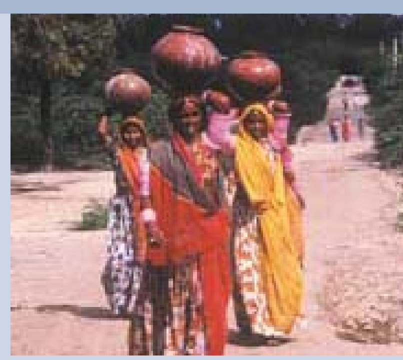
Executive Summary



Executive Summary

Executive Summary

India is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Government of India attaches great importance to climate change issues. The Convention aims to stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system. Eradication of poverty, avoiding risks to food production, and sustainable development are three principles embedded in the Convention. Information provided in the Initial National Communication is in terms of guidelines prescribed for Parties not included in Annex I to the UNFCCC and the inventory is prepared for the base year 1994 as stipulated.

India is a vast country covering 3.28 million km^2 with diverse surface features. India occupies only 2.4 per cent of the world's geographical area, but supports 16.2 per cent of the global human population. India is endowed with varied soils, climate, biodiversity and ecological regimes. Under such diverse natural conditions, over a billion people speaking different languages, following different religions and living in rural and urban areas, live in harmony under a democratic system.

NATIONAL CIRCUMSTANCES

India's land surface may be classified as (a) the Great Mountain Wall of the North; (b) the Northern Plains; (c) the Great Southern Peninsular Plateau; (d) the Coastal Plains; and (e) the Islands. India's unique geography produces a spectrum of climates yielding a wealth of biological and cultural diversity. Land areas in the north have a continental climate with high summer temperatures with cold winters when temperatures may go below freezing. In contrast are the coastal regions of the country where the temperature is more even throughout the year and rains are more frequent. There is large variation in the amounts of rainfall received in different parts of the country. Average annual rainfall is less than 13 cm in the Thar desert, while at Cherrapunji in the North-East it is as high as 1080 cm. The different climate regimes of the country vary from humid in the North-East (about 180 days rainfall in a year) to arid in Rajasthan (20 days rainfall in a year). A semi-arid belt in the peninsular region extends in the area between the humid west coast and the central and eastern parts of the country. The most important feature of India's climate is the season of concentrated rain called the "monsoon". The Southwest (SW) monsoon (May - September) is the most important feature of the Indian climate.

India is a land with many rivers. The twelve major rivers spread over a catchment area of 252.8 million hectares (Mha) cover more than 75 per cent of the total area of the country. Rivers in India are classified as Himalayan, Peninsular, Coastal, and Inland-drainage basin rivers.

The land use pattern is influenced by diverse factors such as population density, urbanization, industry, agriculture, animal husbandry, irrigation demands, and natural calamities like floods and droughts. Despite stresses, the area under forests has increased in recent years due to proactive reforestation and afforestation programmes of the Government of India. Presently 23 per cent of the total land area is under forest and tree cover, while 44 per cent is net sown area. The remaining one-third is roughly equally distributed between fallow land, non-agricultural land, and barren land.

The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats, and the North-east, to dry alpine scrub high in the Himalayas in the north. Between these extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone, and temperate montane forests. According to the Forest Survey of India, the total forest cover in the year 2000 was 6,75,538 km^2.

India is a largely agrarian society with nearly 64 per cent of the population dependent on agriculture, although the share of agriculture in the gross domestic product has been continuously declining over the last 50 years. Crop production in India takes place in almost all land class types, namely, dry, semi dry, moist, sub humid, humid, fluvisols and gleysols. Agriculture will continue to be important in India's economy in the years to come as it feeds a large and growing population, employs a large labour force, and provides raw material to agro-based industries.

India is the second most populous country in the world. The population crossed the one billion mark in 2000. The decadal population growth rate has steadily declined from 24.8 per cent during 1961-1971 to 21.3 per cent during 1991-2001 and is expected to further decline to 16.2 per cent during 2001-2011, due to various policies of the Government of India relating to family welfare, education, health and empowerment of women.

India had more than 160 million households in 1994. Nearly three fourths of these households live in rural areas, accounting for one-third of total national primary energy consumption. With rising incomes, households at all socioeconomic levels are increasingly using energy using devices such as electric bulbs, fans, televisions, refrigerators, washing machines, air-coolers, air-conditioners, water heaters, scooters and cars. The related greenhouse gas (GHG) emissions will continue to rise even though the energy efficiencies of the appliances are continually improving.

