

Climate change and its impact on biodiversity; some management options for mitigation in Arunachal Pradesh

Sanjeeb Bharali* and Mohamed Latif Khan

Climate change is one of the most important global environmental challenges that affect all the natural ecosystems of the world. Due to the fragile environment, mountain ecosystems are the most vulnerable to the impact of climate change. Mountains have been recognized as important ecosystems by the Convention on Biological Diversity. Arunachal Pradesh is a predominantly mountainous state and is home to many endemic, endangered and threatened species, as well as to the indigenous people, who are dependent on its biological resources. Climate change will not only threaten the biodiversity, but also affect the socio-economic condition of the indigenous people of the state. Various activities like habitat loss, deforestation, clear felling and overexploitation amplify the impact of climate change on biodiversity. Therefore, some management initiatives should be taken for mitigating climate change. Also, more research work needs to be carried out in Arunachal Pradesh to monitor the trend of climate change and susceptibility of biodiversity.

Keywords: Biodiversity, climate change, habitat, management initiatives, threats.

CLIMATE is the average weather in a place over a long period. Climate change is the altering of weather and climate patterns that previously have been relatively stable. The changes in climate may be due to natural forces or from human activities. There is growing concern among the scientific community regarding climate change and scientists have proved its occurrence through ample evidence and tested models¹⁻⁵. Climate change is one of the most important global environmental challenges affecting all natural ecosystems⁶. Climate and natural ecosystems are closely related and depend on each other, and the stability of this relation is an important ecosystem service. The Millennium Ecosystem Assessment (MEA) identified climate change as one of the major drivers having adverse effects on biodiversity and associated goods and services⁷. According to the latest assessment report of the United Nations Intergovernmental Panel on Climate Change (IPCC), there is now unequivocal evidence that the earth's climate system is warming, very likely due to anthropogenic greenhouse gas (GHG) emissions. Among all the ecosystems of the earth surface, the mountain ecosystems are considered to be of global importance. These are most fragile and vulnerable to the effect of climate change. About one-tenth of the global population lives in

mountain ecosystems. Thus the United Nations had declared 2002 as the 'International Year of the Mountains'⁸. Under the influence of climate change, mountains are likely to experience wide-ranging effects on the environment, natural resources, including biodiversity and socioeconomic conditions⁹. The Convention on Biological Diversity (CBD) has also recognized mountains as important ecosystems and specifically developed a programme of work on mountain biodiversity in 2004, which aimed at reducing the loss of mountain biological diversity at global, regional and national levels by 2010 (ref. 10).

Sensitivity of biodiversity to climate change

Biodiversity is the multitude forms of life within each ecosystem. These ecosystems are now at risk as a result of human developmental activities. Climate change and habitat destruction are two of the greatest threats to global biodiversity¹¹. Global climate change, along with continued habitat loss and fragmentation is now being recognized as a major threat to future biodiversity. Climate is one of the most important factors controlling the growth, abundance, survival and distribution of species as well as regulating natural ecosystems in a variety of ways¹². The effect of climate change on the natural system may be diverse, such as change in the timing of phenological events of plants, changes in species abun-

Sanjeeb Bharali is in the Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed University), Nirjuli 791 109, India; Mohamed Latif Khan is in the Department of Botany, Guru Ghasidas University, Koni 495 009, India.

*For correspondence. (e-mail: sanjeebbharali@yahoo.co.in)

dance and range, shifts in habitat, etc. Today climate change is happening at an increasingly rapid rate. According to the prevailing extinction theory, the larger and more specialized species are likely to be lost due to habitat destruction¹³. This is a special risk factor for high-altitude species which are sensitive to climate change¹⁴ and more likely to be at risk of extinction. Under continuing climate change, tree species will be affected in different ways and ranges will adjust at different rates and by different processes¹⁵. Species in transition zones between subalpine and alpine are especially vulnerable to climate change, as they have limited scope to move further¹⁰. Levin and Levin¹⁶ have predicted that around the world, a species becomes extinct every 20 min. Although the extinction of various species is a natural phenomenon, the rate of extinction occurring in today's world is exceptional, 100 to 1000 times greater than normal.

