



Climate Change Impact on Forest and Biodiversity of Indian Eastern Himalaya: An Overview

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Abstract-*Intergovernmental Panel on Climate Change (IPCC) has highlighted that warming of the climate system is unequivocal. Global climate change is happening and will present practical challenges for local ecosystems. Climate change is posing serious threat to the ecosystem and communities of the Himalayan region. The Indian Eastern Himalayan region (alias North East Region) is contains more than one-third of India's biodiversity and represents the Indo-Burma global biodiversity hotspot. The region has been characterized by large rural population, low population density, large percentage of indigenous tribal communities and large area under forests (65%). Analysis of long-term temperature data for the eastern Himalaya points to a distinctly rising trend in surface air temperatures. The biodiversity and forest of the region are facing numerous anthropogenic threats aggravated with climate change impacts. Climate change is one of the important arising threats of the Eastern Himalayan region. There is an urgent need for policy actions that promote the conservation and sustainable use of valuable forest and biological resources of the region. In addition to policy interventions, there is immediate need for developing and implementing adaptation strategies to reduce vulnerability of forests and biodiversity due to projected climate change impacts.*

Key words-*Climate change, Eastern Himalaya, Biodiversity Conservation, Forests protection, Adaptation*

I. INTRODUCTION

The Indian East Himalayan region constitutes around 52% of total East Himalaya (total 524,190 sq km). It is often referred as North Eastern Region (NER) in the country. The NER, a distinct socio-cultural entity, is enunciated as 'a rainbow country extraordinarily diverse and colourful, mysterious when seen through parted clouds'. The region includes the seven sisters - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, along with a small and beautiful cousin in the Himalayan fringes, namely, Sikkim covering an area of 2,62,184 km² and constituting about 7.98% of the country's total geographical area (Figure 1). The region has a long international boundary, about 2000 km with China and Bhutan in the north, Myanmar in the east, Nepal in the west and Bangladesh in the south and west [1]. The NE region is uniquely situated in the transition zone between the Himalayan and Indo-Burma, being recognized as one of the 25 mega biodiversity hotspots of the world [2]. It is also among the 200 globally important ecoregions [3]. Located at the tri-junction of Indo-Chinese, Indo-Malayan and Palaearctic biogeographic realms [4], the region exhibits diverse hilly terrain with wide altitudinal range. The region represents nearly 3.8% of total human population of the country and exhibits a great diversity of ethnic groups. The region is home to over 200 of the 635 tribal groups in the country, speaking about 220 dialects with a strong tradition of social and cultural identity [5,6]. The significant linguistic, ethnic and cultural diversity, not only among the people of different states but also within each state in the region is an important feature. The region has two main river basins (Brahmaputra and Barak), and a large dependence of the population on natural resources. The NER is also characterized by diverse climate regimes which are highly dependent on the southwest monsoon (June–September). The region has around 65 % geographical area under forest cover and is the richest for biodiversity with vegetation types ranging from tropical rain forests in the foothills to alpine meadows [7]. Climate Change (CC) is now widely recognized as the major environmental threat facing the entire planet at present [8]. Fifth Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC) revealed that the average global surface temperature is likely to rise by 0.3 to 4.8°C by the end of this century [9]. The above increase in temperature will create substantial impacts on health, agriculture, forests, water resources, coastal areas, biodiversity and ecosystems. AR5 of IPCC also projected sea levels would rise by between 26 and 82 centimeters (10.4 and 32.4 inches) by 2100. According to the IPCC, 20-30% of plant and animal species are likely to be at increased risk of extinction if global average temperature increases exceed 1.5-2.5°C. Climate change modelling studies for India show that the Indian sub-continent is likely to experience a warming of over 3–5°C and significant changes (increases and decreases) in flood and

drought frequency and intensity [10]. The Himalayan region is among the most fragile ecosystems in the world and is under severe threat from Climate Change phenomena. The Himalayas global average surface temperatures are increasing and snow cover and ice extent are decreasing. However, as per the IPCC assessment report the Himalayan region has been identified as a data deficient in terms of climate monitoring [11]. It is pertinent to mention that Himalayan region is a rich repository of rare, threatened, endangered and endemic species hence threats to biodiversity arising from climate change are very sensitive in nature [12].