GDP (at factor cost and constant prices) grew by 7.2 per cent in the fiscal year 1994. In the decade following 1990s, the annual average GDP growth rate was 6.6 per cent making India one of the 10 fastest growing economies of the world. Key socio-economic indicators for 1994 are presented in Table 1.

The Indian economy has made enormous strides since independence in 1947, achieving self-sufficiency in food for a rising population, increasing per capita GDP by over three-times, reducing illiteracy and fertility rates, creating a strong and diversified industrial base, building up infrastructure, developing technological capabilities in sophisticated areas and establishing growing linkages with the world economy. However, much remains to be achieved and the Government of India is committed to developmental targets that are more ambitious than the United Nations Millennium Development Goals. The high incidence of poverty underlines the need for rapid economic development to create more remunerative employment and for investment in social infrastructure such as health and education. Notwithstanding the climate friendly orientation of national policies, the development to

Table 1: National circumstances, 1994

Criteria	1994
Population (million)	914
Area (million square kilometers)	3.28
GDP at Factor cost 1994-95 (1993-94 prices) Rs billion	8,380
GDP at Factor cost 1994-95 (1993-94 prices) US$ billion	269
GDP per capita (1994 US$)	294
Share of industry in GDP for 1994-95 (per cent)	27.1
Share of services in GDP for 1994-95 (per cent)	42.5
Share of agriculture in GDP for 1994-95 (per cent)	30.4
Land area used for agricultural purposes (million square kilometers)	1.423
Urban population as percentage of total population	26
Livestock population excluding poultry (million)	475
Forest area (million square kilometers)	0.64
Population below poverty line (per cent)	36
Life expectancy at birth (years)	61
Literacy rate (per cent)	57

Note: The monthly per capita income poverty lines for rural and urban areas are defined as Rs. 228 and Rs. 305 respectively for 1994-95.

Sources: Economic Survey 1995-1996 and 2000-01. Economic Division, Ministry of Finance, Government of India; Census of India, 1991 and 2001. Government of India.

meet the basic needs and aspirations of a vast and growing population will lead to increased GHG emissions in the future.

Energy use during the past five decades has expanded, with a shift from non-commercial to commercial energy. Among commercial energy sources, the dominant source is coal with a share of 47 per cent. The dominance of coal is because India is endowed with significant coal reserves of about 221 Bt (billion tonnes) that is expected to last much longer than its oil and natural gas reserves. The shares of petroleum and natural gas in the total commercial energy used in the country are 20 percent and 11 percent respectively. The total renewable energy consumption including biomass amounts is about 30 per cent of the total primary energy consumption in India. A number of steps are being initiated to develop renewable sources of energy in a systematic manner. However, coal being abundant, cheap and locally available would remain mainstay of the Indian energy system for energy security reasons.

GREENHOUSE GAS INVENTORY INFORMATION

The 1994 inventory of greenhouse gases for India provides a comprehensive estimate of emissions by sources and removals by sinks of carbon dioxide, methane and nitrous oxide not controlled by the Montreal Protocol. The GHG inventory is reported in terms of the non-Annex 1 guidelines (Table 2). For a transparent and comparable inventory, the revised Intergovernmental Panel on Climate Change (IPCC) guidelines prescribed for development of national GHG inventories have been applied. A major effort has been devoted towards improving the basis for preparing the inventory, which involves use of activity data and country specific greenhouse gas emission coefficients. Emission coefficients in key sectors have been developed which include CO_2 emission coefficients for Indian coal types, CO_2 and CH_4 emission coefficients for road vehicles, CH_4 emission coefficients for coal mining, enteric fermentation, and rice cultivation.

In 1994, 1,228,540 Gg of CO_2-eq of anthropogenic greenhouse gases (GHGs) were emitted from India resulting in a per capita emission of about 1.3 tons. CO_2 emissions were the largest at 793,490 Gg, i.e. 65 per cent of the total national CO_2-eq emissions. The shares of CH_4 and N_2O were 31 per cent (18,082 Gg) and 4 per cent (178 Gg), respectively (see Figure 1a). Details of GHG emissions by sector are given in Table 2. Of the total CO_2-eq emissions in 1994, the largest share of 61 per cent was contributed by the all energy sector, followed by the agriculture sector at 28 per cent, industrial process at 8 per cent, waste at 2 per cent and land use, land use change and forestry at 1 per cent (see Figure 1b).

