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# REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

## (PHASE VI)

teri TATA ENERGY RESEARCH INSTITUTE
NEW DELHI

# REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

## (PHASE VI)

Submitted to the
International Development Research Centre, Canada





Tata Energy Research Institute
New Delhi

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# Impacts of climate change on Indian forests

O.N. Kaul and Vishwanath Shah

## Introduction

Out of a total geographical area of 328.726 million ha, forest ecosystems in India occupy over 66.8 million ha constituting nearly 20.3% of the total land area of the country (Table 1), forestry being a major land use next to agriculture. Nearly 41.4% (136.177 million ha) of the total geographical area is under agriculture (probably the highest in the world) and over 101.8 million ha (31.0%) is under other land uses. No returns exist for 7.3% (23.877 million ha) of the total land area of the country.

While the land use statistics (Table 1) place the area under forests at 66.858 million ha, the area officially recorded as Forest, with or without tree cover, by the State Forest Departments is of the order of 75.18 million ha or 22.8% of the total geographical area (1,2). Furthermore, the reconciled estimates of actual forest cover arrived at by the National Remote Sensing Agency (NRSA) and the Forest Survey of India (FSI) was only 64.2041 million ha (1987 assessment based on imagery of 1981-83) and 64.0134 million ha (1989 assessment based on 1985-87 imagery). This works out, respectively, to 19.52% (1987 assessment) and 19.47% (1989 assessment) of the total geographical area of the country (1, 2). There has thus been a reduction of 0.19 million ha (0.29%) of forest cover over a four year period (1981-83 to 1985-87); the annual rate of loss being 47,500 ha. The actual forest cover is 85.4% and 85.1% of the officially recorded forest area (75.18 million ha) according to 1987 and 1989 estimates respectively.

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## Resource base

### *Floral regions*

The forest flora of most parts of the Indian subcontinent is now fairly well known (4) though there are certain regions, e.g., the richer areas in the Northeast, which are rather imperfectly explored. The flora of India varies considerably in different parts of the country both in specific identity and in the number of species. Some species occur throughout the country whilst others are restricted to very small areas.

Comparative studies of the recorded floras of the various parts of the country have led to the recognition of a number of floral regions each with characteristic features. These regions are: (i) Western Himalayan, (ii) Eastern Himalayan, (iii) Indus Plain, (iv) Gangetic Plain, divisible into dry humid and tidal areas, (v) Central India, (vi) West Coast (Malabar), (vii) Deccan Plateau (with Carnatic), (viii) Northeast India, and (ix) Andaman and Nicobar Islands. The Western Himalayan flora differs from the Eastern Himalayan in the greater representation of conifers. While the European element is conspicuous in the former, the Malayan, Chinese and Burmese are prominent in the latter. The Indus plain flora has received important North African components. If the floras of the nine regions mentioned above are compared with those of adjacent countries, affinities are brought out suggesting the probable origin of the differences. It is evident that there is no 'Indian flora' as a separate entity, but the vegetation of the country is compounded of several elements which are present in very different proportions in different areas. These elements are, in order of dominance for the country as a whole: (i) Malayan, (ii) European and Mediterranean, (iii) Indo-African, (iv) Tibetan and Siberian, practically confined to the Himalayas, and (v) Chinese and Japanese, mainly in the Eastern Himalayas. All the regions have the majority of their species in common but also an appreciable number that are peculiar to them, or are common with only some of the other regions (5).

India has a high degree of endemism in its flora second only to Australia (6). It has been computed that at least 47% of the species of dicotyledons in the country are endemic, the largest proportion occurring in the Himalayan region which has been isolated by glaciation and orogenesis. The Himalayan forests are also the largest reservoirs of biodiversity, genetic variability and gene pools.

