Mysore J. Agric. Sci., 51 (1) : 45-51, 2017

Forests and Climate Change : An Indian Perspective

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Abstract

Climate change is considered to be the most important challenge the forests are likely to face in the future. Among various forests, it is the tropical forests that are highly susceptible and the climate change impact can be observed on the structural, functional and services aspects of these forests. Various models have been used to understand the response of forests to climate change. The four important regions of India *viz.,* Himalayas, Western Ghats, North East and Coastal line has been projected to respond in different ways. However, with certain inbuilt reduced robust methodologies, the projection thus obtained does clearly show a significant effect of climate change on the forests in these regions. At species level, highly valued commercial species such as teak (*Tectona grandis*) seems to be highly vulnerable. In Sikkim Himalaya, there is a certain shift in the species at various elevations. Though studies on climate change on India's forest is far and few, we are of the opinion that policy intervention, sensitizing the society for mitigating climate change along with setting up of long term monitoring plots is the ideal way to face the imminent climate change.

Global patterns of natural ecosystems along with bio-physical diversity of the region is basically determined by the climate. Climate change would be the most important event and challenge that we all face specially from the perspective of its impact not only on our society but also emphasising the need for joining hands at global level to mitigate it. Climate change in terms of global warming is evident from the fact that the temperature now is rising by 0.2 degree centigrade per decade (Hansen *et al.,* 2006) and increased greenhouse gases (GHG) emission which would further raise the temperature. Wide range of information in terms of critical review and scientific proof on climate change and earth systems is being continuously updated by Intergovernmental Panel on Climate Change (IPCC). Being a specialised body, IPCC was jointly established in 1988 by United Nations Environmental Programme and the World Meteorological Organisation which has a mandate to prepare scientific assessments on various aspects of climate change. The Third Assessment Report of IPCC in 2001 is supposed to be highly credible and authoritative source. The fifth Assessment Report of IPCC in 2014 which dwells on the impact of climate change on various sectors like agriculture, trade, health and such others specifically mentions in case of forestry with reference to India as – *a third of forest areas in India are projected to change by 2100, with deciduous forests changing into evergreen ones due to increased precipitation. Human pressures are, however, expected to slow these changes.* The United Kingdom Government in its report on the economics of climate change in 2006 clearly mentions that, acting to lessen the impacts of climate change is a far better economic strategy than managing the social and economic crises that arises when mitigation measures are not taken. India is the fourth largest GHG emitter, accounting for 5.8 per cent of global emissions (Boden *et al*., 2016). Considering the impact of climate change on various sectors, government of India has taken serious view on the impact of climate change and series of measures are in place. India ratified the Paris agreement on climate change, which is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with GHGs emissions mitigation, and adaptation. As per the agreement, India plans to reduce its carbon emission intensity.

Among the natural ecosystems, the intricate impact of forest ecosystem and its role in biogeochemical cycle which in turn influencing climate change has emerged as an important topic for debate and discussion globally as well as regionally. Forests play a significant role in world's carbon cycle and the various substantial changes occurring in forestry sector promotes the fact that forestry can contribute substantially in mitigating climate change. Considering temperature and moisture as two important factors, it is the boundaries of forest biomes which closely follow climate variable patterns (Stephenson, 1990). Therefore, there is a close link between forests and climate change and any disturbance in either of them will have influence on the other (FAO, Forestry Paper 2013). Therefore, IPCC (IPCC, 2014) clearly mentions that on the basis of paleo-ecological records forest vegetation has the ability to respond for the climate change and the response duration may vary from within years to a few decades. The report also categorically projects that in the 21[st] century, forests are impacted by the climate and non-climate stressors resulting in die back of forests, loss of biodiversity and reduced ecological benefits.

Agriculture does play a significant role in climate mitigation, but when it comes to the option of CO_2 sequestration forestry plays a major role. India has been endowed with a diversity of natural biomes considering its varied climate regimes, enormous geographical area, topography, lengthier coastline and oceanic islands. The forest cover which is around 79.42 million has (as of 2015) constitutes different types of forest types. The National Mission for Green India is one of the eight Missions outlined under the National Action Plan on Climate Change by the Ministry of Environment Forests and Climate Change, Government of India. It aims at protecting, restoring and enhancing India's diminishing forest cover and responding to climate change by a combination of adaptation and mitigation measures. It also has a goal to 5 million hectares over the next five years which would have an annual mitigation potential of 55 Mt of CO_2 equivalent. Some of the other initiatives include green highways policy, financial incentive for forests, plantations along rivers, Reducing emissions from deforestation and forest degradation-plus and other policies. Afforestation is given a massive boost to such an extent of about 6.9 billion US dollars is transferred to the states on the basis of forest cover and it is projected to reach upto 12 billion US dollars by 2019-20. Therefore, forests and climate change are intimately connected and IPCC had already identified in 2001 that the biological approaches that can be used to reduce the increase of CO_2 in the atmosphere is by 'conservation' – conserving the existing carbon pool, 'sequestration' – increasing the existing carbon pool size and 'substitution' – by substituting biological products for fossil fuels or energy intensive products.

