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Climate Crisis and Escalating Threat to Forest Biodiversity

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Abstract
Forests are crucial resources for human welfare and development since ancient time. Forests globally are known to be critically important habitats in terms of the biological diversity they contain and in terms of the ecological functions they serve. Forests play a fundamental role in climate change. Forestry activities offer an important potential for reducing GHG emissions and increasing carbon sequestration. The geological past of India indicates that hundreds of forest species have disappeared over the years as they failed to adapt to changing circumstances because of geological events like massive volcanic eruptions, continental drift, or asteroid impacts. Climate change has a major impact on forest biodiversity through changing biome types and shifting forest boundaries. We can observe these changes through three variables: increases in average temperatures, changes in rainfall patterns, and an augment in the intensity and frequency of extreme events. To meet the challenges of global climate change, greenhouse-gas emissions must be reduced. A key challenge in addressing the threat to biodiversity for emerging economies is to balance conservation with the use of their natural resources for growth; and to find ways to protect vital natural resources, without causing suffering to vulnerable and poor citizens who depend on them for their daily subsistence needs.

Key words: Biological Diversity; Carbon Sequestration; Climate Change; Conservation; Extreme Events; Natural Resources.

Introduction:

Forests are one of the most biodiversity rich habitats on Earth. The boost in environmental awareness over the last few decades has underlined the want to enhance our understanding of the ways in which human race and biodiversity act together. The Government of India passed the Biological Diversity Act, 2002, with following objectives:- to regulate access to biological resources of the country with the purpose of securing equitable share in benefits arising out of the use of biological resources; and associated knowledge relating to biological resources; to conserve and sustainable use of biological diversity; to respect and protect knowledge of local communities related to biodiversity; to secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources; conservation and development of areas of important from the standpoint of biological diversity by declaring them as biological diversity heritage sites; protection and rehabilitation for threatened species; involvement of institutions of state government in the broad scheme of the implementation of the Biological Diversity Act through constitution of committees. In short, the Act is aimed to protect and regulate access to plant and animal genetic resources and traditional knowledge. A three tiered system of regulation is envisaged under the Biological Diversity Act, which consists of the National Biodiversity Authority (NBA), followed by State Biodiversity Boards (SBB) and local level Biodiversity Management Committees (BMC) (Tariyal *et al*, 2013). India's forests, which wrap nearly 20% of the country's geographic area, are important for biodiversity, biomass supply, watersheds and livelihoods of forest dependent communities (MoEF, 2009). Forests offer a wide range of goods and services. Goods include timber, fuel wood, as well as food products (berries, mushrooms, etc.) and fodder. As regards important services, forests and trees take part in the conservation of ecosystems, in maintaining quality of water, and in preventing or reducing the severity of floods, avalanches, erosion, and drought. Forests are endowed with a wide range of economic and social benefits, such as employment, forest products, and protection of sites of cultural value (FAO, 2006).

BIODIVERSITY OF THE INDIAN SUBCONTINENT

India is rich in its unique flora and fauna and famous worldwide for this incredible heritage. It is estimated that about 45,000 species of plants and 65,000 species of animals are found in India. The flowering plants comprise 15,000 species of which several hundred (5000-7500) species are endemic. Among the animal species diversity more than 50,000 species of insects, 4,000 molluscs, 6,500 other vertebrates, 2,546 fishes, 197 amphibians, 408 reptiles, 1224 birds and 350 species of mammals are found in different habitats Therefore, this great strength of flora and fauna put the country in the list of mega biodiversity centers (Hot-Spot) of the world. The mega biodiversity places of India are Western Ghat and Eastern Himalaya (MoEF, 2000 and Myers *et al.,* 2000).

