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EDITORIAL NOTE

The charms and challenges of climate change and biodiversity in a warming world

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Introduction

This Special Issue of *Biodiversity and Conservation* presents a series of 11 papers that document studies on the Indian subcontinent through experiments, measurements, and modelling, with or without geoinformatics technology, to enhance our understanding of the effects of climate change that may have on biodiversity of the region. The papers included here have been selected from those presented at the International Workshop on biodiversity and climate change held in the Indian Institute of Technology (IIT), Kharagpur, India, on 19–22 December 2010.

Overview

Biodiversity, the term given to the variety of life on the earth from the genomic to the landscape level, provides, through its expression as ecosystems, goods and services, the environment that sustains all our lives. There are ample charms and challenges in the investigation of the effects of climate change on biodiversity in a warming world. Climate change induced alterations in biodiversity, and the reciprocal effects of those alterations on climate change itself, are too large to be ignored. Extinctions have begun, and many more are projected. Species are moving to track their preferred climates, the timing of biological and extreme events cued to climate is shifting. New plant and animal associations are emerging, while formerly well-established ones are disappearing. Everything, from the colour of the plants across vast areas to the cycling of moisture between plants and the atmosphere, helps determine climate. The cycle is completed as the interactions of climate with biodiversity determine where particular organisms, or groups of organisms, can live, in turn influencing where, how far, and how fast, they are able to adapt to a new situation.

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The amount of the Sun‘s energy reflected (albedo) or absorbed changes when the vegetation changes. The replacement of lichen-dominated tundra by coniferous forest attributed to climate warming is darkening boreal latitudes, increasing heat absorption and causing further warming. Natural carbon dioxide (CO_2) fluxes are large relative to emissions from the burning of fossil fuels, but the human generated emissions are nevertheless sufficient to increase atmospheric concentrations to the extent of reaching critical tipping points with respect to their effects on the biota. How much and how fast CO_2 fluxes will change depends on what is happening in other parts of the worldwide carbon cycle (Hannah 2011). Understanding the sinks, sources, and fluxes of the carbon cycle is another priority, indeed a prerequisite, in getting to grips with the full extent of possible interactions between climate and biodiversity (Behera 2011).

Biodiversity and climate change are interconnected, not only through climate change effects on biodiversity, but also through changes in biodiversity that can affect climate change. Observed changes in climate have already adversely affected biodiversity at the species and ecosystem level, and further deteriorations in biodiversity are inevitable with further changes in climate (Malhi et al. 2010). The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies.

Human pressures on the ecosystems are causing changes and losses at rates not seen historically. People are changing ecosystems more rapidly and more extensively than ever before in human history. Climate change adds yet another pressure on natural systems. Climate is, of course, crucial for almost every aspect of an organism's biology, ecology, physiology, and behavior. The consequences of climate change on the species components of biodiversity include changes in distribution, increased extinction rates, changes in reproduction timings, and changes in the length of growing seasons (Heywood 1995).

Species that are already categorized as threatened are particularly vulnerable to the impacts of any climate change. Projected changes in the climate, combined with land-use change and the spread of invasive alien species, are likely to limit the capability of some species to migrate, and this will lead to further acceleration in the rate of species loss (Singh and Kushwaha 2008). However, the links between biodiversity and climate change run both ways; biodiversity is threatened by climate change, but in some cases the proactive management of biodiversity may reduce the impacts of climate change. However, there will be ‘winners’ as well as ‘losers’. There are several reasons why plants and animals in particular may not be able to adapt to the current phase of global warming. In particular, the rapid pace of change means that many species will simply be unable to adapt quickly enough to the new conditions, or to move to regions more suited for their survival. Equally important, the massive changes humans have made to landscapes, river basins, and the oceans of the world, have limited the survival options previously available to a species under pressure from a changing climate. The formation and maintenance of soils suitable for agriculture, availability of medicinal plants, provision of freshwater, and income from ecotourism, for example, are all underpinned by complex food-webs involving the interaction of species ranging from microscopic bacteria, fungi and protists to the largest animals on Earth. The full extent of organismal interactions in almost all ecosystems is so poorly known that it is difficult to produce meaningful models and predict outcomes if ecological parameters change; there are so many kinds of organisms involved, many of which have unknown roles, that data on all pertinent variables cannot be obtained. For that reason, the precautionary principle has to be high on the priority list of matters to be taken into account in conserving biodiversity.

It is the microclimate, however, that plays a crucial role and in the maintenance of ecosystem structure and ecological processes. A sound knowledge of the microclimate is vital to the understanding of patterns and the processes in ecosystems, theoretical modelling and management decision making. Behera et al. (2012) studied the impact of key microclimatic variables on the forest community and vice versa. They measured understory PAR (photosynthetically active radiation), ambient CO_2, air temperature, surface soil temperature, and air absolute humidity during post-rainy and mid-winter seasons; and observed that PAR and ambient CO_2 make the greatest contribution to the microclimate in defining forest community and plant species associates.

The relationships between biodiversity, productivity and climate are complex. The biodiversity and climate change linkage is not only through the effects of climate change on biodiversity *per se*, but also through changes in biodiversity and ecological processes that can affect climate change. In the tropics, the availability of abundant sunlight, in combination with high moisture levels, promotes plant metabolism. The high diversity of plants in the tropics (and so associated organisms) is mainly a legacy of evolution and the spread of species-poor forests into higher latitudes by the establishment of ectomycorrhizal associations. Higher temperatures and moisture provide favourable conditions for the tropical ecosystems, thus maximizing photosynthetic activity and resulting in higher productivity. Chitale et al. (2012) found that net primary productivity (NPP) was highly correlated with climate and plant species density rather than actual plant diversity in an Indian tropical ecosystem. Kale and Roy (2012), however, observed a good correlation between NPP and plant diversity in another Indian tropical dry deciduous forest site. In yet another study, Kushwaha and Nandy (2012) found a significant decrease in plant species diversity from moist to dry forests differing in rainfall, disturbance, and management practices.