Researchers have highlighted that the Eastern Himalayan region of India is more vulnerable to climate change because of its unique location, geo-environmental conditions and economic under development. The fragile ecosystem, unique climatic conditions and rich biodiversity and forest are more vulnerable to the effects of climate change in the region. Climate change impact on forest landscape of Eastern Himalaya can be visualized as most significant because they provide numerous ecological services, support unique biodiversity, important for carbon sequestration, maintaining hydrological balance, livelihood benefits to dependant populace and have religious significance among indigenous communities [13]. Impact of CC on forest and biodiversity in the region is yet to be carefully studied to establish a relationship. Currently, comprehensive scientific information on Climate Change impacts on forest and biodiversity of eastern Himalayan region is unavailable [13,14].

Keeping in view of above, an attempt has been made in the present paper to review the biodiversity and forest status, trend and projection of climate change, impact of climate change on forest and biological resources and management and mitigation options to address climate change impacts in the Indian Eastern Himalayan region.

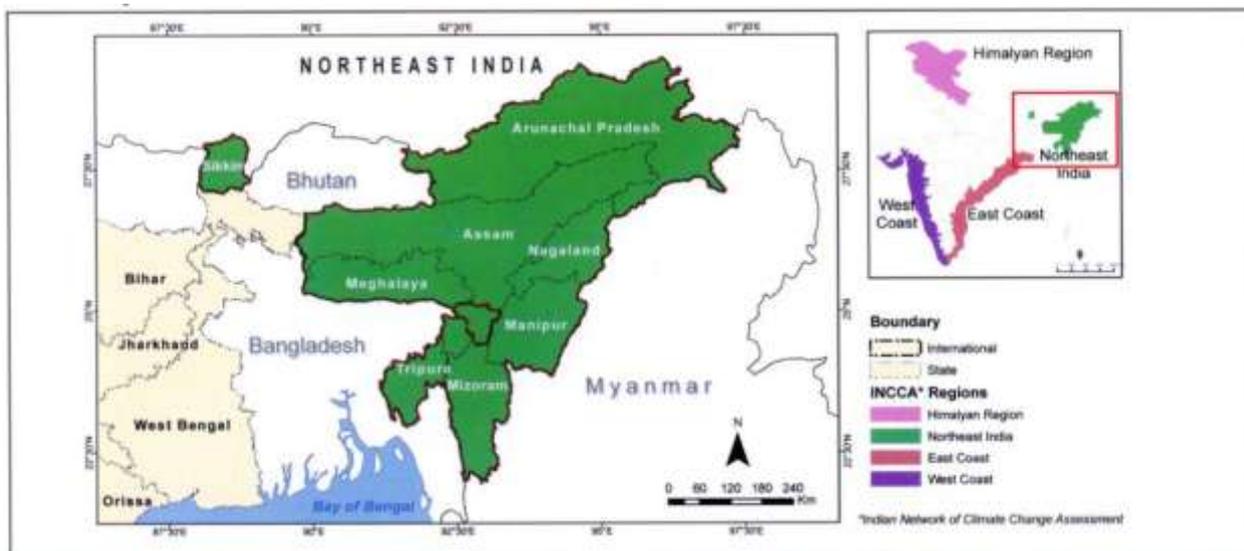


Figure 1: The North Eastern Region and its constituent states in India (Source: MoEFCC, 2010)

II. MATERIAL AND METHODS

The status of biodiversity, forest resource and impact of climate change on biodiversity and forest resources were documented from review of existing scientific literature. The published literature such as research articles, journals, books, reports, thesis, brochure, monographs, etc. were concerned. The information was also obtained from government websites such as Ministry of Environment, forest and Climate Change (MoEF&CC), State forest departments, Forest Survey of India (FSI), National and State Biodiversity Boards etc. Additional papers were located by searching the reference sections of these articles/reports. Discussion with subject experts and local communities were also carried out through brainstorming workshops, focused groups talks and personal interviews to get the first hand information on climate change impact on forest and biodiversity of the region.