FORESTS AND THEIR ECOLOGICAL SIGNIFICANCE

Forests have a potentially noteworthy role in climate change adaptation planning through maintaining ecosystem services and providing livelihood options. Forests control climate and the climate change process mainly by effecting the changes in the quantum of carbon dioxide (CO_2) in the atmosphere. Forests soak up CO_2 from atmosphere, and store carbon in wood, leaves, litter, roots and soil by acting as "carbon sinks". Carbon is then released back into the atmosphere when forests are cleared or burned. Forests by acting as sinks are considered to moderate the global climate. Generally, the world's forest ecosystems are expected to store more carbon than the entire atmosphere (FAO, 2006). Deforestation, mainly conversion of forests to agricultural land, is continuing at an alarmingly high rate. However, the net loss of forest is slowing down as a result of the planting of new forests and of natural expansion of forests (Tariyal *et al*, 2013; FAO 2006). Forests and trees are being planted for many purposes and at rising rates, yet the plantations still account for only 5 percent of total forest area (Tariyal *et al*, 2013). Quantifying the substantial roles of forests as carbon stores, as sources of carbon emissions and as carbon sinks has become one of the keys to understanding and modifying the global carbon cycle.

India is known for its varied forest ecosystems and mega biodiversity. It ranks 10th amongst the most forested nations of the world with 23.4 percent (76.87 million ha) of its geographical area under forest and tree cover (FSI, 2008; FAO, 2006). Globally forests are now regarded as the major repository of nature to be conserved and managed for posterity, and not to be regarded solely as an important source of revenue. In the Indian context, forests are a prominent feature of the Indian landscape, covering almost 79 million hectares which represents almost a quarter (23.8%) of the geographical area of the country (FSI, 2011). These forests are integral to the environment, economy, culture and history of the country. Almost 173,000 villages are classified as forest fringe villages, so there is obviously a great reliance of communities on forest resources. It is imperative to assess the likely impacts of projected climate change on forests, to implement adaptation measures both for biodiversity conservation and protection and for safeguarding the livelihoods of forest dependent people, and to ensure production of round wood for industrial and commercial needs. There are a number of studies done by various researchers on forest carbon. The biomass carbon stock in India's forests was anticipated about 7.94 MtC during 1880 and nearly half of that after a period of 100 years (Richards and Flint, 1994; Tariyal *et al*, 2013). The first available estimates for forest carbon stocks (biomass and soil) for the year 1986 are in the range of 8.58 to 9.57 GtC (Ravindranath, *et al.,* 1997; Haripriya, 2003; Chhabra and Dadhwal, 2004). As per FAO estimates (FAO, 2005), the total forest carbon stocks in India have increased over a period of 20 years (1986–2005) and amount to 10.01 GtC. The carbon stock projections for the period 2006–30 is projected to be increasing from 8.79 to 9.75 GtC (IISc, 2006) with forest cover becoming more or less stable, and new forest carbon accretions coming from the current initiatives of afforestation and reforestation programme (Ravindranath, *et al*., 2008).

THREAT TO FOREST BIODIVERSITY DUE TO CLIMATE CHANGE

Climate change refers to change in weather patterns, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. The increase in annual mean temperatures will cause the biggest problems for plants, animals, and human beings. Climate change is not just about averages, it is also a matter of extremes. Climate change is likely to affect minimum and maximum temperatures and trigger more extreme rainfall events and storms. The geological past of India indicates that hundreds of forest species have disappeared over the years as they failed to adapt to changing circumstances because of geological events like massive volcanic eruptions, continental drift, or asteroid impacts. Presently, humans are the most powerful agents of environmental change driving the latest wave of extinction. Human behavior has already caused the destruction of over one third of the world's forest. The rapidly rising demand for natural resources is resulting genes, species and habitat to vanish at an unprecedented rate. Even at the global level, these forests are important in terms of combating greenhouse gases, soil erosion and climate change. In a due time, as a result of use and abuse of these forests and with wrong or inappropriate property rights and institutional arrangements, they are subjected to severe degradation and depletion resulting in loss of biodiversity. The core causes of habitat and biodiversity loss are largely institutional and socio-economic. A key challenge in addressing the threat to biodiversity for emerging economies is to balance conservation with the use of their natural resources for growth; and to find ways to protect vital natural resources, without causing suffering to vulnerable and poor citizens who depend on them for their daily subsistence needs (Tariyal *et al*, 2013).

