Sustainable Management of Biodiversity in the Context of Climate Change-Issues, Challenges and Response

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Abstract Climate change is a significant global issue of concern especially in context of its impact on environment. It affects the different ecosystems with significant impact on water resources, agriculture, forestry, health, industrial sectors and biodiversity as well. For sustainable management of biodiversity in the context of changing scenario of climate change, a coordinated strategy across the various levels of geographic/governance hierarchy as well as across strategic elements such as capacity building, knowledge dissemination, institutions partnerships, policy/instruments and technology, needs to be pursued. The paper covers the trends and impact of climate change especially on sustainable management of biodiversity in Asia and India.

Keywords Climate change · Biodiversity · Sustainable management · Ecosystems

Introduction

Climate change has emerged as a most-significant global environmental issue. It has attracted the attention of scientists, policy planners, governments and politicians worldwide. It is a threat, challenge and opportunity. The projected climatic changes are likely to affect adversely the key economic sectors and therefore, sustainable development. The impact of climate change in developing countries would be

more severe. The various scientific assessment and special reports brought out by the Intergovernmental Panel on Climate Change [1, 2] reveal that there is discernible human impact on climate system. There are evidences to show that there have been changes in climate over the last century especially more during the current decade, which manifest in the physical and biological systems in different continents and regions. Climate change also shows impact on the biodiversity—the very basis of existence of mankind.

Biodiversity is determined by the interaction of many factors that differ spatially and temporally, for example, by the mean climate and climate variability, by the availability of resources and overall productivity of a site, the disturbance regime and occurrence of perturbations of cosmic (e.g., meteorites), tectonic, climatic, biological or anthropogenic origin; the original stock of biodiversity and dispersal opportunities or barriers; spatial heterogeneity of habitats; the intensity and interdependency of biotic interactions such as competition, predation, mutualism, symbiosis, the intensity, kind of sexual reproduction and genetic recombination. Biodiversity at all levels is not static, as the dynamics of natural evolutionary and ecological processes induces a background rate of change.

Climatologically, India occupies an important position in south-east Asian region. Changes in the present climate system may affect the different ecosystems with corresponding impacts on key sectors, such as, water resources, agriculture, natural ecosystems, forestry, health and industrial sectors.

Keeping these concerns in view, it is imperative to briefly touch upon the context within which it is the need to address challenges posed due to climate change on biodiversity and related sectors. It is stated that global environmental issues emerged as a prominent agenda in the early 90s due to the Earth Summit in 1992 and gained more

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prominence during the World Summit on Sustainable Development (WSSD) in 2002. Environmental issues have evolved from the paradigm of conservation and protection of natural biological resources during 1980s to focus on achieving sustainable development by preventing overexploitation of resources in the 1990s. It is important to note that biodiversity has and will be critical for the development, and its overexploitation would lead to a significant threat even to human existence. Apart from numerous other threats to biodiversity like rapid growth of human population, converting forest into agriculture lands, introduction of alien species and urbanization; climate change is an additional stress on biodiversity. The climate change also affects natural and socio-economic systems, and ultimately the economic growth and development. It significantly affects biodiversity, which sustains life and provides various economic benefits and indirect essential services through natural ecosystems.

The prediction and assessment of impacts of climate change is still an emerging field and is a complex area of research. Scientists in India are working in diverse areas through enhanced knowledge and understanding of climate change impacts. However, intensive research work is needed to understand the possible magnitude and potential consequences of projected climate change and its impact in the country. This paper will discuss climate change trends, projections and its impacts on biodiversity on a global scale particularly in Asia and India. Specifically, in case of India; the authors would look at the key findings of two assessments: “4×4” assessment undertaken under the aegis of INCCA and assessments made under India’s Second National Communication. The paper ends with discussing the appropriate response to the challenges posed by climate change with respect to sustainable management of biodiversity and proposes a multi-dimensional framework as an appropriate tool for future action regarding mitigating the projected impacts of climate change on biodiversity [3].