Total CO_2 emitted in 1994 from all the above sectors was 817,023 Gg and removal by sinks was 23,533 Gg resulting in net emission of 793,490 Gg of CO_2. This constituted 65 per cent of the total GHG released in 1994. CO_2 emissions were contributed by activities in the energy sector, industrial processes, and land use, land use change and forestry (LULUCF). The relative shares of the three sectors to the total CO_2 released from the country were 85 per cent, 13 per cent and 2 per cent, respectively (see Figure 2). The industrial process sector, which includes processes such as iron and steel manufacturing and cement production, is also a major source of CO_2. Whereas

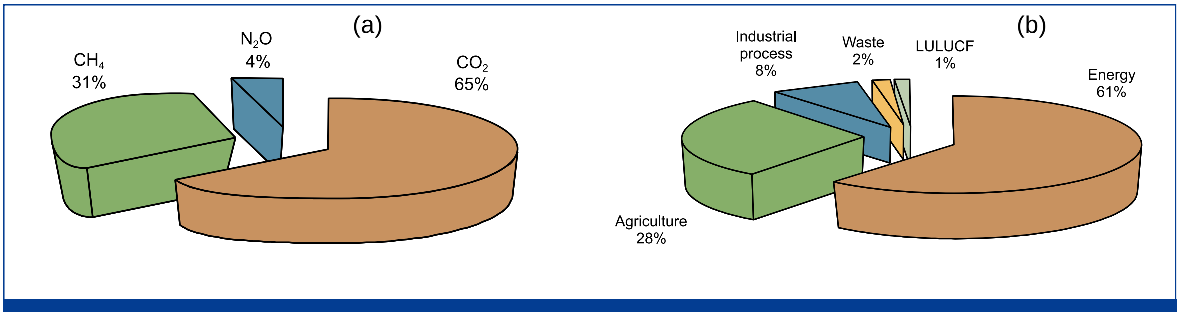


Figure 1: Distribution of GHG emissions from India in 1994 (a) Gas by Gas emission distribution (b) sectoral distribution of CO_2 equivalent emissions.

Table 2: India's national greenhouse gas inventories in Gigagram (Gg) of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for the base year 1994.

Greenhouse gas source and sink categories (Giga gram per year)	CO_2 emission	CO_2 removals	CH_4 emission	N_2O emission	CO_2 eq. emission*
Total (Net) National Emission	**817023**	**23533**	**18083**	**178**	**1228540**
1. All Energy	**679470**		**2896**	**11.4**	**743820**
Fuel combustion					
Energy and transformation industries	353518			4.9	355037
Industry	149806			2.8	150674
Transport	79880		9	0.7	80286
Commercial-institutional	20509			0.2	20571
Residential	43794			0.4	43918
All other sectors	31963			0.4	32087
Biomass burnt for energy			1636	2.0	34976
Fugitive Fuel Emission					
Oil and natural gas system			601		12621
Coal mining			650		13650
2. Industrial Processes	**99878**		**2**	**9**	**102710**
3. Agriculture			**14175**	**151**	**344485**
Enteric Fermentation			8972		188412
Manure Management			946	1	20176
Rice Cultivation			4090		85890
Agricultural crop residue			167	4	4747
Emission from Soils				146	45260
4. Land use, Land-use change and Forestry*	**37675**	**23533**	**6.5**	**0.04**	**14292**
Changes in Forest and other woody biomass stock		14252			(14252)
Forest and Grassland Conversion	17987				17987
Trace gases from biomass burning			6.5	0.04	150
Uptake from abandonment of Managed lands		9281			(9281)
Emissions and removals from soils	19688				19688
5. Other Sources as appropriate and to the extent possible					
5a. Waste			**1003**	**7**	**23233**
Municipal Solid Waste Disposal			582		12222
Domestic Waste water			359		7539
Industrial Waste Water			62		1302
Human Sewage				7	2170
5b. Emission from Bunker fuels #	**3373**				**3373**
Aviation	2880				2880
Navigation	493				493

Not counted in the national totals.