Impact of CC on forest ecosystems is a subject of recent origin. In this context biophysical models in association with regional CC scenarios need to be used to assess the impact of CC on forest ecosystems at national and regional levels in terms of the (i) shifts in boundary of forest ecosystems and upward movement of tree lines, (ii) forest ecosystem change matrix, (iii) change in species mix and composition of vegetation types, and (iv) species vulnerability to identify vulnerable forest ecosystems, regions and hotspots. Implications of CC on biodiversity, biomass production and net primary productivity also need to be kept in view in designing programmes of work (Anonymous, 2009). It is envisaged that the effects of CC on the sub-alpine and alpine plant species that inhabit mountain ranges with restricted habitat availability, above the tree line, would experience severe fragmentation, habitat loss, or even local extinction if they fail in moving to higher elevations (Singh *et al.*, 2010). Identification and management of corridors for facilitating effective movement of biota in the face of CC have, therefore, gained global attention. There is imminent need at the regional level, to have reliable information to predict the most vulnerable forest types as well as regions. Likewise, research based evidences are required to project future scenarios of shifts in boundaries, and/or to highlight potential corridors for movement of forest species and wildlife under changing climate. These aspects, and many more, require immediate attention of the planners, researchers, forest managers with adequate sensitization of stakeholders.

A study by Indian Institute of Science, Bangalore (Ravindranath *et al*., 2008) covering the forests of the entire country, based on analysis of the 35,190 forested grids, reported that more than two third of forested grids are likely to undergo vegetation change by the year 2100. The study indicated that all major forest types are likely to be impacted by the projected Climate Change; however, the actual impacts may be more as different species respond differently to changing climate. A few endemic species may show a steep decline in population and may even become extinct. These impacts are expected to have adverse socio-economic implications for the forest-dependent communities and the economy of the country. Moreover, the impacts of Climate Change on forest ecosystems are likely to be long-term and irreversible. On the positive side, the study reports that the average net primary productivity is projected to increase by 1.5 times for tropical evergreen forests but the rate of increase is expected to be lower for temperate deciduous, cool conifer and cold mixed forests. Approximately 275 million people in India are known to live in the forest fringes and earn bulk of their livelihood from forests (World Bank, 2002). It is also known that and more than 40 per cent of the forests in country are degraded and under-stocked (Aggarwal *et al*., 2009; Bhuguna *et al*., 2004). There are a number of geographical, demographic and socio-economic factors responsible for this degradation. In addition to the fragile ecosystems, increasing population with low agricultural production, large and unproductive bovine population, degraded community forests and restricted means of livelihood constitute a vicious cycle of poverty resulting in tremendous pressure on forests in the country.

A CREEPING IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS OF UTTARAKHAND

It has been projected by a few workers that in the face of climate change shifts in forest boundaries by latitude and upward movement of tree lines to higher elevations; changes in species' composition and vegetation types; and an increase in net primary productivity would happen (Ramakrishna *et al*., 2003; Xu *et al.*, 2007). Alpine plant species on mountain ranges of Uttarakhand with restricted habitat availability above the tree line will experience severe fragmentation, increased soil erosion, habitat loss, or even extinction if they do not move to higher elevations, particularly after an increase of 2ºC (Dirnbock *et al.,* 2003; Xu *et al.,* 2007). According to Cannone *et al.,* (2007), climate change is very rapidly affecting the alpine vegetation of Indian Himalaya. Alpine areas are particularly vulnerable to hydrological disturbances. Because of enhanced hydrological cycles (due to the rapid snow melt and more precipitation) and resultant increased surface instability and disturbance, unexpected changes in vegetation may occur. Change in temperature will narrow down seasonal temperature variation in Himalayas within an annual cycle. This will result in fall in the number of species of deciduous forests (which need a proper seasonal temperature to shed and regain leaves), and will promote only evergreen forests resulting in the loss of biodiversity (Singh *et al.,* 2010).