Climate Change: Trends and Impacts

According to the latest 4th Assessment report of the IPCC [4, 5], warming of the climate system is unequivocal, as is now evident from observations of increase in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level. In last 100 years, between 1906 and 2005, the average global temperature has risen by of 0.74 °C. Rising sea level is consistent with warming. The average Northern Hemisphere temperature during the second half of the 20th century is higher than any other 50 years period in the last 500 years and possibly the highest in past 1,300 years. For over 420,000 years the CO₂ concentration (over geological

Fig. 1 CO₂ concentration in the atmosphere

time scale) in the atmosphere has remained in the range of 180–280 ppmv but recent assessments have projected this concentration to reach the level of more than 650 ppmv by the end of the century (Fig. 1). The changing concentration has been the result of continuous increase in the concentration of greenhouse gases (CO₂, CH₄ and N₂O, in particular) over a long period of time (Fig. 2). The present society faces potential rapid changes in the nature of increasing concentration of greenhouse gases in the atmosphere, due to human activities. As manifested in the IPCC reports [4, 5], this change may significantly alter the atmospheric composition and change the earth’s radiation balance resulting in changes in earth’s surface temperature (Fig. 3) and precipitation (Fig. 4).

Projections of Climate Change and Impacts

The greenhouse gas (GHG) emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century, which would be more significant than those observed during the 20th century (Fig. 5).

For the next two decades a warming of about 0.2 °C per decade is projected [6]. Even if the concentrations of all GHGs and aerosols are kept constant at year 2000 level, a further warming of about 0.1 °C per decade would be expected. Beyond this period, temperature projections increasingly depend on specific emission scenario. A specific case of the IPCC SRES A1B scenario is shown in Fig. 6 which shows that significant warming is expected in different parts of the world in a scenario which has significant penetration of renewable energy technologies. Such changes would be manifested in terms of impacts on various sectors, including biodiversity in a significant way (Fig. 7). It must be reiterated that changes in biodiversity

Fig. 2 Concentration of green house gases over the years

are not only due to direct impact of climate change but also indirectly through the impacts of climate change on related sectors. Biodiversity is the result of interplay of climatic conditions, hence climate change and its impact on resources for biodiversity to survive are significant (such as land and water) (Fig. 8). IPCC assessments [7] have projected that resilience of many ecosystems is likely to be exceeded in the present century by an unprecedented combination of climate change, associated disturbances as flooding and drought and other global change drivers as land-use change and pollution. It is also projected that over the course of the present century, net carbon uptake by terrestrial ecosystems is likely to increase before mid-century and then followed by its weakening or reversal. It is simultaneously projected that nearly 20–30 % of plant and animal species assessed so far are likely to be at increased risk of extinction, if increase in global average surface temperature exceeds 1.5–2.5 °C.

Climate Change and Projected Impacts on Biodiversity in Asia

The Asian region can be divided in four sub-regions: boreal, arid and semi-arid, temperate and tropical. The main characteristic of the temperate forests in Asia is having a high degree of endemism and biological diversity. The tropical Asian region also boasts of very rich biodiversity. Forests in Asia are the home of over 50 % of the world's terrestrial plant and animal species. Some specific examples of the richness of biodiversity in Asia are the rainforests of southeast Asia alone which contain about 10 % of the world's floral diversity; tropical moist forests and woodlands are important resources that provide maximum wood as fuel in some countries. One-tenth of the world's known high-altitude plants and animal species occur in the Himalayas; some of the high and mid-altitude areas are also centers of origin for many crop and fruit-tree

Fig. 3 Variations in earth's surface temperature

Fig. 4 Variations in precipitation

species. Freshwater aquatic ecosystems in Asia have high floral and faunal diversity.