*Converted by using Global warming potential (GWP) indexed multipliers of 21 and 310 for converting CH_4 and N_2O respectively to CO_2 equivalents.

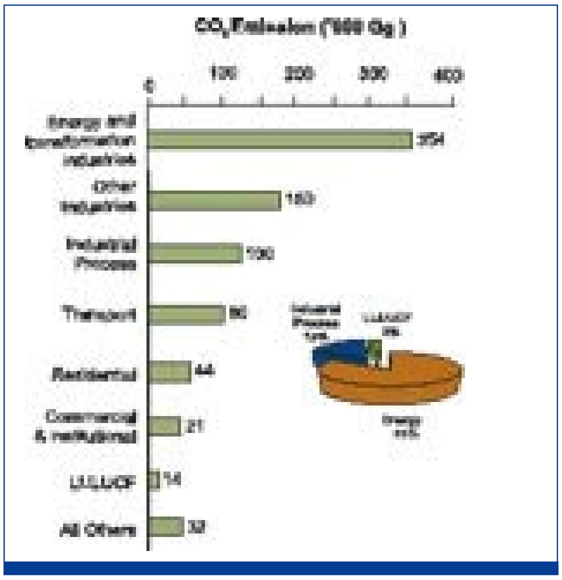


Figure 2: Sectoral CO_2 emissions in 1994.

CO_2 emissions from energy sector include emissions from fossil fuel combustion throughout the economy, CO_2 emissions from biomass fuels are treated as carbon neutral and therefore not included in the national totals.

Total national CH_4 emission in the year 1994 was 18,583 Gg. Of this the share of agriculture sector was 78 per cent. Emission due to enteric fermentation (8,972 Gg) and rice cultivation were the highest (4,090 Gg) sources of CH_4 emission in the agriculture sector.

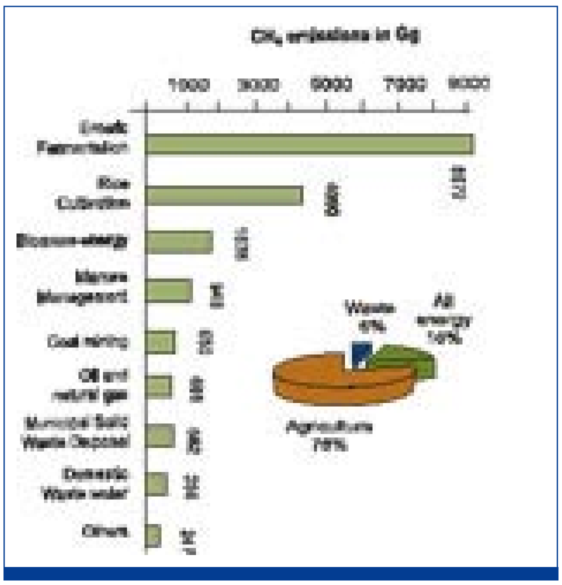


Figure 3: Sectoral CH_4 emission in 1994.

16 per cent of the total CH_4 emissions came from energy sources such as biomass burning, coal mining and handling, and flaring of natural gas systems. Waste disposal activities contributed about 6 percent of the total CH_4 emission. Methane emitted from land use, land use change and forestry sector was minor and was due to the burning of biomass in shifting cultivation practices. Similarly, CH_4 emitted from Industrial processes was only 2 Gg . The sectoral distribution of CH_4 emitted from various sources in 1994 is shown in Figure 3.

Total N_2O emission in 1994 was 178 Gg contributing 4 per cent of the total GHG emissions. Significant emission of N_2O was from the agriculture sector, which accounted for 84 per cent of total N_2O emission. Fuel combustion accounted for 7 per cent of the emission; industrial processes 5 per cent, and waste 4 per cent (see Figure 4). Emission from biomass burning was insignificant.

