Impacts of climate change on forest cover in India

N.H. RAVINDRANATH and R. SUKUMAR

Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India

SUMMARY

In India tropical moist deciduous, dry deciduous and wet evergreen forests dominate. The area under forest has been broadly constant since 1980. Projected changes in climate parameters such as temperature, rainfall and soil moisture are considered at regional level for India. A general increase in temperature in all regions and moderate and uncertain increase in south-west and north-east rainfall in all regions (except north-west India) and a marginal change in soil moisture are projected. Climate change could potentially result in increased productivity and shift forest type boundaries along altitudinal and rainfall gradients, with species migrating from lower to higher elevations and the drier forest types being transformed to moister types. Anthropogenic stresses such as human and livestock population pressures, land use changes, infrastructural factors, biomass demands and fragmented nature of forests will all affect forestry responses to changing climate parameters. Climate change factors are as yet not included in the forest conservation and development programmes given the uncertainites in projections of climate parameters as well as forest responses.

Keywords: climate change, forest impacts, India.

INTRODUCTION

Global models project that, as a consequence of possible changes in temperature, precipitation and soil moisture availability arising from increases in greenhouse gases, 14-65% (with a global mean of 34%) of the current forest area will undergo major shifts in vegetation types. Assessments of the potential impacts of climate change on forests are necessary for all countries in which the people depend significantly on forests for their livelihoods and long term planning is necessary for the promotion of forest resilience. In this paper, we summarise existing information on the forest types and their distribution in India, changes in forest area during recent years, projected changes in climatic parameters relevant to forest ecology such as temperature, rainfall and soil moisture, before making a cautious evaluation of climatic change impacts on tropical forests of the country. We also examine the anthropogenic stresses on forests that affect forest-climate relations, and finally consider the potential adaptation strategies and forest management policies.

AREA UNDER FOREST AND RECENT CHANGES

India has a geographical area of 328 Mha, a human population of 844 million (in 1991) and a population density of 257 persons/km^2. During the period 1951-80 about 4.3 Mha of forest was officially diverted to non-forest uses (FSI 1988). The area under forests (with tree crown cover >10%) as assessed from satellite imagery has practically stabilized around 64 Mha in recent years (FSI 1994, Ravindranath and Hail 1994). This is in sharp contrast to other tropical countries which are experiencing high rates of deforestation. What is of further significance is the continuous increase in the area under dense forest (tree crown density of >40%) in India from 1982 to 1990.

About 66% of forest area is below 600 m asl and 20% in the 600-1800 m asl altitudinal range. The forests of India can be broadly classified into 14 major types ranging from tropical through sub-tropical to temperate (FSI 1988). Of these the tropical moist deciduous and dry deciduous forests are the most extensive accounting for 64% of the total forest area. Tropical wet evergreen forests and sub-tropical pine forests are also significant with 8% and 7% of the total forest area respectively.

PROJECTED CHANGES IN CLIMATE PARAMETERS

Projections of climate change based on coupled ocean-atmosphere general circulation models (GCMs) for the south Asian region susggest that the mean temperature change would be in the range of 0.5° C to 2.5° C by about 2050 (IPCC 1996). Models which take into account only greenhouse gases generally project higher warming as compared to those which consider, in addition, sulphate aerosols (Lal *et al.* 1995, Carson this volume). There are even greater differences between these two classes of models in projections of precipitation changes. With only greenhouse gases an increase in summer precipitation of 5-15% is forecast, while the projections for winter precipitation are very variable in the models. When aerosols are added, a decline in summer precipitation is projected as a result of a decline in land-sea thermal contrast. However, all the models indicate considerable spatial variations.

Assessments of regional changes in climate parameters are more important than the global or continental mean changes and, further, seasonal changes are of consequence as compared to the mean annual changes. Based on GCM experiments incorporating greenhouse gases only, a climate change scenario for the tropics has been prepared by Hulme and Viner (1996). The parameters considered are changes in temperature, rainfall, length of dry season, soil moisture and interannual variation in rainfall.

When annual forest productivity is considered, Melillo *et al* (1996) suggest that annual growth is likely to increase in all zones due to the fertilization effect of increasing atmosphere CO_2 and increase in water use efficiency. On the other hand, forests may also suffer growth losses from effects of increasing climate stress on growth, from increased stress-induced mortality and so on (Solomon and Leemans 1990). The impacts of changes in climate parameters on forest ecosystems and species populations may not be uniform (Prentice *et al* 1993).

Paleo-vegetation and climate data are one means of understanding how natural vegetation is likely to respond to future climate change. While there have been several palaeo-vegetation studies of the desert environment in northwest India (cf. Swain *et al.* 1983, Singh *et al.* 1990), there have been few studies in the tropical forest regions of the sub-continent. There is evidence from pollen studies for savannization of tropical moist forests in North Kanara (13° 55' to 15° 31'N; 74° 9' to 75° 10'E) of Western Ghats at 3500 yr BP (Caratini *et al.* 1991), although it is not clear if this was due to a naturally drier climate or to clearing of forest by people. Stable carbon isotopic analyses of peats in the montane region of Nilgiris (11°-11° 30' N; 76° 20' E) of Western Ghats (Sukumar *et al.* 1993, 1995; Rajagopalan *et al.* in review) indicate shifts in the extent of grassland and forest in response to climate change.