The projected impacts of climate change on biodiversity and vulnerable ecosystems in Asia highlight varied nature. Some of the impacts are: the species in high-elevation

ecosystems tend to shift higher; weedy/invasive species with a wide ecological tolerance will have an advantage over others; in temperate Asia, species are likely to shift pole wards and boreal forest species are projected to show large shifts; frequency and intensity of forest fires and pest

Fig. 5 a–c Green house gas emissions and variation in temperature and sea level

Fig. 6 Showing significant warming in different parts of the world

Fig. 7 Global average annual temperature (°C) change relative to 1980–1999

Fig. 8 Impact of climate change on resources and biodiversity

outbreaks in the boreal forests are likely to increase; forest ecosystems in boreal Asia are expected to be affected by floods and increased volume of run-off as well as melting of permafrost; sea-level rise could cause recession/loss of flat coastal habitats; mangroves (e.g., those in the Sundarbans) and coral reefs are particularly vulnerable. With a 1 m rise in sea level, the Sundarban might disappear, leading to colossal damage to wildlife and local human populations with the decrease in productivity (of 40–90 %), climate change is likely to represent an additional stress on rangelands and affect livelihood of a large population.

Indirect impacts on biodiversity due to climate change may be the melting of glaciers in the Himalayas to increase flooding and rock avalanches from destabilized slopes. It may affect water resources within the next two to three decades. This will be followed by decreased river flow as the glaciers recede. Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins [8], is expected to decrease. Coastal areas will be at great risk due to increased flooding of sea and flooding from rivers in some mega deltas. All these manifestations will have a profound impact on sustaining local biodiversity.

Thus, climate change is projected to impinge on the sustainable development of most developing countries of Asia, as it compounds the pressure on natural resources and the environment, associated with rapid urbanization, industrialization, and economic development.

Climate Change and Biodiversity: Setting, Assessment and Projected Impacts for India

Biodiversity in India

India is a vast country (3.28 million sq km), with diverse physiographical features. At one extreme India has the Himalayan mountains while on the other hand it boasts of a

long coastline, regions of plains, plateau and islands. Although India occupies nearly 2.4 % of the world's land area but supports a massive 16.2 % of the world's population. The most significant feature of the Indian climate is the “Monsoon”—the rainy season [9]. This season is most important since it provides a significant portion of India's freshwater demand, principally to sustain agriculture. India is also endowed with varied soils, biodiversity and ecological regions. The varied eco-climatic conditions coupled with unique geological and cultural features have contributed to an astounding diversity of habitats. India represents two “Realms”—the Himalayan region and the rest of the sub-continent; five Biomes, ten bio-geographic zones and 27 bio-geographic provinces. Of the 34 globally identified biodiversity hotspots, India harbors four hotspots, i.e., Himalaya, Indo-Burma, Western Ghats, Sri Lanka and Sundaland.

Biodiversity and Climate Change: Assessments in the Indian Context

Climate change can be expected to have major impact on key resources and structure and function of many of the ecosystems. Climate change is an additional stress on ecosystems and constituent species. The changes are considered to be rapid not allowing sufficient time for the species to respond or adapt to such changes. The ecosystems such of coral reefs, arctic, alpine and tropical regions are particularly vulnerable to the climatic changes as they are considered irreversible.

Some of the recent assessments under the aegis of INCCA and India's Second National Communication to the UNFCCC bring out distinct concerns regarding projected impacts of climate change on biodiversity. Although assessment of impacts of climate change on biodiversity in India is rather fragmentary and inadequate [10, 11], much of the implications on Indian biodiversity are being assessed on the basis of application of knowledge from other regions and countries.

Water Resources

In the recent assessment for the A1B scenario, it was found that majority of the river systems show increase in precipitation at the basin level. A majority of the northern river systems show increase in evapotranspiration (ET) under 2021–2050 scenario whereas majority of the southern river systems show marginal reduction in ET despite the increase in precipitation. The study also indicates that a majority of the river basins show an increase in flooding between 10 and over 50 % of the existing magnitudes [12].

Agriculture

In the recent assessment by the Ministry of Environment and Forests (MoEF) [13] for four climatically sensitive regions; it was found that productivity of irrigated rice fields is likely to reduce by 4 % in most of the areas of the region. Similarly, it was also found that climate change is likely to reduce yields of maize and sorghum by 50 %.