III. RESULTS AND DISCUSSION

3.1 Biodiversity status in the Indian Eastern Himalaya

The Indian East Himalayan region contains more than one-third of the country's total biodiversity and represents the Himalayan and the Indo-Burma (Myanmar) global biodiversity hotspots. The region is popularly known as 'cradle of all

flowering plants' as it contains nearly 50% of the total flowering plant species in India [4]. The flora of NER comprises about 7,500 flowering plants, 700 orchids, 63 bamboo species, 64 citrus species, 28 conifers, 500 mosses, 700 ferns, 728 lichens species [15]. The richness of floral species reported from various states of Northeast is shown in Table 1. The region is recognized as 'Orchid Paradise' because of having the highest concentration of orchid species. Diversity of Orchidaceae in the region is amazing with > 57% of total Indian orchids. The NER represents approximately 67% of the pteridopyhtes known from the country [16]. Out of the 48 species of gymnosperms known from India, 28 species (58.3%) of wild nature grow in the NER. Out of the 28 gymnosperm species known from NER, 17 species (60%) grow in wild state in Arunachal Pradesh [17]. The NER is represented by 129 taxa of Rhododendron (around 97% taxa of India), out of which 16 taxa are endemic to North East India. The maximum number (12) of endemic taxa occurs in Arunachal Pradesh followed by Manipur and Nagaland (6 taxa each), Meghalaya, Mizoram and Sikkim (2 taxa each) [18]. Bamboos play a pivotal role in day to day life of tribal people of NER. Out of 150 bamboo species so far known in India, 63 species in 22 genera are found in NER. About 25 species of bamboo are considered rare in NE region. Rattan, commonly known as cane, is one of the most important no timber forest products from northeast India. Of 60 species of canes reported from India, the NE Region has over 26 species [19]. The region has been identified by the Indian Council of Agricultural Research (ICAR) as a centre of rice germplasm and National Bureau of Plant Genetic Resources (NBPGR) has highlighted the region as being rich in wild relatives of crop plants. The region, being remote and inaccessible in most cases has not been explored completely and holds great potential for new plant discoveries.

Table 1: Floral biodiversity of North East India

S.No.	State	No. of Floral species
1	Arunachal Pradesh	5000
2	Sikkim	4500
3	Meghalaya	3500
4	Assam	3010
5	Manipur	2500
6	Nagaland	2250
7	Mizoram	2200
8	Tripura	1600

(Source: Chakravarty et. al 2012)

According to the Indian Red Data Book, 800 species of endangered flowering plants are reported from the region, which accounts for 55% of the country. The eastern Himalaya supports one of the world's richest alpine flora, with high level of endemism [20]. Besides having rich plant diversity, NER is adobe of rich and unique faunal species. Of the 15 known species of primates in India, 9 occur in NER [19]. Among 6 big cats in India, four– the tiger (*Panthera tigris*), the leopard (*Panthera pardus*), the snow leopard (*Uncia uncia*), and the clouded leopard (*Neofelis nebulosa*) have been reported from the region. All the Indian bear species are recorded from the NER. The region probably supports maximum diversity of birds in the Orient. Among lower vertebrates, 137 species of reptiles 64 species of amphibians are recorded from the region. The NER has reported 3,624 species of insects and 50 mollusc [15]. The biodiversity of the NER is facing various threats such as natural and anthropogenic disturbance, illegal and over extraction of forest products, illegal hunting, wildlife trade, shortening of jhum cycle (fallow period), encroachment of forest area, un-controlled grazing, forest fires, illegal trade of NTFPs, monoculture plantations, introduction of exotic varieties of plants, unplanned development activities etc. These factors are considered the main causes for depletion of biodiversity in the NER.