| Land Use | | Area (Million ha) | % of the total reporting area | % of the total geographical area |
|---|---|---|---|---|
| 1. | Forests | 66.858 | 21.9 | 20.3 |
| 2. | Area not available for cultivation | | | |
| (a) | Area under non-agricultural uses | 20.809 | 6.8 | 6.3 |
| (b) | Barren and unculturable land | 20.391 | 6.6 | 6.2 |
| 3. | Other uncultivated land (excluding fallow) | | | |
| (a) | Permanent pastures and other grazing land | 11.848 | 3.9 | 3.6 |
| (b) | Land under miscellaneous tree crops and groves not included in net area sown | 3.535 | 1.2 | 1.1 |
| (c) | Culturable wastelands | 15.626 | 5.1 | 4.8 |
| 4. | Fallow lands | | | |
| (a) | Fallow other than current fallow | 11.134 | 3.7 | 3.4 |
| (b) | Current fallow | 18.471 | 6.1 | 5.6 |
| 5. | Agriculture (Net area sown) | 136.177 | 44.7 | 41.4 |
| 6. | Total reporting area | 304.849 | 100.0 | |
| 7. | Area for which no returns exist | 23.877 | | 7.3 |
| 8. | Total geographical area | 328.726 | | 100.0 |

Note: Area officially recorded as Forest (with or without tree cover), by the Forest Departments, is 75.18 million ha (22.8% of the total geographical area) (1,-2).
Source: (3).

## *Forest types*

The extensive dispersion of forest over the Indian subcontinent is accompanied by considerable diversity in their specific composition. Accordingly, the forests of the country have been divided into 16 Type--Groups (4) ranging from Tropical Wet Evergreen forests to Alpine types; the Tropical Deciduous types (both moist and dry) constituting the bulk (65.48%) of our forests. Nearly 8% of the actual forest cover consists of Tropical Wet evergreens, just about 9% of montane Subtropical forests including Subtropical pine (Pinus roxburghii - over 6%) and over 10% of montane Temperate and Alpine forests (1).

### Altitudinal distribution

The altitudinal distribution of the actual forest cover for the country is shown in Table 2. Over two-thirds of the actual forest cover in the country is located at elevation less than 600 m and the occurrence of forests is negligible over 4,000 m.

Table 2: Altitudinal Distribution of Actual Forest Cover (1987 Assessment)

| Altitude (m) | Geographical area | Actual forest cover | Actual forest cover as % of geographical area | Actual forest cover as % of total |
|---|---|---|---|---|
| | (Million ha) | | | |
| Upto 600 | 255.3 | 42.6276 | 16.7 | 66.4 |
| 600-1,800 | 43.4 | 16.5057 | 38.0 | 25.7 |
| 1,800-4,000 | 30.0 | 5.0708 | 16.9 | 7.9 |
| Total | 328.7 | 64.2041 | 19.52 | 100.0 |

Source: (1).

**Species composition**

Of the total recorded forest area of 75.18 million ha, coniferous forests constitute 4.1 million ha (5.5%), the balance of 94.5% (71.1 million ha) consisting of non-coniferous species. While relatively pure coniferous forests are situated in the high mountain areas of Northern and North-eastern regions and there are also extensive gregarious forest of sal (16%) and teak (13%), perhaps both as a result of human interference, and a few other species of local occurrence, the moister semi-evergreen and evergreen forests are composed of a large number of species. Bamboos (including plantations) occur in nearly 9% of the recorded forest area (7). Consequently, the utility of different species and their values in the context of present uses and future utilisation, varies from region to region.

**Forest cover density**

Whereas the outer Himalayan forests and evergreen forests of the West Coast and Northeast are fairly well stocked, large areas in Central India region, Indo-Gangetic plain and in the coastal strips and in other fertile valley systems are either partially stocked or entirely devoid of forests. Of the actual forest cover of over 64.01 million ha (Table 3) only 37.8470 million ha are of adequate density (crown density 40% or more), while little over 25.74 million ha are open forest with crown density varying from 10 to 40%. Over 0.42 million ha constitute the mangroves. Thus, the effective forest cover (37.8470 million ha- 1989 assessment) is limited to 11.51% of the geographical area of the country.