Forest as an ecosystem in India is highly susceptible to multiple pressures primarily due to anthropogenic factors. Some of the important factors that have contributed in creating enormous pressure and vulnerability on India's forests are –shifting cultivation, increasing demand for fuelwood, timber and non-timber forest products, grazing, forest fires, invasive species, conversion of land for agricultural and industrial purpose, forest fragmentation, afforestation, sivilcultural practises, and the insect outbreaks. It is an established fact that forests are inherently dynamic as they are continuously subjected to climatic variations and also has the resilience to adapt to the environmental changes. Therefore, forests are considered to be resilient when they are well conserved (Drever *et al.*, 2006) which results in high biodiversity and thereby evolving complex structure primarily due to complete absence of anthropogenic interference (Thompson *et al.,* 2009). In contrast, highly disturbed forests are inherently vulnerable due to forest fragmentation, poor germination and adverse influence of invasive species (Kant and Wu, 2012). But, the climate change is so swift and debilitating that forests are not unable to adapt and re-establish (Afreen *et al.*, 2011). Among various forests, it is the tropical forests that are highly susceptible to this and the climate change impact can be observed on the structural, functional and services aspects of these forests (Betts *et al.*, 2008).

An assessment by Ravindranath *et al.* (2006) about forest ecosystems in India using the Regional Climate Model of Hadley Centre considering two different elevated CO_2 concentrations as 740ppm (A2 scenario) and 575 ppm (B2 scenario) reveal interesting information. The climate projection by the year 2085, about 77 and 68 per cent of the forested grids are expected to experience shift in forest types. Chaturvedi *et al.* (2011) predicted that based on the number of forested grids selected (35899 grids), 39 and 34 per cent of these forested grids would undergo vegetation type change under the A2 and B2 scenario, respectively. Some of the states such as Chhattisgarh, Karnataka and Andhra Pradesh having dominant forest area are projected to undergo changes to an extent of 73, 67 and 62 per cent, respectively. A vulnerability index for India was developed on the basis of observed data sets of forest density, biodiversity and model predicted vegetation type shift. As per IPCC Working group II, Vulnerability is "*the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and its variation to which a system is exposed, its sensitivity, and its adaptive capacity*". The vulnerability index under A1B climate scenario (atmospheric CO_2 concentration of 490 ppm) by 2035 was used to assess the impact of climate change with reference to vegetation type on four important regions of India – Himalayas, Coastal region, Western Ghats and North East region. It was interesting to note that, Himalayas due to their higher elevations and North East region is most and least vulnerable while coastal region and Wester Ghats are moderately vulnerable. Considering Western Ghats which is one of the rich biodiversity hot spots of the world, it is predicted to have fragmented forests in its northern parts, but also vulnerable to higher risk of forest fire and pest attack. Within the Western Ghats, northern and central parts appear to be vulnerable to climate change. As the regions are less fragmented, southern Western Ghats forests are quite resilient as they are comparatively less fragmented, highly diverse and would support the tropical wet evergreen forests (INCCA, 2010). Considering the Himalayan region, out of the 98 grids studied, it is projected that 56 per cent of them would undergo change in 2030s while the net primary productivity (NPP) would be increasing by about 57 per cent. In case of Western Ghats the NPP of the forest would increase by 20 per cent. In case of North eastern and coastal lines, the NPP would increase on an average by 23 per cent and 31 per cent, respectively.

