogenic reasons. Natural causes include continental drift, volcanoes, earth's tilt, solar output variations and ocean current while human causes are green house gas emissions and land use change etc. However, the reason for worry is that climate change is taking place at a much faster rate than expected by the human interference. The IPCC has been publishing periodic assessment reports on atmospheric carbon concentration and its likely impact on the environment. According to this International scientific body the CO_2 concentration has increased from a value of about 280 ppm during pre-industrial era to 400 ppm in 2013. Similarly, the global atmospheric

concentration of methane and nitrous oxides and other important GHGs, has also increased considerably. Accordingly to the IPCC, this has resulted in warming of the climate system by 0.74 ^{o}C±18 ^{0}C between 1906 and 2005. In the instrumental recording period of global surface temperature since 1850, out of a total 12 warmest years, 11 years fell in the 1995–2006 period. Global average sea level rose at an average rate of 1.8 mm per year over 1961–2003. The IPCC has projected a temperature increase in the range 1.1 to 6.4 ^{o}C by the end of this century. For South Asian including Indian region, the IPCC has projected 0.5 to 1.2^{o}C rise in temperature by 2020, 0.88 to 3.16 ^{o}C by 2050 and 1.56 to 5.44 ^{o}C by 2080, depending on the scenario of future development (IPCC 2007). Climate change is projected to increase the global temperatures, cause variations in rainfall, increase the frequency of extreme events such as heat, cold waves, frost days, droughts, floods, etc with immense impact on ecosystem services.

3. Ecosystem Services

Ecosystems provide many products and services that are crucial to human survival. The benefits that humans derive from ecosystems and include services like: provisioning (e.g., food, timber, firewood), regulatory (e.g., climate regulation, water purification, pollination, pest control), supporting (e.g., soil retention and formation) and cultural (e.g., the use of natural areas for recreation). Ecosystems affect biogeochemical and physical feedbacks to the biosphere and atmosphere hence are important for the functioning of the Earth's systems. Ecosystems form a landscape and are connected in many ways, often by streams, rivers, and wildlife. Thus, landscape fragmentation, along with other human activities, affects ecosystems' ability to meet human needs and will continue to do so for the future, possibly at a faster rate. Changes in global climate and atmospheric composition are likely to have an impact on most of these goods and services, with significant impacts on socioeconomic systems.

Ecosystems are subject to many pressures (e.g., land-use change, resource demands, population changes); their extent and pattern of distribution is changing, and landscapes are becoming more fragmented. Climate change constitutes an additional pressure that could change or endanger ecosystems and the many goods and services they provide. The sustainable supply of Ecosystem services is used as an indicator of human well being. Millennium Assessment Report (2003) indicated that the sustainable supply of ecosystem services is vulnerable to the human induced global environmental changes.

4. Paradigms Describing Ecosystem Responses to Climate Change

There are two paradigms about the way ecosystems will respond to global change. The ecosystem movement paradigm assumes that ecosystems will migrate relatively intact to new locations that are closer analogs to their current climate and environment. This paradigm clearly is a gross simplification of what will actually happen, but it has the advantage that the well-demonstrated relationship between ecosystem range and existing climate can be used to project new ecosystem distributions under changed climate scenarios. Basic ecological knowledge suggests that the ecosystem movement paradigm is most unlikely to occur in reality because of different climatic tolerance of species involved, including intra-species genetic variability .different longevities, including clonal regeneration, different migration abilities and the effects of invading species. It is an idealized working paradigm that is useful for screening scenarios of climate change for potential significant effects.

The alternative paradigm, ecosystem modification, assumes that as climate and other environmental factors change there will be *in situ* changes in species composition and dominance. These changes will occur as some species decline in abundance or become locally extinct and others increase in abundance. The longevity of individuals, the age structure of existing populations, and the arrival of invading species will moderate these changes. The outcome will be ecosystem types that may be quite different from those we see today. Paleoecological data indicate that ecosystem types broadly similar to those seen today did exist in the past, but that there also occurred combinations of dominant species that are not observed today.