Climate change and the Eastern Himalaya

The northeastern states of India are expected to be greatly affected by climate change because of their geo-ecological fragility, strategic location vis-à-vis the Eastern Himalayan landscape and international borders, their trans-boundary river basins and the inherent socio-economic instabilities. However, the impacts of climate change on North East India have been less explored and less known till now, making the future scenarios more uncertain for vulnerability assessment and risk management¹⁷. It should also be recognized that the impact on biodiversity of this region due to direct human-induced land-use changes may also accelerate the impact of climate change. High-elevation ecosystems of the Himalayan region are the most vulnerable geographic regions of the world outside of the polar region to climate change^{18,19}, which has been considered as the most serious threat to mountain forests²⁰. Climate change will affect all natural ecosystems, but the impacts will be more prominent on the already stressed ecosystems of the Eastern Himalayas¹⁰. Climate change increases the risk of extinction of species that have a narrow geographic and climatic range^{21,22}, and endemic and threatened species are the most vulnerable. However, it is extremely difficult to assess the impact of climate change on plants in the presence of other threats/pressures. This is a big challenge mainly due to limited data availability and uncertainties associated with the climate scenarios¹⁰.

Arunachal Pradesh – nature's gift

Arunachal Pradesh, the largest state in the northeastern region of India, is located between 26°28'–29°30'N lat. and 91°30'–97°30'E long., and covers a geographical area of 83,743 sq. km with a population density of 13/sq. km (2001 Census). The state forms a major part of the East-

ern Himalayas and is predominantly hilly and mountainous. Varying altitudes, climates and geological conditions are responsible for different forest types and vegetation in Arunachal Pradesh. The state is also recognized as one among the 200 globally important ecoregions²³. Based on flora and altitude, Kaul and Haridasan²⁴ have classified the vegetation of Arunachal Pradesh into six broad forest types, viz. tropical forest, subtropical forest, temperate forest, subalpine, alpine and secondary forests. The secondary forests are found in all the climatic zones up to 3000 m amsl. The total forest cover of the state is 67,353 sq. km, i.e. 80.43% of the total geographical area²⁵. The forests of Arunachal Pradesh support a rich floral and faunal diversity due to the varied climate, altitude and ecosystem types. The flora of the state comprises well over 4000 species of flowering plants, including some aromatic, medicinal, ethnobotanical and economically important species like *Acorus calamus*, *Berberis aristata*, *Cinnamomum tamala*, *C. zeylanica*, *Cordiceps sinensis*, *Embelia ribes*, *Paris polyphylla*, *Rubia cordifolia*, *Gynocordia odorata*, *Illicium griffithii*, *Taxus wallichiana*, *Valeriana jatamansi*, *Piper longum*, *Podophyllum hexandrum*, *Rhododendron* spp., *Caryota urens*, *Hedychium longipedunculatum*, *Drosera peltata*, *Coptis teeta*, *Panax* spp., *Pinus* spp., *Fritillaria cirrhosa*, *Dipterocarpus macrocarpus*, *Terminelia belerica*, *Bombex ceiba*, *Gmelina arborea*, *Abies* spp. and *Gymnocladus* spp. Besides these, the state has nearly 600 bird species, including three hornbill species and the endangered White-winged duck and rare pheasants^{26,27}, 105 fish species, 42 amphibian species, along with a large number of reptiles, butterflies and other terrestrial mammals²⁷.

Climate change and Arunachal Pradesh – some recent evidences

Climate change is now recognized as a phenomenon that will be seen and experienced by people all over the world. It is a global phenomenon, but impacts are regional and local. The impacts of ongoing changes in climate have already been experienced by the hill communities of Arunachal Pradesh. During a verbal discussion, a few old people from Mechuka, West Siang District, Arunachal Pradesh, informed us that since the last few years (12–15 years) they have been experiencing a change in the snowfall pattern and intensity. Earlier snowfall started from late October and reached up to their homes. Now snowfall starts only during December and rarely reaches near their homes. The Gaon Burah (headman) of Thungri village in Bomdila informed us about a similar change in snowfall pattern and narrated that he still remembers the last snowfall in their village 10–12 years ago, with about half a foot snow deposited on the ground. Now snowfall is restricted to the top of the mountains only. The villagers believe that this may be due to increase in population

as well as in temperature; hence the snow dries up in the air before reaching the ground. Moreover, few villagers from Mechuka also informed us that 15–20 years ago the apples in Mechuka were sweet, but now the fruits taste sour. Earlier apples used to flower only once in a year during February. Now they flower twice a year, in late March and September. The flowers that bloom in March produce fruits, while those that bloom in September do not produce any fruits. They also informed us that in the past many tree species like *Rhododendron*, *Abies*, etc. were found in lower altitude areas, but now they are restricted to higher ridges of the mountains. The lower ridges are now gradually occupied by pine species (Figure 1 *a*). Some of the local people in Bomdila mentioned that there is change in snowfall pattern in Sela pass on the way to Tawang. In the past, snowfall used to start from early November and end by February. Now it starts in December and continues till early April.