The anticipated effect on the environment and people's livelihoods in the Himalayan region could be substantial. The changes will certainly be complex and to date they are not fully understood. Therefore, there is an urgent need to study implications of climate and environmental change on people's livelihoods in the Himalayas. It is clear that the foreseen changes will affect the provision of Himalayan water resources (Eriksson, 2006). Due to a large number of anthropogenic activities the global climate has changed since last few decades. The main consequences of climate change are green house effect, global warming and ozone depletion (IPCC, 2007). The ever increasing demand for the resources of the population put the pressure on the biological resources of the world. Industrialization, urbanization, transportation and deforestation are main anthropogenic activities that change the environment and influence climate (IRC, 2002). Climate change is likely to have a number of impacts on biodiversity from ecosystem to species level. The most obvious impact is the effect that temperature and precipitation have on species, ranges and ecosystem boundaries. Any particular ecosystem consists of an assemblage of species, some of which will be near the edge of their ranges and others of which will not. Those at the edge of their ranges may need to move due to climate change (Lemoine and Böhning-Gaese, 2003). The major proximate causes of species extinction are habitat loss and fragmentation etc, extremely accerelated by climate change through various ways. The genus *Schizothorax* is represented by at least six endemic species in the high mountain lakes and streams, while two other genera of these snow trout, the genus *Ptychobarbus* and the Ladakh snow-trout (*Gymnocypris biswasi)* is a monotypic genus now thought to be extinct and are also unique to the Himalaya Hotspot (IUCN, 2004). The biggest factor of present concern is the increase in green house gases mainly CO_2 level which change the climate and weather pattern of the world. The shrinkage of glaciers, decreasing water flow of the perennial rivers depleting ground water level directly and indirectly affect the biodiversity of the subregion. Some of the most immediate effects of recent climate change are becoming apparent through affects on biodiversity. The life cycles of many wild plants and animals are closely linked to the passing of the seasons and climate. Many developmental processes of the organisms are dominantly dependent on day length and the other on temperature or precipitation. In principle, at least, this could lead to extinctions or changes in the distribution and abundance of species. These changes in climatic pattern disrupt the ecological wealth of this region. By 2000, the region had lost 15 per cent of its forest cover compared with the early 1970s. By 2100, it will have lost almost half its forests. Less than one-third of the dense forest on which many native species depend will survive in the western Himalaya, while less than three quarters in the eastern Himalaya will remain (NSE, 2006). Climate change during last few decades had a significant impact on the high mountain glacial environment. Glaciers are highly sensitive to minor changes in the atmospheric temperature. Therefore, glaciers are considered as very good indicators that help us to quantify changes in the Earth's climate. It is widely confirmed that climate change is the main factor behind the accelerated glacier retreat observed in the Himalayas.

FEW EVIDENCES OF CLIMATE CHANGE AND RESULTING IMPACTS ON FOREST BIODIVERSITY OF UTTARAKHAND

Negi (1989) found that forest trees along an altitudinal gradient of 600 - 2200 m altitude in Kumaun Himalaya vary with respect to periodicity of phenol-phases such as vegetative bud break, flowering, fruiting and leaf drop. These phenophases were found to be influenced by variations in temperature and rainfall changes over two consecutive years (1985-1987). For example, at approx. 2000 m altitude leaf initiation was advanced by a week in 1985 (spring temperature in March and April were 17.6 & 20.9 ºC, respectively) as compared to that in 1986 (spring temperature in March = 14.8 ºC and April = 16.5 ºC). However, this annual shift in occurrence of phenophases was not observed for all the species. In the year 1985 when the spring temperature was higher as compared to 1986 flowering was also advanced by 1-3 weeks (in tree species like *Quercus* spp., *Rhododendron arboreum, Pinus* *roxburghii* - the dominant forest trees) in 1985 as compared to 1986 (Negi 1989). It appears that plant taxa are impacted differently by CC calling for further detailed investigations. Spread of alien invasive species such as *Lantana, Eupatorium* and *Parthenium* spp.) in the natural forests has also been linked with CC, which will have a competitive impact on existing species. Research on alpine vegetation suggests that many species are able to start their growth with the supply of snow-melt water well before the monsoon begins in June (Negi *et al.* 1991). Growth and life cycles of these species are already being disturbed because of reduced water from snow melt. Increased incidences of forest fire are another prominent change that is linked with CC. The frequency, size, intensity, seasonality, and type of fires depend on weather and climate in addition to forest structure and composition. In four districts of Uttarakhand (Almora, Chamoli, Tehri and Pauri Garhwal), in one of the most devastating forest fires of recent decades on 27 May, 1995 a total of 2115 km^2 (between altitudes 600 m to 2650 m) was damaged severely (Semwal & Mehta 1996). A comparison of air temperatures during the fire season for the two years 1994 (no fire event) and 1995 (large fire events) in Binsar Wildlife Sanctuary, Kumaun Himalaya showed that in 1995 the air temperature was higher (Sharma & Rikhari 1997). It is expected that with the CC, scenario of the forests, both in terms of structure and functioning, is likely to change substantially. In the case of many dominant forest species of the region like sal (*Shorea robusta*), tilonj oak (*Quercus floribunda*) and kharsu oak (*Q. semecarpifolia*) seed maturation and seed germination coincide with monsoon rainfall. In wet conditions these species show vivipary. A rise in temperature and water stress may advance seed maturation, which might result in the breakdown of synchrony between monsoon rains and seed germination (Singh *et al*. 2010).