Forests

In the assessment under A1B scenario, it was found that at national level, about 45 % of the forested grid is projected to undergo change [11, 14]. Even in a relatively short span of 50 years, most forest biomes in India appear highly vulnerable to the changing climate. About 70 % of the vegetation is likely to find itself less optimally adapted to its existing location, making it more vulnerable to adverse climatic conditions as well as biotic stresses.

Sustainable Management of Biodiversity in the Light of the Challenges Due to Climate Change: Response and the Road Ahead

The formation of Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change—A COP initiative was a significant initial step. Its mandate proposes ways and means to improve the integration of biodiversity considerations and traditional and local knowledge related to biodiversity, with particular reference to communities and sectors vulnerable to climate change; to identify opportunities for, and possible negative impacts on, biodiversity and its conservation and sustainable use, as well as livelihood of indigenous and local communities; and to identify options to ensure that possible actions for reducing impacts from deforestation and forest degradation do not run counter to the objectives of the CBD but rather support the conservation and sustainable use of biodiversity.

Within India, significant initiatives have been taken at all levels to protect biodiversity from the adverse impacts of climate change. India has evolved a sustained strategy for conservation and sustainable utilization of biodiversity based on initiatives framed and formulated largely by MoEF and appropriately supported by other Ministries/Departments. Major building blocks of policy frameworks, legislations and action plans include Biological Diversity Act (BDA) [15], National Wildlife Action Plan (NWAP) [16], National Environment Policy (NEP) [17], National Biodiversity Action Plan (NBAP) [18] and National Action Plan on Climate Change (NAPCC) [19]. The country also ensures integration of biodiversity concerns and social development through various instruments and mechanisms, which include, greater participation of community groups

in Forest Development Agencies (FDAs), technology dissemination through a network of Krishi Vigyan Kendras, Agricultural Technology Management Agencies and implementation of National Rural Employment Guarantee Scheme (NREGS). Various scientific assessments have been initiated on vulnerability due to climate change on various production systems, socio-economic sectors and natural ecosystems in India. Many research activities have already been initiated in this direction. It is proposed to widen the scientific assessments during the 12th five year plan period by launching new and renewed scientific programmes within the broader issue of climate change and towards understanding its impact on myriad sectors with more certainty. Some such proposed programmes are:

- GHG Inventory Management System (GHG-IMS)
- Black Carbon Research Initiative (National Carbonaceous Aerosols Programme) BCRI-NCAP
- Long-term Ecological Research Observatory (LTERO) for climate change
- Co-ordinated studies (CS) in the North-Eastern Region on Climate Change (NECC) (CS-NECC)
- Climate Change Assessment Studies (CCAS)
- Total proposed outlays for the 12th FYP—INR 370 crores

On 30 June 2008, India announced and launched its National Action Plan on Climate Change [19]. The NAPCC, guided by the principles of sustainable development, aligns the environmental and economic objectives. Broadly, the NAPCC is based on the following principles: protecting the poor and vulnerable sections of society through sustainable development strategies that are sensitive to climate change; achieving national growth targets through means that enhance ecological sustainability; devising an efficient and cost-effective strategy for demand-side management; deploying appropriate mitigation and adaptation technologies extensively and at an accelerated pace; promoting sustainable development through innovative and new forms of market, regulatory and voluntary mechanisms; effecting implementation through unique linkages with civil society, local governments, and public–private partnerships (PPPs) and finally, welcoming international cooperation for research and development sharing, and transfer of technologies driven by external funding and facilitating global intellectual property rights (IPR) regime for such a technology transfer under the UNFCCC. The NAPCC has eight missions:

- National Solar Mission
- National Mission on Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for sustaining the Himalayan ecosystem

- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for climate change

In the context of managing biodiversity related issues within the changing climate, the following missions are specifically targeted to ensure that adequate policy response is generated to the projected adverse impacts due to climate change.