Threats to biodiversity of Arunachal Pradesh

The ecological systems in Arunachal Pradesh, due to its physiographic condition are more fragile, complex and vulnerable to global climatic change and are found to be easily disturbed. Climate change will not only impact the biodiversity of Arunachal Pradesh, but also affect the livelihood of local communities as they fully dependent on the natural resources. Further, climate change will have important impacts on biodiversity, with agricultural and other use values. Rapid melting of the Himalayan glaciers or decrease in snow cover will affect the overall availability of water for drinking, agriculture, hydro-power and other purposes in many places of the state. Extreme precipitation events (heavy rainstorm, cloudburst) may have their own impacts on the fragile geomorphology of the Arunachal Himalaya, causing more widespread landslides and soil erosion (Figure 1 *b*). Two

extremely intense cloudbursts of unprecedented intensity in Arunachal Pradesh in 2008 and 2010 produced devastating flash floods causing many deaths and enormous loss to the forested and agricultural land.

As a part of the Eastern Himalayas, Arunachal Pradesh is also rich in endangered, endemic and threatened floral and faunal species with restricted distribution and narrow habitat ranges²⁸, which are at particular risk due to climate change¹⁰. Examples include flora like *Amentotaxus assamica*, *Gleditsia assamica*, *Gymnocladus assamicus*, *Coptis teeta*, *Rhododendron* spp., *Paphiopedilum fair-rieanum*, *Aneilema glanduliferum*, *Capparis pachyphylla*, *Acer oblongum* and *Acer sikkimense* and fauna like snow leopard (*Uncia uncia*), red panda (*Ailurus fulgens*), tiger (*Panthera tigris*) and other members of the cat family (Felidae) and Asian elephant (*Elephas maximus*) which are all found in small, isolated, widely scattered habitats within the state. Similarly, the region is home to narrowly endemic species like Namdapha flying squirrel (*Biswamoyopterus biswasi*), takin (*Budorcas taxicolor*), White-winged wood duck, Sclater's Monal (*Temmincks Tragopan*), Black-necked crane, Mishmi wren and Bengal florican. These species and many others, by virtue of their specific habits and habitat needs, are more vulnerable to climate change and more likely to face extinction risk due to the expected changes^{10,29}.

One of the most dangerous consequences of reckless deforestation along the lower reaches of the Arunachal Himalayas is drastic climate change. The biodiversity of Arunachal Pradesh is already under heavy pressure due to habitat loss, deforestation, clear felling, species overexploitation, etc. These amplify the climate change effects by causing fragmentation, degradation and drying up of the ecosystems, including increased incidence of fire³⁰, and subsequently result into substantial changes in species abundance and composition due to structural and functional changes in the ecosystems³¹. The significant drivers of the change in forest area in Arunachal Pradesh



Figure 1. *a*, Gradual development of pine forest in Mechuka. *b*, Landslide damaging forest in hill slope.



Figure 2. *a*, Clearance of forest for agriculture. *b*, Forest cleared for tea plantation.

Table 1. Some important rhododendrons found in transition zone between two bioclimatic zones in Arunachal Himalaya

Bioclimatic zone	Species
Subtropical–temperate	<i>Rhododendron coxianum</i>
Temperate–subalpine	<i>R. glaucophyllum</i> var. <i>tubiforme</i> , <i>R. pendulum</i>
Subalpine–alpine	<i>R. arboreum</i> ssp. <i>cinnamomeum</i> , <i>R. ciliatum</i> , <i>R. megeratum</i> , <i>R. niveum</i> , <i>R. tanastylum</i>

Source: Paul *et al.*³³.

include clearance of forests (Figure 2 *a*) for agriculture, tea cultivation, slash and burn mode of cultivation with ever reducing ‘jhum’ cycle and alteration of prime natural habitat for developmental and industrial activities. The recent shift of interest of the people towards tea cultivation is a major pressure on the forest area, especially in the eastern part of the state. This can be easily seen in the Tirap and Changlang districts of Arunachal Pradesh, where large forest areas in the hill slopes have been cleared for tea plantation (Figure 2 *b*).