There is now a growing realization that conservation and rational use of biodiversity in the Himalayan region could bring enormous economic benefits to the inhabitants and contribute to the sustainable development of region. More than 80% of the population in the region is involved in agriculture, animal husbandry, forestry and other biodiversity dependent vocations. There is need to identify the climatic amplitude of the species that are of economic interest and are classified as rare and threatened growing in the Himalayan region, and conserving them in the protected areas with larger climatic amplitude so that species are able to shift their distribution ranges naturally in the event of changing climate (DST, 2010). The IPCC Third Assessment Report (TAR) (IPCC, 2001), identified mountain regions as having experienced above-average warming in the 20^{th} century, a trend likely to continue. Related impacts included an earlier and shortened snow-melt period, with rapid water release and downstream floods which, in combination with reduced glacier extent, could cause water shortage during the growing season. The TAR suggested that these impacts may be exacerbated by ecosystem degradation, pressures such as land-use changes, over-grazing, trampling, pollution, vegetation destabilization and soil losses, in particular in highly diverse regions such as the Caucasus and Himalayas. Upper tree lines, which represent the interface between sub-alpine forests and low stature alpine meadows, have long been thought to be partly controlled by carbon balance. In many mountains, the upper tree line is located below its potential climatic position because of grazing, or disturbances such as wind or fire. In other regions such as the Himalaya, deforestation of past decades has transformed much of the environment and has led to fragmented ecosystems. Although temperature control may be a dominant determinant of geographical range, tree species may be unable to migrate and keep pace with changing temperature zones (Singh *et al.*, 2010).

SUSTAINABLE FORESTRY IN THE STATE

Sustainable forestry in this region region has been identified as a part of desirable adaptation policies to improve regional sustainability in the National Mission for 'Sustaining the Himalayan Ecosystems', one of the eight missions under Prime Minister's National Action Plan on Climate Change. It calls for a combination of both standard silvicultural knowledge and involvement of communities with traditional ecological knowledge available in the realm of forest management. It is known that introduction of socially valued species with ecological keystone value, along with socially valued ecosystems (e.g. sacred groves) and socially valued cultural landscapes for implementation of JFM has facilitated biodiversity conservation linked sustainable forestry practices in certain parts of the ecosystem. Further extension of such traditional practices of forest management to larger parts of the Himalaya will be explored under the Mission (DST, 2010).

MITIGATION STRATEGY - CARBON SEQUESTRATION

Carbon sequestration refers to the long-term storage of carbon in the terrestrial biosphere so that the buildup of CO_2 in the atmosphere will be reduced or slowed down in order to improve environmental conditions and check the processes of environmental degradation (Yadava, 2011). A great significance of forests lies in regional and global C cycles because they store large quantities of C in vegetation and soil; exchange C with the atmosphere through photosynthesis and respiration; are sources of atmospheric C when they are disturbed by human or natural causes; become atmospheric C sinks during regrowth after disturbance; and can be managed to sequester or conserve significant quantities of C on the land (Brown *et al.,* 1996). In the context of climate change, forest ecosystems are of worth consideration because they can act as sources as well as sinks of CO_2, the most copious greenhouse gas (Haripriya, 2002; Tariyal *et al*, 2012).