In case of various forest vegetation types in India, Ravindranath *et al.* (2006) predicted based on the number of grids selected, under the two scenarios of A2 and B2, tropical xerophytic shrub land is expected to undergo maximum change compared to current scenario (from 40%) to about 2 per cent in A2 scenario and 2.5 per cent in B2 scenario. In case of tropical evergreen forest and it is expected to increase from the current scenario of 2-2.5 to 35 per cent, while tropical savanna would increase 21.5 to 26 per cent (A2) and 18 per cent (B2) from the current scenario of 4 per cent (Table I). Considering the forest types classified by Champion and Seth, Gopalakrishnan *et al.* (2011) reported that among the forest types (considering the Champion and Seth classification), Himalayan moist temperate forests are significantly vulnerable to climate change (Table II). Eventhough, all these models have certain inherent technical assumptions and deficiencies, the fact that climate change is having its impact is well accepted and even an impact of mere 20 per cent what the prediction says becomes true, it can be safely assumed that our forests are highly susceptible for climate change.

While considering different forest ecosystems, it is also essential to consider the mangrove forests and its response to climate change. Sunderbans located at the North East region of India at the tip of Bay of Bengal represents largest contiguous mangrove ecosystem in the world. These forests provide some of the most essential ecosystem services as they have a direct impact on the socio-economic, environmental functions on the coastal livelihood. Considering above ground biomass of the three dominant mangrove species *viz., Sonneratia apetala, Avicennia alba* and *Excoecaria agallocha* significant spatial variation and better growth was observed in the western sector compared to the central sector which is primarily attributed to the changes in the salinity. Though, Raha *et al.* (2012) mentions that it is difficult to differentiate between the effect of climate change and anthropogenic effect, they conclude that cumulatively their role have impacted the diversity and productivity of mangrove. They stress that long term monitoring is crucial and policies have to lay major emphasis on this aspect.

While assessing vulnerability of forestry sector to long term climate change, it is also of paramount importance to understand the impact of climate change on species level. Though Himalaya being an important hot spot for biological diversity, impact of species response to climate change has not yet been very well

TABLE I

Annual rainfall and temperature changes scenario for the year 2085 in the different forest types of India (according to Forest Survey of India, FSI) considering CO_2 at 575 ppm

Forest Type	Mean annual rainfall (mm)	Change in rainfall (mm)	Mean temperature (ºC)	Change in temperature (ºC)
Fir	730.1	221.6	9.5	3.0
Blue-Pine	763.0	223.5	10.5	3.0
Chir-pine	1373.4	437.4	17.1	2.8
Mixed conifer	930.1	375.9	9.3	3.0
Hardwoods Conifers mix	1560.7	585.6	13.1	2.8
Upland Hardwoods	1523.8	476.9	16.4	2.7
Teak	1314.6	353.0	26.1	2.9
Sal	1435.2	348.3	24.6	2.7
Bamboo Forest	2268.3	564.9	23.8	2.7
Mangrove	1734.3	280.8	26.6	2.5
Miscellaneous forest	1679.8	374.5	23.0	2.7
Western evergreen forest	3111.3	368.7	25.4	2.4

(Source: Ravindranath *et al*., 2006)

TABLE II

Percentage of FSI grids projected to undergo change, aggregated by Champion and Seth forest types

Forest type on the basis of Champion & Seth	Number of FSI grids	Projected to change by 2035 (%)	Projected to change by 2085 (%)
Tropical dry evergreen forest	37	70.27	72.97
Sub-tropical dry evergreen forest	133	54.14	67.67
Himalayan dry temperate forest	106	52.83	76.42
Himalayan moist temperate forest	1144	52.62	88.02
Sub-alpine and alpine forest	400	49.75	77.50
Tropical thorn forest	1278	41.39	75.12
Tropical semi evergreen forest	1239	30.67	50.36
Littoral and swamp forest	7	28.57	28.57
Tropical dry deciduous forest	9663	25.62	46.73
Tropical moist deciduous forest	11266	22.63	37.88
Sub-tropical pine forest	1662	20.64	17.39
Sub-tropical broadleaved hill forest	192	15.10	15.10
Tropical wet evergreen forest	2862	14.61	14.68
Montane wet temperate forest	940	5.64	0.32

(Source: Gopalakrishnan *et al*., 2011)