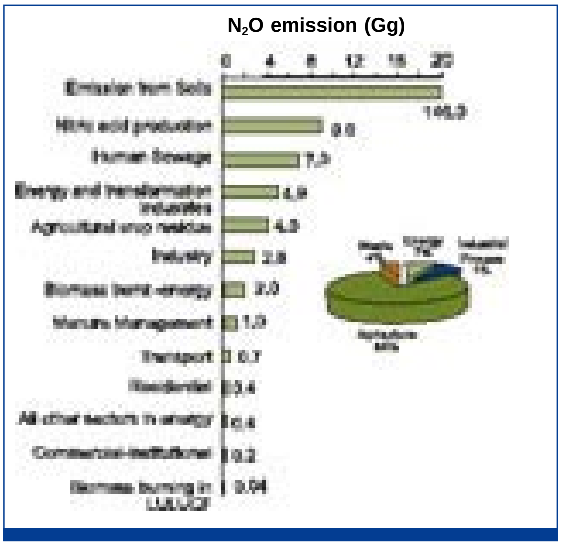


Figure 4: Sectoral N_2O emissions in 1994.

VULNERABILITY ASSESSMENT AND ADAPTATION

India has reasons to be concerned about the impacts of climate change. Its large population depends on climate-sensitive sectors like agriculture and forestry for livelihoods. Any adverse impact on water availability due to recession of glaciers, decrease in rainfall and increased flooding in certain pockets would threaten food security, cause die back of natural ecosystems including species that sustain the livelihoods of rural households, and adversely impact the coastal system due to sea level rise and increased frequency of extreme events. Apart from these, achievement of vital national development goals related to other systems such as habitats, health, energy demand, and infrastructure investments would be adversely affected.

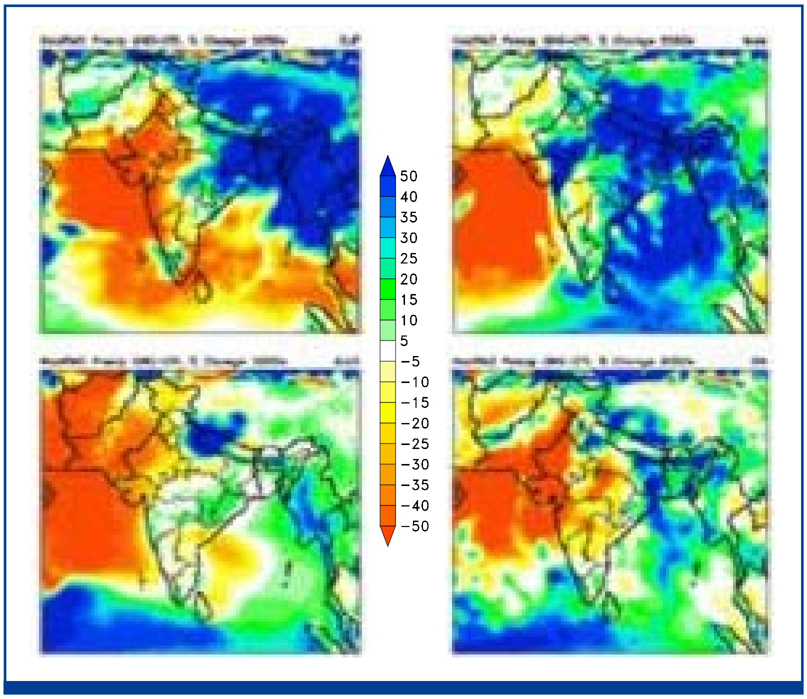


Figure 6:. Projections of seasonal precipitation for the period 2041-60, based on the regional climate model HadRM2.

Climate projections: Significant increase of the order of 0.4°C in the past one hundred years in the annual global average surface air temperature has already been observed. While annual average monsoon rainfall at the all-India level for the same period has been without any trend and variations have been random in nature, increase in monsoon seasonal rainfall have been recorded along the west coast, north Andhra Pradesh and north-west India (+10 to +12 per cent of normal/100 years) while decreasing trends have been observed over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and Kerala (-6 to -8 per cent of normal/100 years). Using the second generation Hadley Center Regional Model (Had RM2) and the IS92a future scenarios of increased greenhouse gas concentrations, marked increase in seasonal surface air temperature is projected into the 21st century, becoming conspicuous after the 2040s (Figure 5). Climate projections indicate increases in both maximum as well as minimum temperatures over the region south of 25°N, the maximum temperature is projected to increase by 2-4°C during the 2050s. In the northern region the increase in maximum temperature may exceed 4°C. Model projections also indicate an increase in minimum temperature by 4°C