Table 3: Actual Forest Cover by Density Classes

| Density class | 1987 Assessment (1981-83 Imagery) (Million ha) | 1989 Assessment (1985-87 Imagery) |
|---|---|---|
| 1.Dense Forest (Crown density above 40%) | 36.1412 (10.99) | 37.8470 (11.51) |
| 2.Open Forest (Crown density 10 to 40%) | 27.6583 (8.41) | 25.7409 (7.83) |
| 3.Mangroves | 0.4046 (0.12) | 0.4255 (0.13) |
| Total | 64.2041 (19.52) | 64.0134 (19.47) |
| 4. Scrub Area (Tree lands with less than 10% crown density) | 7.6796 (2.34) | 6.6121 (2.01) |

Note: Figures in brackets indicate percentage of the total geographical area.

Source: (2)

**Growth and yield**

The growing stock of the actual forest cover (64.2041 million ha) in Indian forests ranges from as low as 10 $m^3$ per ha in Rajasthan to as high as 277 $m^3$ per ha in the coniferous forests of Kulu valley, the average growing stock being 65 $m^3$ per ha (1,2). The total estimated growing stock, of wood, in the country is placed at 4,196 million $m^3$ while the recorded production of wood (timber and fuelwood) during the last 10 years has varied from 26 million $m^3$ to 32 million $m^3$; average annual production being of the order of 30 million $m^3$. Unrecorded production in the form of dead/dying and annually fallen wood which is removed as head-loads for domestic energy is estimated at 22 million $m^3$. Thus, the average annual production, within silviculturally permissible limits, is 52 million $m^3$ which may reasonably be assumed to be the net annual increment amounting to 1.24% of the total growing stock. Considering the recorded forest area of the country (75.18 million ha), the average annual production of 52 million $m^3$ works out to 0.7 $m^3$ per ha.

On the basis of field inventories carried out by FSI, it is reported that India's forests are not capable of producing more than 90 million $m^3$ of wood, annually, because of the existing state of our forests. This figure is about three times greater than the current annual average production of 30 million $m^3$. In fact, the annual production of wood in any year since the beginning of scientific forest management in India has not exceeded 32 million $m^3$ (2).

### Natural regeneration

Excessive grazing, frequent fires and other biotic factors have affected adversely the natural regeneration of our forests to a considerable extent. Indications are that except in Andaman and Nicobar Islands, natural regeneration is either absent or inadequate in 52.8% of the forest area of the country (1), which is rather alarming.

### Man-made forests

While the existing naturally regenerated forests of the country continue to provide wood raw material, natural regeneration systems are not able to adequately cope up with the rising demands of wood because of many limitations including the absence of natural regeneration in a large proportion of our forests. This has led to the adoption of artificial regeneration practices and so far (1988-89) plantations have been raised over an area of over 15.365 million ha (8, 9).

### *Minor forest products*

Reference needs to be made to a host of non-wood forest products (NWFP) like canes, gums, resins, dyes, tannin, lac, fibre, floss, medicinal plants, etc. obtained from forests which sustain a large number of rural cottage and other industries and are also exported.

### *Native fauna*

India is gifted with a very rich and varied fauna due to the diversity in her physical features revealing itself in the corresponding differences in the types of forest and the variety of wildlife, which can live in such physically complex areas. There are about 500 different species of mammals, over 1,200 species of birds, 250 species of snakes, about 30,000 species of insects and many species of fish, reptiles and amphibians besides gorgeous and gigantic oceanic fauna. Some unique species like the gaur - the biggest oxen, the black buck, four-horned antelope, the musk deer and the lion tailed macaque are found no where else in the world.

The existing wildlife in India is an admixture of Indian, Indo-Chinese, Ethiopian and European elements, each predominating in those parts of the country which are most suited to their requirements. The rate of endemism is 62%, 33%, 8% and 4% in amphibians, reptiles, mammals and birds respectively (10).

### *Grasslands*

Grass and grazing constitute the major source of fodder in India. While grasses as fodder are not cultivated on any scale in the country, most of the grass production is obtained from natural grasslands within forest areas and areas outside the forests. The extent of grass producing areas in the country (excluding forest) is estimated to be of the order of nearly 44 million ha or over 13% of the total land area of the country (11).

Most of the grasslands in the country are very poor, degraded and overgrazed and as such their productivity is very low which is estimated to be, on the average, about 3 and 1.5 tonnes/ha/year from forest and other grass producing areas respectively (12).