CONCLUSION

Uttarakhand state is considered as the home of rich biodiversity which strongly need attention. Climate change is posing a challenge before us both at local and global level. Especially when we talk about this region, the problem is more severe because impacts are rapid and irreversible. With increasing magnitude of climate change, the need for planned adaptation becomes more acute. There is a strong need of adequate information on the status of biodiversity, trends in environmental change including climate change, and its potential impacts on biodiversity, human resources, expertise, institutional capacity, political commitments and the financial resources for planned adaptation measurement. Some important information on climatic parameters, physical and biological conditions, and socio-cultural and livelihoods situations in the Himalayas is necessary for generating consistent representative data. The information generated then could be used for sustainable development and for responding to climate change impacts. There is a strong need of ongoing scientific research and deepening our knowledge on ecosystems and their inherent natural (dynamic) processes (e.g., monitoring and measuring, as well as appraisal of biodiversity). Biodiversity is a result of historic and evolutionary processes, the possibility for artificial enhancement of biodiversity, creation or reconstruction needs to be assessed. Incorporation of biodiversity into sound ecological, well-adapted management concepts in forestry is an essential prerequisite for the sustainable conservation, stability and elasticity of one of the most area-extensive habitats on earth. There should be frequent consultations and joint bio-diversity programmes between neighboring countries.

References:

1. Aggarwal, A., Paul, V. and Das, S. (2009). Forest Resources: Degradation, Livelihoods, and Climate Change. In: Looking Back to Change Track (Datt, D. and Nischal, S., eds.).. New Delhi: TERI. pp.91-108.

2. Anonymous, 2009. Climate Change and India: Towards Preparation of a Comprehensive Climate Change Assessment. Ministry of Environment and Forests, Govt. of India. 24 pp.

3. Anonymous, 2010. Report of the Task Force- To look into problems of hill states and hill areas and to suggest ways to ensure that these states and areas do not suffer in any way because of their peculiarities. Planning Commission, Govt. of India, New Delhi. 112 pp.

4. Bhuguna, V. K., Mitra, K., Capistrano, D. and Saigal, S. (2004). Root to Canopy: Regenrating Forests through Community State Partnerships. New Delhi Winrock International India/ Commonwealth nForestry Association India Chapter. pp. 309-316.

5. Brown, S., Sathaye, J., Cannell, M. and Kauppi, P. 1996. Mitigation of carbon emission to the atmosphere by forest management. *Commonwealth For. Rev.,* 75 (1): 80–91.

6. Cannone, N., Sgrobati, S. and Guglielmin, M., 2007. Unexpected impacts of climate change on alpine vegetation. *Front. Ecol. Env.,* 5(7): 360–364.

7. Chhabra, A. and Dadhwal, V. K. (2004). Assessment of major pools and fluxes of carbon in
8. Dirnbock, T., Dullinger, S. and Grabherr, G. 2003. A regional impact assessment of climate and land-use change on alpine vegetation. *J. Biogeog.,* 30: 401–417.

9. DST, 2010. Mission Document on National Mission for Sustaining the Himalayan Eco- System under National Action Plan on Climate Change. Government of India, Department of Science & Technology, New Delhi.

10. FAO. (2005). State of the World's Forests. FAO, Rome.

11. FAO. (2006). Global Forest Resources Assessment 2005: Progress towards sustainable forest management. FAO Forestry Paper 147. Food and Agriculture Organisation of the United Nations, Rome.

12. FSI, 2011. India State of Forest Report 2011. Forest Survey of India, Dehradun, India.

13. FSI. (2008). Forest Survey of India, Ministry of Environment and Forests Government of India, Dehra Dun, India.

14. Haripriya, G. S., (2003). Carbon budget of the Indian forest ecosystem. Climate Change, **56:** 291–319.

15. Haripriya, G.S. 2002. Biomass carbon of truncated diameter classes in Indian forests. *For. Ecol. Mgmt*., 168: 1–13.

16. IISc (2006). Forest conservation and afforestation/reforestation in India: implications of forest carbon stocks and sustainable development. Report of project No. 6/2/2006-CCC. Indian Institute of Science, Bangalore, 560 012, India.

17. IPCC (2007). Special Report on The Regional Impacts of Climate Change: An Assessment of climate change. Inter-governmental Panel on climate change (IPCC).

18. IPCC, 2001. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Summary for Policymakers (available at: www.ipcc.ch).

19. IRC (2002). Climate Change and the Indian Subcontinent: India Resource Center (IRC) Retrieved October 23, 2002 from http://www.rediffnews.com.