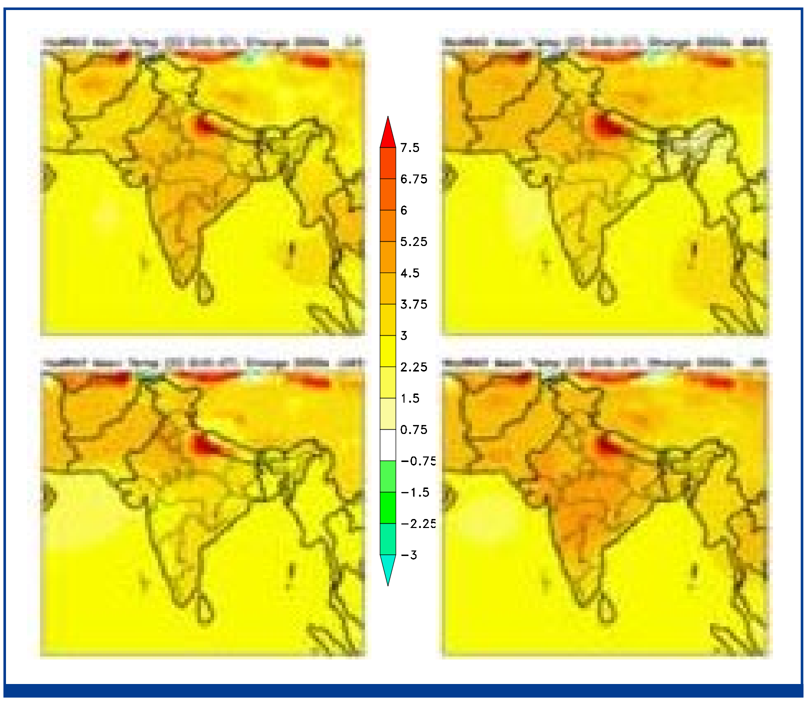


Figure 5:. Projections of seasonal surface air temperature for the period 2041-60, based on the regional climate model HadRM2.

all over the country, which may increase further in the southern peninsula. Little change in monsoon rainfall is projected up to the 2050s at the all-India scale level (Figure 6). However there is an overall decrease in the number of rainfall days over a major part of the country. This decrease is greater in the western and central parts (by more than 15 days) while near the Himalayan foothills (Uttaranchal) and in northeast India the number of rainfall days may increase by 5-10 days. Increase in rainfall intensity by 1-4 mm/day is expected all over India, except for small areas in northwest India where the rainfall intensities may decrease by 1 mm/day.

Assessment of the projections of future climate by different GCMs show a consistent rise in temperature across all models, indicating that these predictions are robust. However, the projections of rainfall vary across models. Though the climate models used for assessing future climate have their inherent limitations and uncertainties, the results obtained through these models give an indication of the likely changes in climate in the future. The consequences of these expected changes would vary greatly across the length and breadth of India due to its complex geography and climate patterns. Regional and sectoral variability in levels of social and economic development requires in-depth regional and sectoral assessment of vulnerability due to the projected climate change, and formation of adaptation strategies. The information available for assessments of impact is fragmentary. An effort was made during preparation of the Initial National Communication to undertake modeling and research studies and collate existing information on impact assessment and development strategies which may mitigate some impacts.

Water resources: Water is a precious natural resource supporting human activities and ecosystems, and at the same time very complex to manage judiciously. The hydrological cycle, a fundamental component of climate, is likely to be altered in important ways due to climate change. Using the SWAT (Soil and Water Assessment Tool) water balance model for hydrologic modeling of different river basins in the country, in combination with the outputs of the HadRM2 regional climate model, preliminary assessments have revealed that under the IS92a scenario, the severity of droughts and intensity of floods in various parts of India is likely to increase. Further, there is a general reduction in the quantity of available runoff under the IS92a scenario. River basins of Sabarmati and Luni, which occupy about one quarter of the area of Gujarat and 60 percent of the area of Rajasthan, are likely to experience acute water scarce conditions. River basins of Mahi, Pennar, Sabarmati and Tapi are likely to experience constant water scarcity and shortage. River basins of the Cauvery, Ganga, Narmada and Krishna are likely to experience seasonal or regular water stressed conditions. River basins of the Godavari, Brahmani and Mahanadi are projected to experience water shortages only in a few locations (Figure 7).

Figure 7: Broad variation in vulnerability of different regions to projected climate change.