3.2 Status of forest in Indian Eastern Himalaya

As per the India State Forest Report (ISFR 2015), the total forest cover in the region is 1,71,964 sq km, which is 65.58 % of its geographical area in comparison to the national forest cover of 21.34 %. Very dense, moderately dense and open forests constitute 14.81 %, 43.85 % and 41.34 % respectively. Forests of this region are unique, both in terms of their structure and species composition. The altitudinal variation and rainfall patterns of southwest and northeast monsoon play a significant role in the development of ecological niches in NE region of India [21]. Unlike other regions of India, administrative control of forest in Northeast is predominantly by community with much of the forests listed as "unclassed forests". Saha and Sundriyal, 2012 assessed that the tribal communities of NER use 343 NTFPs for diverse purposes like medicinal (163 species), edible fruits (75 species) and vegetables (65 species) [22]. The analysis of last 26 years (period 1987-2013) forest cover data of forest survey of India indicates an increase in forest cover of 7,172 km², at an annual rate

of increase of 0.16% for NER. The recent ISFR 2015 reported that the NER registered a decrease of 628 square kilometers of forest area during the period from 2013 to 2015. Reports indicate that the NER is also probably the lowest greenhouse gas emitting region, and forests of the NER sequester highest quantity of carbon in the country. Shifting cultivation practice, encroachment, soil erosion, earthquake induced landslide, grazing, forest fire, developmental projects, urbanization, illegal logging and NTFPs collection are some important factors responsible for change in forest cover in NER states [7,21,23]. Climate change is major arising threat for forest and biodiversity of NER. Impacts of climate change on forests have severe implications for the people who depend on forest resources for their livelihoods [6]. State- wise forest cover in the region, along with the changes as compared to the previous assessment is shown in table 2.

Table 2: Forest Cover in the North-Eastern States

States	Geographic Area (sq.km)	Forest Cover 2015 (sq.km.)				Forest cover (% of GA)	Change w.r.t. to ISFR 2013 (sq.km.)	Scrub land (sq.km.)
		VDF	MDF	OF	Total			
Arunachal Pradesh	83,743	20804	31301	15143	67248	80.30	-73	264
Assam	78,438	1441	11268	14914	27623	35.22	-48	384
Manipur	22,327	727	5925	10342	16994	76.11	4	1182
Meghalaya	22,429	449	9584	7184	17217	77.08	-71	348
Mizoram	21,081	138	5858	12752	18748	88.93	-306	0
Nagaland	16,579	1296	4695	6975	12966	78.21	-78	622
Sikkim	7,096	500	2160	697	3357	47.31	-1	311
Tripura	10,491	113	4609	3089	7811	74.45	-55	55
Total	2,62,184	25,468	75,400	71,096	1,71,964	65.58	-628	3,166

(Source: India State Forest Report, 2015)

3.3 Protected Area Network (PAN) in NER

The NER has a large network of Protected Areas for in-situ conservation on wild flora and fauna. At present there are 16 National Parks, 55 wildlife sanctuaries, 6 Tiger reserve and 5 biosphere reserve covering about 6749 sq. km, 10658 sq.km, area, 8907.77 sq.km. and 12153.42 sq.km. respectively (Table 3). The protected area networks of NER play potential role in biodiversity conservation and ecotourism development in the region.

Table 3: Protected Area Network in NE Region

Name of State	Wildlife Sanctuary		National Park		Tiger reserve		Biosphere Reserve	
	Number	Area km ²	Number	Area km ²	Number	Area km ²	Number	Area km ²
Arunachal Pradesh	11	7,487.75	2	2,290.82	2	3251.27	1	5111.50
Assam	18	1,840.14	5	1,977.79	3	4668.50	2	3602.00
Manipur	1	184.4	1	40	-	-	1	820.00
Meghalaya	3	34.2	2	267.48	-	-	-	-
Mizoram	8	1,090.75	2	150	1	988.00	-	-
Nagaland	3	20.34	1	202.02	-	-	-	-
Sikkim	7	3,99.10	1	1,784.00	-	-	1	2619.92
Tripura	4	5,66.93	2	36.71	-	-	-	-
Total	55	10,658	16	6,749	6	8907.77	5	12153.42

(Source: <http://wiienvs.nic.in/>)