POTENTIAL IMPACTS OF CLIMATE CHANGE ON INDIAN FORESTS

The forests in southern India are mainly in two distinctive belts, one along the Western Ghats and the other along the Eastern Ghats. The Western Ghats rise to over 2000 m asl, and their complex topography provides sites for a wide spectrum of tropical vegetation types from wet evergreen forest along the western slopes receiving high rainfall (typically >2000 mm/annum) and montane stunted evergreen forest and grassland (at altitudes >1800 m), through semi-evergreen forest, moist deciduous forest, deciduous forest and dry thorn forest in areas of lower rainfall to the east of the ghats.

A shift in vegetation type boundaries may be expected both along a west-east gradient (with moist forest types expanding further east) and along an altitudinal gradient (with species adapted to the warmer, lower elevations migrating to higher altitudes). The montane regions of the Western Ghats featuring a mixture of stunted evergreen forest and grasslands with sharp ecotones are a sensitive indicator of past climate change (Sukumar *et al.* 1993, 1995). With temperature increases and a reduction in frost incidence, the montane forests could potentially expand into grasslands, although with anthropogenic disturbances such as fires and conversion of grasslands into plantations of wattle and eucalyptus, it is more likely that these exotic plants (of C3 photosynthetic type) would establish further in the grasslands in the absence of management to restore the grasslands. An increase in dry season length could place some forest types such as dry and moist deciduous forests at increased risk from dry season fires. The central Indian forests are mostly moist deciduous and dry deciduous forests. Increased rainfall and soil moisture during the south-west monsoon could potentially transform these to moister vegetation types. Sal (*Shorea robusta*) forest characteristic of the moister belt could replace teak (*Tectona grandis*) forest in the drier belt.

The forests of northwest India are mostly dry deciduous and dry thorn forests. No change in soil moisture storage is indicated for this region. Thus there may be no scope for any significant changes in forest type or productivity. Northeast India has a wide diversity of tropical and sub-tropical forests and grasslands associated with the flood plains of rivers. The climate change scenario for northeast India is not very clear. There seems to be much greater variability in the various climatic parameters over even a small area. This region already experiences very heavy rainfall and any small changes in rainfall may not be of much consequence for vegetation. However, the projected increase in temperature in all the seasons is likely to result in shifts of lower altitude tropical and sub-tropical forests to higher altitude temperate forest regions, resulting in contraction or dying of some temperate vegetation types. It is important to remember that for this region, most of the tropical and sub-tropical forests are not government-controlled reserve forests, and hence are subject to clearing for slash-and-burn shifting cultivation at a rate much higher than in any other part of India. This consideration is likely to override any climate-related change in the coming decades.

It is important to note that these scenarios may be entirely different if climate change is driven according to the model incorporating sulphate aerosols (Lal *et al.* 1995).

IMPACT OF NON-CLIMATE MEASURES ON FORESTRY RESPONSE TO CLIMATE CHANGE

The impact of climate change on forests will be influenced by non-climate factors and further forest responses will also be affected by anthropogenic pressures.

Land for food production

Despite the fact that the population has nearly doubled during the last 30 years the area under crops has nearly stabilized at around 140 Mha since 1970 (Ravindranath and Hall 1995).

Further, given the low productivity of food crops (less than 2 t/ha/year) there is a large potential to double or treble food production without increasing the area under crops. Unlike the position in other tropical countries it is considered that forest lands are unlikely to be converted for food production on any significant scale. The Forest Conservation Act 1980 also bans such conversion of forest lands. This is contrary to the view of Zudeima *et al.* (1994) who project that the area under forest would sharply decline in the coming decade in India.

Human and livestock population density and infrastructure

India is home to 15% of the world's cattle, 10% of sheep and goats and 50% of buffaloes but has only 4% of global land area. Deforestation, or at least forest degradation, caused by livestock grazing pressure is significant in India (Brandon and Ramankutty in press). The grazing pressure on forests is about 5 livestock per ha of forest and pasture land. This heavy livestock grazing pressure will affect the forest regeneration, succession and potential shift of species driven by climate parameters. Infrastructure factors such as human settlements, roads, other communications and artificial water bodies are likely to interfere with climate change driven shifts in forests or species. The area under crops of 43% (142 Mha) is one of the highest among tropical countries. Thus forest areas are unlikely to expand even if the climate is suitable except in areas at high altitudes with low population density.

Biomass demands

Fuelwood is the dominant biomass demand on the forests. The current consumption level has been estimated to be 224 Mt (Ravindranath and Hall 1995) and is projected to increase to 350 Mt by 2005. Harvesting of shrubs and lopping of trees could affect plant diversity in the lower canopy due to opening of canopies; it may also lead to forest degradation and ultimately to invasion of pioneer species suppressing natural regeneration.