Ground water inventory is presently 0.34 million km^3. Although efforts are being made to promote improved water management practices such as water conservation, artificial recharge and watershed management, and integrated water development, the projected water demand of over 980 billion cubic meters in 2050 will require intensive development of ground water resources, exploiting both dynamic and in-storage potential.

It is obvious that the projected climate change resulting in warming, sea level rise and melting of glaciers will adversely affect the water balance in different parts of India and quality of ground water along the coastal plains. Climate change is likely to affect ground water due to changes in precipitation and evapotranspiration. Rising sea levels may lead to increased saline intrusion into coastal and island aquifers, while increased frequency and severity of floods may affect groundwater quality in alluvial aquifers. Increased rainfall intensity may lead to higher runoff and possibly reduced recharge.

Agriculture sector: Food grain production in India has increased from 50 million tons in 1951 to 212 million tons in 2002, while the mean cereal productivity has increased from 500 kg ha^{-1} to almost 1800 kg ha^{-1}. Despite this progress, food production in India, is still considerably dependent on the rainfall quantity and its distribution, which is highly variable spatially as well as temporally. In the past fifty years, there have been around 15 major droughts, due to which the productivity of rainfed crops in drought years was adversely affected.. Limited options of alternative livelihoods and widespread poverty continue to threaten livelihood security of millions of small and marginal farmers in the rainfed agriculture region. Food security of India may be at risk in future due to the threat of climate change leading to increase in frequency and intensity of droughts and floods, thereby affecting production on small and marginal farms.

Simulations using dynamic crop models, having the flexibility to independently assess the impacts of temperature rise and CO_2 increase on crop production, indicate a decrease in yield of crops as temperature increases in different parts of India. These reductions were, however, generally offset by the increase in CO_2; the magnitude of this response varied with crop, region, and climate change ("pessimistic" or "optimistic", "pessimistic" scenario refer to high increase in temperature and low increase in CO_2, while "optimistic" scenario refers to large increase in CO_2 and a low change in temperature). Irrigated rice yields may have a small gain, irrespective of the scenario throughout India. Wheat yields in central India are likely to suffer drop in crop yield up to 2 per cent in pessimistic scenario but there is also a possibility that yields may increase by 6 per cent if the global change is optimistic. Sorghum, being a C4 plant, does not show any significant response to increase in CO_2 and hence these scenarios are unlikely to affect its yield. However, if the temperature increases are higher, western India may show some negative effect on productivity due to reduced crop durations.

Forest eco-systems: Preliminary assessments using BIOME-3 vegetation response model, based on regional climate model projections (HadRM2) for India show shifts in forest boundary, changes in species-assemblage or forest types, changes in net primary productivity, possible forest die-back in the transient phase, and potential loss or change in biodiversity. Enhanced levels of CO_2 are projected to result in an increase in the net primary productivity (NPP) of forest ecosystems over more than 75 per cent of the forest area. Even in a relatively short span of about 50 years, most of the forest biomes in India seem to be highly vulnerable to the projected change in climate (Figure 8). About 70 per cent of the vegetation in India is likely to find itself less than optimally adapted to its existing location, making it more vulnerable to the adverse climatic conditions as well as to the increased biotic stresses. Biodiversity is also likely to be adversely impacted. These impacts on forests will have adverse socio-economic implications for forest-dependent communities and the national economy. The impacts of climate change on forest ecosystems are likely to be long-term and irreversible. Thus, there is a need for developing and implementing adaptation strategies to minimize possible adverse impacts. Further, there is a need to study and identify the forest policies, programmes and silvicultural practices that contribute to vulnerability of forest ecosystems to climate change.