5. Impacts of Climate Change on Ecosystem Services

Climate change will likely put at risk many of nature's benefits, or ecosystem services, that humans derive from our lands and waters. Climate-mediated loss or disruption of ecosystem functions are very likely to have repercussions for society's dependence on ecosystems for wild-caught and farmed food, recreation, nutrient cycling, waste processing, protection from natural hazards, climate regulation, and other services. One of the many advantages of nature-based services is that not only can they provide jobs and economic opportunities, but they are not subject to "economic bubbles" – in other words they can be reliably counted on as long as ecosystems are well-managed. In addition, ecosystem structures and functions typically provide multiple services; for example, the same habitats that can buffer devastating impacts of floods or storms also provide other benefits, including critical habitat for commercial and recreationally valued species, filtration of sediment and pollutants, and carbon storage and sequestration.

The social values of ecosystem services are broad and include those reflected in markets, avoided damage costs, maintenance of human health and livelihoods, and cultural and aesthetic values. Understanding how human activities and a changing climate are likely to interact to affect the delivery of these ecosystem services is of the utmost importance as we make decisions now that affect the health of terrestrial, coastal, and marine systems and their ability to sustain future generations. Because there is no national assessment of ecosystem services for most of the countries, it is, therefore,

impossible to report on the overall status of all of the nation's natural assets. However, specific studies and analyses have reported the impacts of recent climate changes on ecosystem services and their values.

6. Food Security

Most of the crops are likely to benefit from increase in CO_2 but increase in temperature and water scarcity may affect agriculture production thus challenging the food and nutritional security. The environmental changes projected due to climate change are likely to increase the pressures on Indian agriculture, in addition to the on-going stresses of yield stagnation, land-use, competition for land, water and other resources, and globalization. Recent report of the IPCC and a few other global studies indicate a probability of 10−40% loss in crop production in India with increases in temperature by 2080−2100 (Parry et al., 2004; IPCC, 2007). These studies assume that current management is continued to be followed and no or very low adaptation measures are taken up by the stake holders.

The year 2002 was a suitable example to show how Indian food grain production depends on rainfall of July and it was declared as all- India drought, as the rainfall deficiency was 19% against the long period average of the country and about 30% area was affected due to drought. The *kharif* food grains production was adversely affected by a steep fall of 19.1% due to all India drought during monsoon 2002. Similar was the case during all –India drought in 1979 and 1987 as well as during *kharif* season 2009 in Himachal Pradesh. It reveals that the occurrence of droughts and floods during the Southwest monsoon across the country affects foodgrains production to a greater extent.

Agricultural productivity is the ultimate determinant for the carrying capacity of the Earth. With present food grain production of about 1800 million tonnes, world is still short of required food supply by about 90 million tonnes every year. Despite technologically advances like improved varieties, fertilizers, irrigation methods, biotechnology, etc; weather is still the key determining factor for agricultural productivity.

6.1. Impacts, adaptation and vulnerability

Rise in temperature increases transpiration and in drier regions leads to water stress causing yield reduction. In India only about 40% area is irrigated and remaining 60% is rainfed. Even if we realize full irrigation potential in the country, nearly 50% area will still remain rainfed. Under such circumstances increase in temperatures and changes in rainfall patterns are likely to reduce agricultural productivity in rainfed areas. A recent study at Indian Agricultural Research institute has indicated a possibility of loss of 4−5 mt in wheat production with every1 ^{o}C rise in temperature.

The climate change will probably lead to a decrease in crop productivity, but with important regional differences (McCarty et al., 2001). In tropical and sub-tropical regions like in India where the crops are already near the limit of their temperature tolerance, even a slight increase in temperature will result in drastic fall in crop productivity. However, crop productivity is expected to rise slightly in mid to high latitudes for mean temperature increases of upto 3^{o}C. Coupled with enhanced CO_2 concentration, food productivity in these areas is expected to increase with rise in temperature upto 3^{o}C and fall with further rise in temperature.