FOREST MANAGEMENT AND ADAPTATION STRATEGIES

Owing to the uncertainties involved in projections on climate change parameters and the response of forest vegetation, it is difficult to suggest region-specific adaptation measures. In the face of this uncertainty, reforestation strategies should emphasise conservation, diversification and broader deployment of species, seed sources and families. Planting programmes may have to deploy non-local seed sources, imported from southern latitudes or from lower elevations (Ledig and Kitzmiller 1992).

Currently the forest conservation and development programmes in India do not include climate change considerations in policy formulation, planning and implementation programmes. Any climate adaptation measure should be compatible with current goals of forest development such as biodiversity conservation, watershed protection and the provision of multiple forest products to local communities.

More reliable information is required on projected climate changes and forestry responses before regional adaptation measures are developed for policy makers and local communities.

ACKNOWLEDGEMENTS

This study is based on a number of investigations conducted under the projects funded by Ministry of Environment and Forests, New Delhi. The paper is based on an earlier compilation presented at the conference on 'Potential impacts of climate change on tropical forest ecosystems' at San Juan, Puerto Rico during April 24-28, 1995.

REFERENCES

BRANDON, C. and RAMANKUTTY, R. 1993 Toward an environmental strategy for Asia. World Bank Discussion Paper 224. Washington D.C.

CARATINI, C., FONTUGE, M., PASCAL, J. P., TISSOT, C. and BENTALEB, I. 1991 A major change at ca 3500 years BP in the vegetation of the Western Ghats in North Kanara, Karnataka. *Current Science* **61**(8, 9 and 10):669-672.

FSI. (Forest Survey of India) 1994 State of forest report 1993. Forest Survey of India, Ministry of Environment and Forest, Dehra Dun, India.

FSI. 1988 State of forest report 1987. Forest Survey of India, Ministry of Environment and Forests, Dehra Dun, India.

HULME, M. and VINER, D. 1995 A climate change scenario for assessing the impact of climate change on tropical rain forests. A report prepared by the Climate Change Unit for WWF (US), University of East Anglia, Norwich, UK.

IPCC 1996 *Climate change: impacts, adaptation and mitigation options*. Cambridge University Press.

LAL, M., CUBASCH, U., VOSS, R. and WASZKEWITZ, J. 1995 Effect of transient increase in greenhouse gases and sulphate aerosols on monsoon climate. *Current Science* **69**(9):752-763.

LEDIG and KITZMILLER 1992 Genetic strategies for afforestation in the face of global climate change. *Forest Ecology and Management* **50**:153-169.

MELILLO, J. M., PRENTICE, I. C., SCHULZE, D., FARQUHAR, G. and SALA, O. 1996 Terrestrial ecosystems: responses to global environmental change and feedbacks to climate. Chapter 9, IPCC WG I Second Assessment Report. Cambridge University Press.

PRENTICE, I. C., SYKES, M. T., CRAMER, W. P. 1993 A simulation model for the transient effects of climate change on forest landscapes. *Ecological Modeling* **65**:51-70.

RAJAGOPALAN, G., SUKUMAR, R., RAMESH, R., PANT, R. K., RAJAGOPALAN, G. (Forthcoming) Late quaternary climatic changes inferred from carbon isotope analysis of peats in southern India. *Global Biogeochemical Cycles* (submitted).

RAVINDRANATH, N.H. and HALL, D.O. 1994 Indian forest conservation and tropical deforestation. *Ambio* **23**(8):521-523.

RAVINDRANATH, N. H. and HALL, D.O. (Forthcoming) *Biomass, energy and environment - a developing country perspective from India*. Oxford University Press (in press).

Singh, G., Wasson, R. J. and Agrawal, D. P. 1990 Vegetational and seasonal climate changes since the last full glacial in the Thar desert, Northwestern India. *Review of Paleobotany Palynology* **64**:351-358.

Solomon, A. M. and Leemans, R. 1990 Climatic change and landscape ecological response: Issues and analysis. *In*: Boer, M.M. and de Groot, R.S. (eds.) *Landscape ecological impact of climate change*, IOS Press, Amsterdam, pp. 293-316.

Sukumar, R., Suresh, H. S. and Ramesh, R. 1995 Climate change and its impact on tropical montane ecosystems in southern India. *Journal of Biogeography* **22**:533-536.

Sukumar, R., Ramesh, R., Pant, R. K. and Rajagopalan, G. 1993 A d13C record of late Quaternary climate change from tropical peats in southern India. *Nature* **364**:703-706.

Swain, A. M., Kutzbach, J. E. and Hastenrath, S. 1983 Monsoon climate of Rajasthan for the Holocene; estimates of precipitation based on pollen and lake levels. *Quat. Res.* **19**: 1-17.

Zuidema, G., van den Born, G. J., Alcamo, J. and Kreileman, G. J. J. 1994 Simulating changes in global land cover as affected by economic and climatic factors. *Water, Air and Soil Pollution* **76**:163-198.