## Protected areas and nature reserves

Data obtained from landsat imagery of 1985-87 (1989 assessment) put the extent of mangrove cover in India at 425,500 ha. However, according to field surveys the total mangrove area, including the area permanently under water, is reckoned at about 674,000 ha (13). Wetlands which exhibit significant ecological diversity, primarily because of climatic and topographical variability extend over an area of over 4 million ha (14).

There are 73 and 412 (1990) national parks and sanctuaries which constitute over 4 and 17% of the total geographical area and recorded forest area (75.18 million ha) of the country, respectively (15). A network of 188 preservation plots exits throughout the country covering an area of over 8,400 ha both in natural forests and plantations (16). Thirteen sites (3,427,500 ha) have been proposed to be declared as biosphere reserves (17).

India has a coastline of nearly 7,517 km and about 2 to 5 m of land, on an average, is reported to be lost every year due to sea erosion at different places. Apart from other economic activities like fishing, exploitation of petroleum resources, etc., a number of popular beach/sea resorts as centres of recreation have been developed. Large areas in the country are ecologically fragile.

## Climatic changes

In a future scenario of doubled Carbon dioxide, the Intergovernmental panel on Climate Change has indicated the following climatic changes for Southeast Asia (18, 19).

- Current best estimates for the year 2020 in Southeast Asia (5 -30 °N, 70°-102 E) indicate general warming will occur throughout the year by 1 to 2°C. Precipitation will change little in winter but generally increase throughout the region by 5-15% in summer. Summer soil moisture will increase by 5-10%.

- Sea level is expected to rise mainly due to the thermal expansion of the oceans and the melting of some land ice. Sea level will rise by about 20 cm (with a probable range of 10-32 cm) by 2020, and by 2070 it will have risen by about 45 cm (with a range of 33-75 cm).
- With the possible exception of an increase in the number of intense showers, there is no indication yet that weather variability will change in the future.
- There are no indications about the frequency and intensity/shifts of tropical and mid-latitude storms from climatic models.

The above indications are based on simulation results of various climate models and, in general, confidence in these estimates is low especially for changes in precipitation and soil moisture.

From the above, it can be seen that the main impacts of global warming on Asia are expected to be sea level rise and a possible increase in climatic variability. The areas sensitive to sea level rise in Asia are the major deltas, such as the Ganges-Brahmaputra-Meghna delta of Bangladesh and the Mekong delta of Viet Nam, and low-lying islands like the Maldives.

### *Impacts on forests*

In view of the great diversity in its physical features and climate and the extensive dispersion of forests accompanied by considerable variation in their specific composition, the impacts of climate change on forests, in India, are expected to be different in different regions of the country.

Regional rise in temperature could create moisture stress particularly in the drier parts of the country which in turn could cause poor microbial and mycorrhizal activities and increased drought conditions leading to loss of tree vigour and susceptibility to insect and fungal attack. Most of the sal (Shorea robusta) forests in the Shivalik and peninsular India are today experiencing higher rate of mortality primarily due to drought conditions (20,21). The dying process may take as long as 2 to 10 years.

Inadequate soil moisture during drought year seems to be a cause of heavy sal mortality in dry regions as well as along water courses in Bihar (22). Sal trees along water courses develop superficial root systems when the water table is high. During persistent drought conditions these root systems, not used to moisture deficiencies, experience excessive drought and the trees die. On poor or shallow soils of dry regions even the normal soil moisture fluctuations can very soon approach critical levels for survival of sal. On the other hand, in years of scanty rainfall during drought years, surface rooters stand better chance of survival by utilizing the surface moisture available (23). In Uttar Pradesh, investigations of the severest and most widespread drought of 1907-08 in the moist plains sal forests revealed that while in some cases trees died on a large scale, over patches of considerable area, elsewhere, mortality was in small groups (23).