National Water Mission

The main objective of the mission is “conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through integrated water resource development and management”. The main identified goals of the mission are: development of a water database in the public domain, particularly regarding the assessment of the impact of climate change on water resources; promoting water conservation, augmentation and preservation; focusing attention on over-exploited areas from water use perspective, increasing water use efficiency by 20 % and promoting basin level integrated water resource management.

National Mission on Green India

The mission aims at addressing climate change by enhancing carbon sinks in sustainably managed forests and ecosystems, enhancing the resilience and ability of vulnerable species/ecosystems to adapt to the changing climate and enabling adaptation of forest dependent local communities in the face of climatic variability. There are three main objectives of the mission: doubling the area under afforestation/eco-restoration in the next 10 years (total area to be afforested/eco-restored be 20 million ha), increasing the GHG removal by the forests to 6.35 % of India’s annual total GHG emissions by the year 2020, and enhancing the resilience of forests/ecosystems under the mission.

National Mission on Sustaining Himalayan Ecosystem

This mission identifies the importance of continuity and enhancement in the monitoring of the Himalayan ecosystem, in particular, the state of glaciers and the impact of changes in the glacial mass and its subsequent impact on river flows. It envisages an appropriate form of scientific collaboration and exchange of information among South Asian regions so as to enhance the understanding of ecosystem changes and their effects. It is also identified, under the mission, to empower local communities through Panchayati Raj Institutions (PRIs), so as to assume greater

Table 1 Framework for sustainable management of biodiversity in the light of the challenges due to climate change

Geographic hierarchy strategies	Local	National	Regional/global
Capacity building	Monitoring, observation awareness/assessment at state/district/community levels	Scientific assessment, measurement, models, national research agenda	Participation in global/regional modeling and assessments
Knowledge/information	Locale specific databases, scenarios and assessment, local monitoring networks	Research networks, national databases (e.g., NATCOM), scientific and policy models, national scenarios, technology inventory	Interface with IPCC assessments, interfacing with regional/global and databases, scenarios and assessments, technology inventory database
Institutions/partnerships	Community initiatives, early warning networks	Stakeholders networks, public/private programs	FCCC processes, trans-boundary impacts assessment
Policy/instruments	Local specific adaptation plans, community based adaptation programs	Science-policy linkage, economic instruments (e.g., insurance, R&D funds), integration with national development/planning process	Adaptation funds, trans-boundary regulations
Technology	Locale specific technology adaptation	Targeted R&D, technology transfer protocols, demonstration/pilot projects	Scientific exchange, technology transfer

responsibility for the management of natural resources. These measures are over and above the specific measures/strategies identified in the National Environmental Policy [17].

Adaptation to Climate Change: The Road Ahead

Given the inter-linkages that exist between climate change and biodiversity, there is a need to identify and conserve biodiversity components that are especially sensitive to climate change as to preserve intact habitats so as to facilitate the long-term adaptation of biodiversity, improve the understanding of the climate change—biodiversity linkages, and fully integrate biodiversity considerations into climate change mitigation and adaptation plans. Therefore India needs to promote sustainable management, conservation and enhancement of sinks and reservoirs, take climate change consideration into account to minimizing adverse effects on the economy, public health and on the quality of environment and promote and cooperate scientific research, education training, public awareness and exchange scientific information.

Conclusions

The broad framework within which biodiversity concerns the changing climate is given in Table 1. It must be noted that a coordinated strategy across the various levels of geographic/governance hierarchy as well as across strategic elements such as capacity building, knowledge/dissemination, institutions/partnerships, policy/instruments and technology needs to be pursued.

It is reiterated that climate change is emerging to be a significant additional threat to biodiversity. The projections (international and national) indicate adverse impacts on biodiversity and the related sectors due to climate change. Within this context, it is stated that adaptation is the key to sustainable management of biodiversity. However, the extant base and basis of knowledge needs to be enlarged and subsequently enhanced.

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