3.4 Climate change vulnerability for forest and biodiversity of Eastern Himalaya

The climate change trend analysis showed that during the last century the maximum temperature increased over North East India by 1°C during winter and 1.1°C during the post-monsoon months. There have been small increases in rainfall during winter, pre-monsoon and post-monsoon seasons [24]. The report 'Climate change and India: a 4x4 assessment a sectoral and regional analysis for 2030s' of Indian Network for Climate Change Assessment (INCCA) projected that the forest and biodiversity of the NE region are vulnerable to projected climate change in the short term i.e. 2030s [1]. The report projected that surface air temperature in NE region will rise by 25.8 to 26.8°C in 2030's with a standard deviation ranging from 0.8 to 0.9. The rise in temperature with respect to 1970's is ranging from 1.8 to 2.1°C. The projected mean annual rainfall for NE region is varying from a minimum of 940 to 1330 mm. The study projected that the climate change may bring changes in rice yields by about -10% to 5%, while the impacts on rain-fed rice are likely to be in the range of -35% to 5% in NE region. Maize crop yields are also projected to reduce by 40% in NE region. Forest vulnerability analysis observed that the forests in the northern part of the North East are primarily impacted by climate change, leading to extreme vulnerability of the Himalayan biodiversity hotspot. Net primary productivity is projected to increase by 23% in NE region, followed by increased biomass and soil carbon, leading to probable changes in vegetation type [10]. Arunachal Pradesh State Action Plan on Climate Change (APSPCC) has projected that maximum temperature will increase by 2.2°C to 2.8°C during 2030s as compared to baseline i.e. 1961-1990 and towards 2080s the increase is projected by 3.4°C to 5°C. State action plan has concluded that the future climate is not optimal or suitable to the existing forest types and biodiversity (25). Higher altitude species are most sensitive to climate change due to pristine ecological conditions and narrow distribution pattern. The species like Rhododendron, which occur in transition zone between alpine and subalpine ecosystem may face more threat due to limited scope of upward movement [26,14]. The endangered, rare, threatened and endemic plants and animal species with very small populations and special habitats requirement are likely to be less resilient and more vulnerable to climate change in the NE region. The rising temperature of water bodies renders them more suitable habitat for invasive species that outcompete native species and synergistically interact with climate change to threaten native organisms. The prevailing rise in temperature and changes in precipitation patterns leading to increased incidence of extreme weather that could lead to diminishing crop and livestock diversity and have direct implications on agrobiodiversity and food security in the NE region [27,28,29]. At present, people of the NE region are also experiencing the climate change impacts in form of change in snowfall and perception period and pattern, increase in atmospheric temperature, change in phenological behaviour of plants species viz. flowering and fruiting pattern, increase in the number of invasive alien species, vegetation shifting in higher altitudes areas etc.

IV. CONCLUSION: WAY FORWARD ACTIONS

From the foregoing discussion it has been clearly emerged out that NE region is reckoned as a mega-centre of biodiversity and endowed with rich forest resources in the entire Indian subcontinent. The forest of the region provides numerous ecosystem services (water regulation, soil protection, non-timber forest products including food and fiber, climate regulation and support biodiversity) for the upstream and downstream communities. In recent couple of decades, the NE region forests are experiencing an extensive process of forest fragmentation, degradation, deforestation and forest conversion. Climate change is one of the major rising threats for forest and biodiversity of the region. Researchers have projected that climate change will create potential impact on the forest resources, flora and fauna of the region. Therefore, there is urgent need to carry out further research on climate change using multiple approaches to vulnerability profile development for forest and biodiversity of the region. Considering the uniqueness and richness of biodiversity and forests in the NE region, intricate linkages of human and natural resources, and realizing the sensitivity of biodiversity elements of the region for human and climate induced changes, comprehensive policies and strategies need to be formulated for forest protection and biodiversity conservation of the NE region. Organization of mass awareness and educational programmes on biodiversity conservation, protection of forests, climate change vulnerabilities, adaptation and management strategies among different stakeholders of society will help in mitigate the negative impacts of climate change in the region. Community participation will play key role in conservation of biodiversity and sustainable management of forests in changing climate scenario of NE region.

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