Prospects for adaptation of plant material to increased air temperature through traditional breeding and genetic modification appear promising. More research on possible adaptation of crop species to elevated CO_2 is needed before more certain results can be presented. Degradation of soil and water resources is one of the major future challenges for global agriculture. These processes are likely to be intensified by adverse changes in temperature and precipitation. Land use and management have been shown to have a greater impact on soil conditions than the direct effects of climate change; thus, adaptation has the potential to significantly mitigate these impacts. A critical research need is to assess whether resource degradation will significantly increase the risks faced by vulnerable agricultural and rural populations.

7. Wildlife

Recent estimates indicate that 25% of the world's mammals and 12% of birds are at significant risk of global extinction. Climate change is only one of a long list of pressures on wildlife. Other pressures include exploitation of animals, pollution and other biochemical poisonings, extreme climatic events, wildlife diseases, collisions with towers and other structures, anthropogenic barriers to dispersal, and war and other civil conflicts.

7.1. Impacts, adaptations and vulnerabilities

Many animals already may be responding to local climatic changes. The types of changes already observed include pole ward and elevational movement of ranges, changes in animal abundance, changes in body size, and shifts in the timing of events, such as earlier breeding in spring. Possible climatically associated shifts in animal ranges and densities have been noted on many continents and within each major taxonomic group of animals. Laboratory and field studies have demonstrated that climate plays a strong role in limiting species ranges. Even though only a small fraction of all species have been monitored long enough to detect significant trends, changes exhibited over the past few decades in the bulk of these species are consistent with local warming and expected physiological responses.

Concern over species becoming rare or extinct is warranted because of the goods and services provided by ecosystems and the species themselves. Most of the goods and services provided by wildlife (e.g., pollination, natural pest control) are derived from their roles within systems. Other valuable services are provided by species contributing to ecosystem

stability or to ecosystem health and productivity. The recreational value (e.g., sport hunting, wildlife viewing) of species is large in market and nonmarket terms. Species loss also could impact the cultural and religious practices of indigenous peoples around the world. Losses of species can lead to changes in the structure and function of affected ecosystems and loss of revenue and aesthetics. Understanding the role each species plays in ecosystem services is necessary to understand the risks and possible surprises associated with species loss. Without this information, the probability of surprises associated with species loss is high.

Humans may need to adapt not only in terms of wildlife conservation but also to replace lost ecological services normally provided by wildlife. It may be necessary to develop adaptations to losses to natural pest control, pollination, and seed dispersal. Although replacing providers of these services sometimes may be possible, the alternatives may be costly. Finding replacements for other services, such as contributions to nutrient cycling and ecosystem stability or biodiversity, are much harder to imagine. In many cases, such as the values of wildlife associated with subsistence hunting and cultural and religious ceremonies, any attempt at replacement may represent a net loss. In many countries, climate change impacts, such as reductions in wildlife populations, may have the greatest impact on the lowest income groups, those with the least ability to adapt if hunting opportunities decline.

8. Rangelands

Most rangelands in the world have been affected by human activity, and many are degraded in some way. Desertification tends to be associated with land degradation in rangelands, however, desertification combines many land degradation processes and can be exacerbated by climate change. Many of the rangelands of the world are affected by ENSO events and are sensitive to the frequency of these events, resulting in changes in productivity of these systems.

8.1. Impacts, adaptations and vulnerabilities

Based on observations and modeling studies, the effects of elevated CO_2 and climate change could result in increased plant productivity and thus an increase in soil carbon sequestration in many rangelands. However, some of the gains in productivity would be offset by increases in temperatures and by human management activities. Modeling studies and observations suggest that plant production, species distribution, disturbance regimes (e.g., frequencies of fires, insect/pest outbreaks), grassland boundaries and nonintensive animal production would be affected by potential changes in climate and land use. In many parts of the world that are dominated by rangelands, lack of infrastructure and investment in resource management limits available options for adaptation and makes these areas more sensitive and vulnerable to the impacts of climate change. Some adaptation options (e.g., integrated land management) could be implemented irrespective of technology and infrastructure. Other adaptation options could be implemented through active involvement of communities in the management of rangelands.