Deforestation not only decreases the forest area, but also affects the regional climate by reducing carbon sequestration resulting into increase in temperature. On the other hand, the Namdapha National Park in Changlang District, one of the largest protected areas for biological conservation in the Indian Eastern Himalayas, is under heavy pressure of deforestation by clear-felling for human settlements; shifting agriculture and massive extraction of non-timber forest products, particularly *Zalacca secunda*, an endemic, stemless rattan palm; hunting and poaching of rare and endangered fauna and uncontrolled fishing in the river³². Although habitat loss has primarily threatened lowland species, highland species in intact habitats are now facing the additional threat of warming temperatures, and most vulnerable are the species in transition zones between subalpine and alpine, as

they have limited scope to move further¹⁰. There are many *Rhododendron* species in Arunachal Pradesh, which are exclusively found only in the transition zone between two bioclimatic zones; these are most vulnerable to the impact of changing climate (Table 1)³³.

Some management options to mitigate climate change

Climate change is a natural process. However, the rate at which the change takes place now is far greater than normal; this is due to anthropogenic activities. Conservation and management strategies that maintain and restore biodiversity can be expected to reduce some of the negative impacts of climate change. As mentioned earlier, Arunachal Pradesh is predominantly a mountainous state, and mountains are the most vulnerable and likely to experience the wide-ranging effects of climate change. Thus, there is an urgent need of some measures to mitigate climate change in Arunachal Pradesh. The following are some management options for the state. Some of these are adapted from ‘Secretariat of the Convention on Biological Diversity’³⁴.

- Maximizing the resilience of the species and ecosystems to climate change by increasing forest area through initiating afforestation and reforestation programmes in barren and degraded forest areas.
- Increasing protected areas within the state. Improving the connectivity of the protected areas and the natural landscapes to provide opportunities for species to adapt to climate change by migration, and to increase the probability of maintaining viable populations of species.
- Examining models to determine areas with future climatic suitability for ecosystems and treat these areas as potential priorities for conservation.

- Identification of areas within the state with high endemism and protect them, as many of these areas have been relatively climatically stable for millions of years and have species with a high degree of specialization.
- Local traditional knowledge is vital for preserving biodiversity, especially the sacred groves, which are considered a successful mitigation strategy. This knowledge should integrate into formal climate change mitigation and adaptation strategies. It can be done by establishing specific guidelines for promoting the traditional knowledge of conservation.
- Creating environmental awareness and knowledge of global climate change among the people, especially the students.

Conclusion

There is ample evidence that climate change has affected global biodiversity and many species of flora and fauna have become extinct from their natural habitat. The change in climate will also have adverse and often irreversible impacts on many ecosystems and their services, and ultimately will affect the social, cultural and economic condition of the human society. The International Centre for Integrated Mountain Development undertook a series of research activities together with partners from 2007 to 2008 to provide a preliminary assessment of the impacts and vulnerability of the Eastern Himalayas due to climate change. Arunachal Pradesh is also being affected by climate change, but no assessments have been done in the long term to monitor the vulnerability of biodiversity. Hence, there is an urgent need of effective research work to be carried out in Arunachal Pradesh to assess the trend of climate change and susceptibility of biodiversity. Risks to biodiversity from climate change can be initially assessed using available vulnerability and impact assessment guidelines.

Phenology, discipline of the timing of recurring biological events, is a widely accepted robust ecological indicator of the impacts of environmental variation and climate change on biodiversity and ecosystem processes across scales from individuals to landscapes^{35,36}. Phenology can be used as an indicator of species sensitivity to climate change, or can be combined with climatological data as an integrated indicator of climate change. Studies on the phenology of some specific species may be carried out to monitor the trend of climate change within the state. Most organisms found in the Arunachal Pradesh are confined to specific habitats such as high altitude, dense forests, etc. Most of them are sensitive to climate change and their phenology is being affected. Orchids, *Coptis teeta*, *Ginseng* spp., *Illicium* spp., *Rhododendron* spp. and *Primula* spp. are few of the important plant species that show a close link to seasonality for their various pheno-

phase events such as leaf flushing, flowering, fruiting, seed maturation, etc. Studies on these plant species which require specific climate for growth and development may be undertaken to address the phenological monitoring programme on climate change in Arunachal Pradesh. Furthermore, research work may be carried out through coordinated projects to review the state of indigenous knowledge and identify the best practices adopted by traditional resource management systems in the Eastern Himalayan region, especially in Arunachal Pradesh. This can be achieved by generating more data through intensive research and their adoption at field level with proper extension and support policies.

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