documented. One such attempt was carried out by Telwala *et al.* (2013) in their study on Sikkim Himalayas where they recorded a shift of 23–998 m in species' upper elevation limit and a mean upward displacement rate of 27.53±22.04 m / decade. Warming-driven geographical range shifts were recorded in 87 per cent of 124 endemic plant species. However, they were of the opinion that more focused studies are needed to understand the impact of human activities on the regional Himalayan climate change. Another such assessment was carried out through modelling by Gopalakrishnan *et al.* (2010) on a commercially important tree species *Tectona grandis* (teak). Keeping aside the inherent deficits in the modelling methodology, it is projected that 30 per cent of the teak grids in India are vulnerable to climate change. However, due to increase levels of elevated CO_2 the net primary productivity and biomass are expected to increase. They opined that it is essential to impart long term studies on such commercial trees as they have both social and commercial ramifications. The studies must also be extended some of those species which are endemic as well. A similar study was carried out in the neighbouring country on one of the important threatened species *Dysoxylum binectariferum* reveals an interesting aspect. The model clearly predicts that a complete loss of suitable habitat for *D. binectariferum* in the studied area by both 2050 and 2070 (Sohel *et al*., 2016). Therefore, using species distribution models in predicting the likely changes in the distribution of species in future climate change scenarios is of paramout importance. Agroforestry must be provided with great attention not only at national, but international level as it has a direct relevance to social and environmental impacts (Mbow *et al.,* 2014). Effects of climate change on agroforestry is yet to be fully understood though there are extensive efforts in modelling climate analogs and future climate impacts models (Luedeling *et al.,* 2014; Mbow *et al.,* 2014). Climate change considerations being carefully measured with reference to matching for the tree component in case of agroforestry is far and few. One such study was carried out on *Prosopis africana* in the semi-arid region in West African Sahel, where seed distribution strategy was adopted. Based on the relationship of growth parameters, survival and wood density with reference to rainfall pattern, Weber *et al.* (2008) suggested that germplasm transfer of this species must be commenced in a single direction *i.e.,* from drier to wetter zones.

Climate change science and possible impacts of it on forests in general and tropical forests in particular is not understood well, the options of speculations are still continuing. However, there is a general consensus that what we call the saturation point in general sense when impacted as regards forest ecosystem is concerned, the catastrophic effects cannot be ruled out and we have to equip ourselves to face it. Therefore, we have the narrow options of tolerating and treating as the way forward when it comes to forest ecosystem. Rollinson (2007) lists some of the important actions needed to be considered as far as forests and climate change is concerned. They include reducing deforestation on one hand and encourage sustainable management of existing forests on the other hand to conserve carbon stocks. Through the activities of afforestation and reforestation to enhance carbon sequestration, sustainable use of biomass as a substitution of fossil fuel is required to reduce carbon emissions. Another important effort would be greater and sustainable use of wood and its products in reducing carbon foot prints. Therefore, a new momentum with clear strategic response from forests and forestry sector is the need of the hour as it can become a major institution in itself to support the political and economic actions to mitigate climate change. Understanding the impact of CO_2 responsiveness on the older forests ecosystem, interaction between elevated CO_2 and other biotic and abiotic factors is still not understood. Significance of adaptive genes in trees need to be examined for which focussed research on tree breeding and genomic studies are essential. All these pertinent aspects are probably still not known in case of tropical forests.

Forest management plans must aim at reducing the negative impacts of climate change on forests. By determining the timing and direction of forest adaptation, vulnerability of the forests can be reduced. Though, most of the impact of climate change on forest sector seems to be sensitive, there is an urgent need to incorporate the climate change adaptation strategies as an integral component while documenting forest management plans (Spittlehouse and Stewart, 2003).

Therefore, what is paramount importance in Indian context is to assess all the ongoing and proposed afforestation programmes especially with reference to climate change impact and arrive at suitable methods that encourages adaptation and participatory programmes aiming at strengthening the forests to face the climate change impacts both at regional and national level (Afreen *et al.,* 2011).

Using the process based and dynamic vegetation models, it has been possible to obtain spatial, temporal information at plant functional types, biomes or major vegetation types. Sukumar *et al.* (2016), are of the view that under future climate prediction, most of the forest grid points in higher rainfall zones are less likely to be impacted when compared to that of drier forests. They are of the opinion that nearly one third of the India's forested area is to be impacted to such an extent that they may be modified in character to another type before the end of the century and already studies by Telwala *et al.* (2013) in Sikkim Himalaya supports it. Considering the impact of climate, there is no doubt that India, during 21st century is highly susceptible to the climate change. Singh and Kushwaha (2016) stressed that there is need to develop capabilities to detect and predict the impact of climate change on deciduousness through long-term phenological network in tropics. Remote sensing techniques can generate valuable ecological information such as leaf level drought response and phenological patterns. Deciduousness has the potential to emerge as an important focus for ecological research to address critical questions in global modelling, monitoring, and climate change. Immediate attention not only by the policy makers, but, also by the end users of various forest produces is needed.

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(*Received :* January, 2017 *Accepted :* February, 2017**)**