9. Forests and Woodlands

Loss in forest cover appears to have slowed in recent years relative to 1980–1995. However, fragmentation, nonsustainable logging of mature forests, degradation, and development of infrastructure, all leading to losses of biomass has occurred over significant areas in developing and developed countries. Pressure from disturbances such as fires appears to be increasing around the world. Fire suppression in temperate managed and unmanaged forests with access to infrastructure and human capital has been largely successful, but regions with comparatively less infrastructure have been more susceptible to natural and human-caused fires. Deforestation will continue to be the dominant factor influencing land-use change in tropical regions. Non-wood forest products (NWFP) such as edible mushrooms, nuts, fruits, herbs, spices, gums, aromatic plants, fodder, medicinal and cosmetic products, resins etc. make important contributions to household income, food security, national economies, and the environmental objectives of conservation of biodiversity.

9.1. Impacts, adaptations and vulnerabilities

Forest response to climate change and other pressures will alter future carbon storage in forests, but the global extent and direction of change is unknown. The largest and earliest impacts induced by climate change are likely to occur in boreal forests, where changes in weather-related disturbance regimes and nutrient cycling are primary controls on productivity. The effect of these changes on NPP and carbon storage is uncertain. Questions of saturation of the CO_2 response can be addressed through longer term experiments on tree species grown under elevated CO_2 in open-top chambers under field conditions over several growing seasons. Results from these experiments show continued and consistent stimulation of photosynthesis and little evidence of long-term loss of sensitivity to CO_2; the relative effect on aboveground dry mass was highly variable and greater than indicated by seedling studies.

At the regional and global scale, the extent and nature of adaptation will depend primarily on wood and non-wood product prices, the relative value of substitutes, the cost of management, and technology. On specific sites, changes in forest growth and productivity will constrain and could limit choices of adaptation strategies. In markets, prices will mediate adaptation through land and product management. Adaptation in managed forests will include salvaging dead and dying timber and replanting with new species that are better suited to the new climate. Paying farmers to increase soil carbon may compensate for the negative impacts of climate change on carbon sequestration.

10. Inland Wetlands

Wetlands play an important role in maintaining biological diversity by providing a habitat for many plant and animal species, some of which are endemic or endangered. They also have significant scientific value that goes beyond their plant and animal communities. Peat-accumulating wetlands are important for global change because of the large carbon store accumulated over the millennia and the risk that this store would be released to the atmosphere in conditions modified by global change. Besides being carbon sinks, wetlands are sources of methane to the atmosphere.

10.1. Impacts, adaptations and vulnerabilities

Peat lands underlain by permafrost are likely to become net carbon sources rather than sinks, mainly because of melting of permafrost and lowering of the water table. Most wetland processes are dependent on catchment-level hydrology. Thus, adaptations to projected climate change may be practically impossible. For degrading key habitats, small-scale restoration may be possible if sufficient water is available. The bog communities on permafrost with small catchment areas are likely to be most vulnerable to climate change. The increasing speed of peat land conversion and drainage in Southeast Asia is likely to place these areas at a greatly increased risk of fires and affect the viability of tropical wetlands.

11. Recreation

Recreation is considered an ecosystem service not only because it has economic value, but also because it contributes to cultural well-being. The potential for longer stretches of more pleasant weather for enjoying the outdoors may actually increase some recreation opportunities, or simply shift others to new areas. For these activities, it is unclear what the net effect in human well-being will be; for instance, one study found that visitors to Rocky Mountain National Park would increase with higher temperatures, while other parks are projected to lose visitors if catastrophic fires result from drier conditions.“Winter sun” and “summer cool” destinations for tourists may change. Whereas, diving will experience losses due to declines in coral reef habitat. Beach recreation losses will result from loss of beach width due to the combined effects of sea level rise and erosion. Narrower beaches make it harder to access fishing sites for anglers, and are less attractive to sunbathers.