Remote sensing-based biosphere models have shown significant potential for estimating NPP as they incorporate the interrelationship between plant physiology and the environment. Chitale et al. (2012) used the Carnegie–Ames–Stanford Approach (CASA) model to estimate the monthly and annual NPP at decadal frequency using satellite-derived input variables. Kale and Roy (2012) used a production efficiency model to estimate NPP based on light use efficiency (LUE) and the intercepted photosynthetically active radiation (IPAR), and found a good correlation with ground-based NPP assessments. Species distribution models are static and probabilistic in nature as they statistically relate the geographical distribution of species or communities to their present environment. Matin et al. (2012) utilized the GPS-based location information on *Medicago sativa* and *Plantago annua* to simulate their potential distribution in the year 2020 (SRES A1B scenario, IPCC) using the Maxent model in part of Ladakh Himalaya. The model suggested that the distribution of both the species would tend to move in the direction of shorter cold seasons. Kumar (2012) has analysed the distribution of Rhododendron species in climate change scenario and pointed out that climate data reliability holds the key to such studies in hilly mountainous terrains.

Geoinformatics technology compliments ground-based studies on biodiversity. Matin et al. (2012) demonstrated a method to integrate the faunal component in a recently completed nationwide biodiversity study in India using the plants alone (Behera and Roy 2010). The study highlights the potential contribution of geoinformatics to biodiversity assessments (Roy et al. 2012). Porwal et al. (2012) highlighted the role of the existing baseline geospatial data for the detection of change in an extreme weather event, the tsunami that hit the Andaman and Nicobar islands on 26 December 2004. Raha et al. (2012) analysed land transformation on a few islands in the Indian Sunderbans using maps and satellite images from 1924 to 2008, again demonstrating the utility of geoinformatics for the study of climate change induced sea level rises.

Over recent decades, evidence of increases in extreme weather events such as tsunami, cyclones, hurricanes, droughts, heat waves and heavy precipitation events have accumulated. They have enormous direct and indirect human, environmental, and economic impacts. Such events are expected to become more severe and frequent with changes in climate and tectonics. Considering a given probability distribution of occurrence for any climatic parameter, changes in mean values such as increased temperature, as well as increased variance in amplitude, will inevitably lead to more frequent and more intense extreme events at one tail of the distribution (Meehl et al. 2000) Extremes at the minimum end of a given parameter will virtually disappear when climatic mean values increase, whereas historically unprecedented intensities will arise at the maximum, so that biota will face novel events and habitat conditions. However, science has not yet generated sufficient knowledge on the effects of extreme weather events on ecosystems and their functioning (Jentsch et al. 2007). In coastal areas, plants have adapted to tolerate diurnal tidal effects through physiological and morphological trait modifications, thereby developing a specialized and complex ecosystem by evolution over tens of thousands of years; those modifications can be eliminated by a tsunami in just a few seconds. Porwal et al. (2012) estimated the extent and magnitude of destruction/alteration, and linked this to distance from the epicentre, coastal topography, and vulnerability to powerful wave actions.

Climate change induced sea level rise (SLR), together with human-modified environments, led to changes in species diversity and productivity in the Sunderbans. Raha et al. (2012) were able to describe the scenario using historical records with respect to hydrological conditions, sedimentation load, and morphological processes. Their study advocates a diverse, interdisciplinary, multi-institutional approach, with strong networking, for the conservation of the Sunderban ecosystem. The increasing atmospheric CO_2 concentration is changing the carbon chemistry of surface seawater, soil, and plants; the roles of all need to be clearly understood through experiment and measurement. Only then can mitigation options, including carbon capture and storage, be prescribed and practiced.

Biswas et al. (2012) studied the responses of marine plankton from water samples from the Bay of Bengal coast to incubation under ambient conditions but with high CO_2 levels for 5 days. They observed a significant increase in the average relative abundance on tintinnids under elevated CO_2, which was explained by the multiple impacts on the energy transfer, nutrient, and carbon cycling, in the coastal water. The study shows that microzooplankton would respond positively, and so expedite tropical energy transfer. Kallarackal and Roby (2012) reviewed the research on trees using elevated CO_2, and assessed the different methods available, including FACE. Finally, Srivastava et al. (2012) highlighted the importance of soil carbon sequestration (SCS) as a mitigation option to address the increasing atmospheric CO_2 levels which trigger global warming and climate change.

Conclusions

The focus of this special issue of *Biodiversity and Conservation* is the documentation of studies aimed at understanding the relationships between biodiversity and climate change in the Indian sub-continent, based on experiments, measurements, and modelling, with or without geoinformatics technology. Geoinformatics can be useful in biodiversity database and information system creation, where it has many advantages, such as: (1) a quick appraisal of habitat attributes for identification of new sites for conservation planning; (2) all species can be tagged to their location information; (3) amenability to easy modification, retrieval, and query; and (4) receptivity to any addition or deletion of spatial and non-spatial attributes for any specific biodiversity study Geoinformatics is consequently useful in kinds of studies, for instance species distribution modelling, biodiversity monitoring, productivity, ecosystem ecology, biogeochemistry, and climate change. The challenge lies in data generation, and in the understanding of linkages through modelling exercises, and the use of the latest technologies, such as geoinformatics, to realize the charms!

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