There is increased evidence of lowering of water table in dry deciduous forests of Madhya Pradesh. While in 1951 the average depth of water in South Raipur Forest Division was 7.33 m, it receded to 8.95 m in a span of 15 years (1966), going further down to 11.22 m in 1988 (24). Lowering of water table has been correlated with the mortality of sal (23, 25, 26). Under abnormal rainfall and temperature conditions, the drought period lengthens beyond the normal limit of tolerance leading to mass mortality of sal (27).

Future increases in temperature could considerably increase the rate of sal mortality in India. Other exacting species growing in arid and semi-arid conditions may similarly be affected by the lack of available moisture. However, it is difficult to predict the extent to which moisture stress caused by increased temperature would be offset by increase in levels of precipitation. It is likely that surface rooters may survive the stress conditions during summer drought periods.

Increase in temperature particularly in the high latitude forest may enhance the breeding conditions for insects and pests and extend their ranges. This could endanger pure stands of natural forest as well as monocultural plantations being raised in the country. Most of the gregarious species in India grow in pure stands and therefore, may be prone to increased insect and pest damages in future.

Fire damage is expected to increase with the susceptibility of forests. Warmer drier sites could have a higher incidence of severe fires, specially where stands are in a state of decline because of climatic change. Occurrence of frequent fires is a major cause of injury to forests in the country. Retrogression caused by forest fires may completely alter the composition of forests by the elimination of fire tender species as seen in the substitution of deciduous forest for moist evergreen forest in many places, and of scrub or bamboo breaks for evergreen hill forest in the higher Himalayas. Tropical wet evergreen forest which is exceptionally sensitive to fire has been eliminated by fire from large tracts in South India in favour of more resistant species of the deciduous forest. The abrupt edge of the evergreen forest often reveals this history. Similar is the driving back of the temperate evergreen forests in favour of grasslands in South India, though lack of frost hardiness in the trees is also believed to play a part.

Even in the case of trees that are fairly fire hardy when above a certain size, fire will effectively prevent all regeneration except for a limited number of specially adapted species. Forests comprising of fire sensitive species as well as those where deliberate burning is practiced would, therefore, be exposed to increased risks of fire damage. Chir pine forests, and tropical dry deciduous forests could be exposed to increased risks of forests fires. The north- eastern region where shifting cultivation is practiced could similarly experience high incidence of forest fires due to increased temperature.

Under the scenario of doubled carbon dioxide, area under subtropical forest is expected to decrease by 22% whereas rain, wet, moist and dry areas of tropical forests are expected to increased by an extent of 28% (28). The area of subtropical forests in India could, therefore, decrease from a current level of 5.77 million ha to 4.50 million ha. The increase in extent of tropical forests could be about 14.56 million ha amounting to an area of 66.56 million ha.

The geological history of the flora of the Jhelum valley in Kashmir reveals existence of rich deposits of fossil impressions in some of the Karewa clays laid down in the Tertiary lake of which a part still exists. Identification of the leaves and other parts of a large number of species has been possible and the evidence has been greatly extended by fossil pollen. The most interesting features are the proof that oaks, now virtually absent from the valley, once predominated, and that other coniferous genera such as Larix were present though no longer found in part of the Western Himalaya now (29). Palynological evidence also suggests that the subtropical and montane temperate flora extended more widely in protohistorical times than at present. Pollen grains recovered from Maski (Andhra Pradesh) in lime deposits dating to second century B.C. have been identified as resembling those of pine, Brassica, Campanula, Stellaria, etc. Some pine tracheids have also been identified (30). The present vegetation of this site in gneissic country in Andhra Pradesh is predominantly dry deciduous scrub.

The above, however, could be an exception as available evidence indicates that the climate and vegetation of India have been essentially stable during the last five millennia, except for changes brought about by biotic factors attendant upon settling of virgin land and possible slight shifts in monsoon regime and drainage pattern which have probably accentuated retrogression (31).

Knowledge of the Harappan Period (3000-1500 B.C.) tends to establish that the then climate, although not arid, was certainly dry. Forests and marshlands must have existed, but the forest need not have been very moist (32).