Lakes and rivers which are also very important sites for recreation and fisheries are reported to be impacted by climatic changes as well as other pressures such as land and water use, pollution, capture and culture fisheries, water extraction, and hydrologic engineering structures such as dams, dykes, and channelization. These pressures interact with pressures from climate change and vary in their impact even at local levels mediated through changes in hydrology.

11.1. Impacts, adaptations and vulnerabilities

There is a loss of habitat for cold and cool water fishes and gain in habitat for warm water fishes. Human activities to manage water flow may exacerbate the impact on lakes and rivers, for example, the increase in hydrologic engineering structures is likely to result in fewer free-flowing streams. Attempts to manage the pole ward movement of fauna and flora, especially in lakes whose isolation are likely to slow down species from moving pole ward, are likely to be contentious and produce frequent surprises and unexpected dynamics of freshwater communities. New opportunities need to be provided for aquaculture of warmer water species in more pole ward locations. As a class of ecosystems, inland waters are vulnerable to climatic change and other pressures, owing to their small size and position downstream from many human activities. The most vulnerable elements include reduction and loss of lake and river ice, loss of habitat for coldwater fish, increases in extinctions and invasions of exotics, and potential exacerbation of existing pollution problems such as eutrophication, toxics, acid rain, and ultraviolet-B (UV-B) radiation. The traditional ecological knowledge that has guided weather prediction and risk assessment for centuries need to be documented and utilized for achieving resilience.

12. Critical Gaps in Knowledge, Research and Data Needs for Climate Impacts on Ecosystem Services

Ecosystem services do not vary independently of one another, and as a result, one general strategy for responding to harmful reductions in one ecosystem service is to boost another ecosystem service, or to reduce interacting stressors. Better management of supporting services in general may provide substantial adaptive capacity for the negative impacts of climate change on other services. Policies and incentives aimed at getting people to behave differently, or change the location and type of livelihoods they engage in, are urgently required. Therefore, to understand the gaps in our scientific understanding of how ecosystem services will respond to climate change, the following points need to be studied:

- The likely effects of climate change on rates of carbon storage and sequestration in soils and vegetation.
- Impacts of climate change on water quality regulation in freshwater streams and rivers.
- Fishery management in line with changes in climate to maintains harvest and jobs without putting the resource base at risk
- Impacts of promotion of green energy as a response to climate change on ecosystem services. For example, how do windmills, solar panel arrays, and land area and water used to create biofuel feedstocks affect service delivery and their values.
- Evaluation of implementation of specific incentives, regulations, management strategies, or investments for

communities who are performing fishing, farming, timber, agricultural and aquaculture to adapt to changing and more variable climate conditions.

• Relative cost-effectiveness of engineered versus ecosystem-based approaches to reducing vulnerability of communities to coastal hazards

• Development and popularization of proper weather forecasts, accurate projections on climate change and their impacts at local and regional scales for promoting resilience

13. Conclusion

Climate of the planet earth is always in a state of change as a natural process influenced by both natural variability and induced environmental changes due to anthropogenic reasons. Climate change will likely put at risk many of nature's benefits, or ecosystem services, that humans derive from our lands and waters. Climate-mediated loss or disruption of ecosystem functions are very likely to have repercussions for society's dependence on ecosystems. Better management of supporting services in general may provide substantial adaptive capacity for the negative impacts of climate change on other services.

14. References

IPCC, 2007. Climate change 2007. Climate change impacts, adaptation and vulnerability. Summary for Policy Makers. Intergovernmental Panel on Climate Change.

McCarty, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S., 2001. Climate change 2001. Impacts, adaptation and vulnerability. Contribution of Working Group II to the third Assessment Report of The IPCC. Cambridge University Press, Cambridge, UK.

Parry, M.L., Rosenzweig, C., Iglesias Livermore A.M., Fischer, G., 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Environmental Change 14, 53–67.