20. IUCN (2004). The IUCN Red list of Threatened species. Gland, Switzerland: The world Conservation Union.

21. Lemoine, N. and Böhning-Gaese, K. (2003). Potential impact of global climate change on species richness of long-distance migrants. *Conservation Biology* 17(2):577–586.

22. Mats Eriksson (2006). Climate change and its implications for human health in the Himalaya. ICIMOD Newsletter - Sustainable Mountain Development in the Greater Himalayan Region, No. 50 11-13.

23. MoEF (2000). Annual Report 1999-2000, New Delhi: Ministry of Environment and Forests, Government of India.

24. MoEF, (2009). India's Forest and Tree Cover Contribution as a Carbon Sink.

25. Myers, N., Mittermeier, R.A., Mittermeier, da Fonseca, G.A.B. and Jennifer, K. 2000. Biodiversity hot spots for conservation priorities. *Nature*, 403: 853-858.

26. Negi, G. C. S. 1989. *Phenology and Nutrient Dynamics in Tree Leaves of Kumaun Himalayan Forests*. Ph.D. Thesis. Kumaun University, Naini Tal.

27. Negi, G. C. S., H. C. Rikhari & S. P. Singh. 1991. Phenological features in relation to growth forms and biomass accumulation in an alpine meadow of the central Himalaya. *Vegetatio* **101:** 161-170.

28. NSE, News Scientist Environment (2006). A Special Report on climate change on Himalayan forest. Retrieved October18, 2006 from http://www. News Scientist.com

29. Ramakrishna, R.N., Keeling, C.D., Hashimoto, H., Jolly, W.M., Piper, S.C., Tuker, C.J., Myneni, R.B. and Running, S.W. 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999. *Science*, 300: 1560-1563.

30. Ravindranath, N.H., Rajiv Kumar Chaturvedi., and Murthy, I.K., (2008). Forest conservation, afforestation and reforestation in India: Implications for forest carbon stocks. *Curr. Sci.*, 95(2): 216-222.

31. Ravindranath, N.H., Somashekhar, B.S. and Gadgil, M. 1997. Carbon flows in Indian responses and development options. *Climate & Dev.,* 2: 221–232.

32. Richards, J. F., and Flint, E. P., (1994). Historic land use and carbon estimates for South and

33. Science: **95 (2)**: 216-222.

34. Semwal, R. L. & J. P. Mehta. 1996. Ecology of forest fires in Chir Pine forests of Garhwal Himalayas. *Current Science* **70:** 426-427.

35. Sharma, S. & H. C. Rikhari. 1997. Forest fire in the central Himalaya: climate and recovery of trees. *International Journal of Biometeorology* **40**: 63-70.

36. Singh, S.P., Singh, V. and Skutsch, M. 2010. Rapid warming in the Himalayas: Ecosystem responses and development options. *Climate & Dev.*, 2: 221–232.

37. Tariyal, K., and Melkania, U. 2012. A Note on CO_2 Mitigation Potential of Himalayan Forest Ecosystems. Glimpses of Forestry Research in the Indian Himalayan Region (Special Issue on International Year of Forests-2011). *ENVIS Centre on Himalayan Ecology*. ISBN: 978-81-211-0860-7. Pp- 107-111.

38. Tariyal, K., Kaphalia, B., and Melkania, U. 2013. Forest Biodiversity and Conservation Measures with Special reference to India. Forest Biodiversity: Conservation and Management. *Pointer Publishers*. ISBN 978-81-7132-751-5. Pp- 1-16.

39. World Bank (2002). Biodiversity and Forests at a Glance– World Bank Assistance, 1992 - 2002. The World Bank Group, Washington D.C.

40. Xu, J., Shrestha, A., Vaidya, R., Eriksson, M. and Hewitt, K. 2007. The Melting Himalayas: Regional Challenges and Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods. ICIMOD Technical Paper, Kathmandu, Nepal. ISBN 978 92 9115 0472.

41. Yadava, A. K. 2011. Potential of agroforestry systems in carbon sequestration for mitigating climate changes in Tarai region of central Himalaya. *Nature & Sci.*, 9(6):72-80 (ISSN: 1545-0740). http://www.sciencepub.net.