At the time of Alexander's invasion and retreat, Sind was perhaps still a fertile track although by AD 712 Southern Baluchistan had certainly reached its present aridity. The Indus basin might have, however, retained a somewhat moister climate till later times. Dense forests grew near Ohind, sufficient to enable Alexander to construct the first Indus flotilla. Hiuen-Tsang in his record of the climate and vegetation of India informs that in general the plains below the western mountains were dry and saline although there were dense and shady forests near Jallandhar, now a typical dry tract; there were good forests and rivers near Ahichhatra (near Barielly) and Malwa was well forested. This indicates that while desert conditions had settled in the lower Indus valley, the south-western part of Rajasthan and the Punjab plains from Multan to Jallandhar had not been desiccated to anything like their present condition.

It may be concluded that while a certain degree of desiccation has certainly taken place, the vegetation and climate in northern India were not much different 2000 years ago from what they are now (32). Deforestation has proceeded apace and the local climate rather than natural climate has changed and has caused a profound change in the vegetation.

In view of the scant information available for vegetational shifts in India, no conclusions can be placed on record regarding future zonal shifts of vegetation. Marginal forest areas, on the higher extremes of temperature ranges, like the tropical thorn forests may suffer an extinction of species. Desertification process in the Kutch region could be catalyzed increasing the extent of desert thorn forests in states of Rajasthan, Gujarat, etc. Warming may also tend to raise the timber line in the Himalaya. The high level Himalayan species like birch, junipers, etc., of the Western Himalaya and Rhododendrons of the Eastern Himalaya could encroach into erstwhile subalpine and alpine regions, the latter, in their turn, having moved higher up in the Himalaya.

While in some areas, forests may expand because of warming, in some others there may be increased productivity of forests due to $CO_2$ fertilisation effects (increased photosynthesis). This is, however, open to question because it is not certain that increasing $CO_2$ concentrations would increase the efficiency of use of growth limiting inputs like water, N, P etc., in the context of changed climatic conditions.

It has been stated that regeneration would be enhanced for species with seed and vegetative reproduction. However, success rate of plantation establishment could be reduced. This would mean that those species which are being regenerated primarily through plantation programmes like e.g. Teak, Eucalyptus could suffer from regeneration problems because of increased harshness of site conditions and increased competition from other vegetation.

Sea level is expected to rise mainly due to thermal expansion of the oceans and melting of some land ice by about 20 cm by 2020 and by 2070 it would have risen by about 45 cm. Submergence of coastal regions in the country could lead to a loss of existing coastal and estuarine ecosystems and creation of new ones. The Sunderbans of West Bengal and Casuarina plantations raised along the Indian coast could suffer inundation and consequent loss of valuable ecosystems.

Changes in the habitat and availability of food and water may increase pressures on wildlife thus affecting their very existence. In case of endangered species, such changes could be disastrous. Since most natural ecosystems, particularly forest could experience increased mortality and associated short or long term losses in productivity, wildlife could be significantly disrupted. Vegetational changes in the past have had adverse impact on the country's wildlife. The swamp deer is known to have crowded the reed beds of the Indus. Tens of thousands of black buck were estimated to inhabit the Punjab region. The rhino and the wild buffalo, favouring moist conditions, inhabited many terrains of Western India which are deserts or semi-deserts today. The tiger population had reduced from 40,000 at the turn of the century to only 1,827 in 1972. Although indiscriminate game hunting and poaching is one of the reasons for this unfortunate trend, it is also certain that vegetational and consequent climatic changes have significantly altered the number and distribution of wildlife in India. Logical extrapolation of the trend would mean that future climatic and vegetational changes might similarly affect wildlife by causing changes in natural habitat conditions.

As climatic changes are expected to affect the extent and nature of forest ecosystems, they would consequently result in loss of biodiversity in general and the survival of vulnerable/endangered species in particular through changes in population size and distribution. The reasons for this would be changes in pattern of precipitation, evaporation, wind, frequency of storms, fire, sea level rise, and loss of coastal wetlands and coral sites. The present human land use practices would be impediments to shifting of their ranges. Besides, spread of forest tree species and corals may not keep pace with the climatic changes (10). The effect would probably be more pronounced in the Himalayan region which has high biodiversity, genetic variability and gene pools.

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