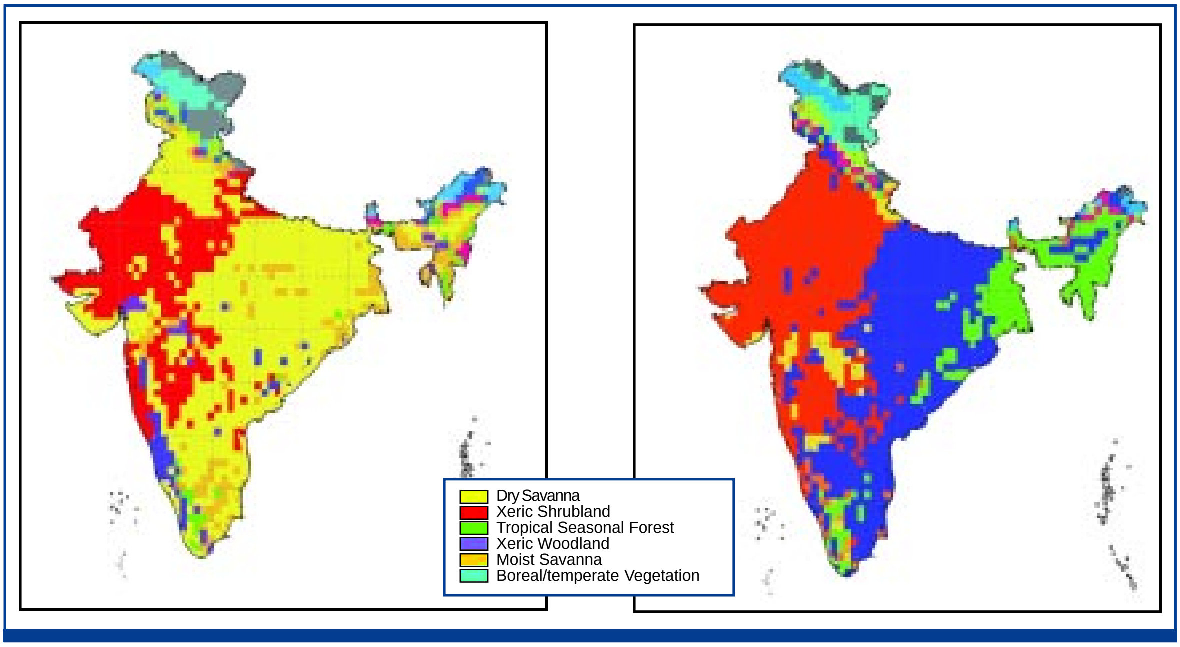


Figure 8: Vegetation map for the year 2050 (right) under GHG run of HadRM2 considering all grids of India and potential vegetation (including grids without forests). The control run (without GHG increase) is shown on the left.

Natural ecosystems: Natural ecosystems such as grasslands, mangroves, and coral reefs are also likely to be affected by climate change. Increasing atmospheric CO_2 levels would favour C3 plants over C4 grasses, but the projected increases in temperature would favor the C4 plants. Climate change would thus be region-specific and involve a complex interaction of factors. Sea level rise would submerge mangroves as well as increase the salinity of wetlands. This would favour mangrove plants that tolerate higher salinity. Increased snowmelt in the western Himalayas could bring larger quantities of fresh water into the Gangetic delta. This would have significant consequences for the composition of the Sundarbans mangroves, favoring mangrove species that have relatively lower tolerance to salinity. The projected sea-level rise of 0.09-0.88 m between the years 1990 and 2100 seems within the ability of Sundarbans mangrove ecosystem, which presently face tidal amplitudes up to 5 m, to adapt. This may not be true for other mangroves such as the Pichavaram and Muthupet where tidal amplitudes are much lower at 0.64 m and much of the inland areas are already under agriculture. Changes in local temperature and precipitation would also influence the salinity of the mangrove wetlands and have a bearing on plant composition.

An increase in sea-surface temperature would lead to the bleaching of corals. Coral reefs could also be potentially impacted by sea-level rise. Healthy reef flats seem able to adapt through vertical reef growth of 1 cm per year, that is within the range of the projected sea-level rise over the next century. However, the same may not be true for degraded reefs that are characteristic of densely populated regions of South Asia.

Coastal zone: The coastal zone is an important and critical region for India. It is densely populated and stretches over 7,500 km with the Arabian Sea in the West and Bay of Bengal in the East. The total area occupied by coastal districts is around 379,610 km^2, with an average population density of 455 persons per km^2, which is about 1.5 times the national average of 324 persons per km^2. Under the present climate, it has been observed that the sea-level rise (0.4-2.0 mm/year) along the Gulf of Kutchh and the coast of West Bengal is the highest. Along the Karnataka coast, however, there is a relative decrease in the sea level.

Future climate change in the coastal zones is likely to be manifested through worsening of some of the existing coastal zone problems. Some of the main

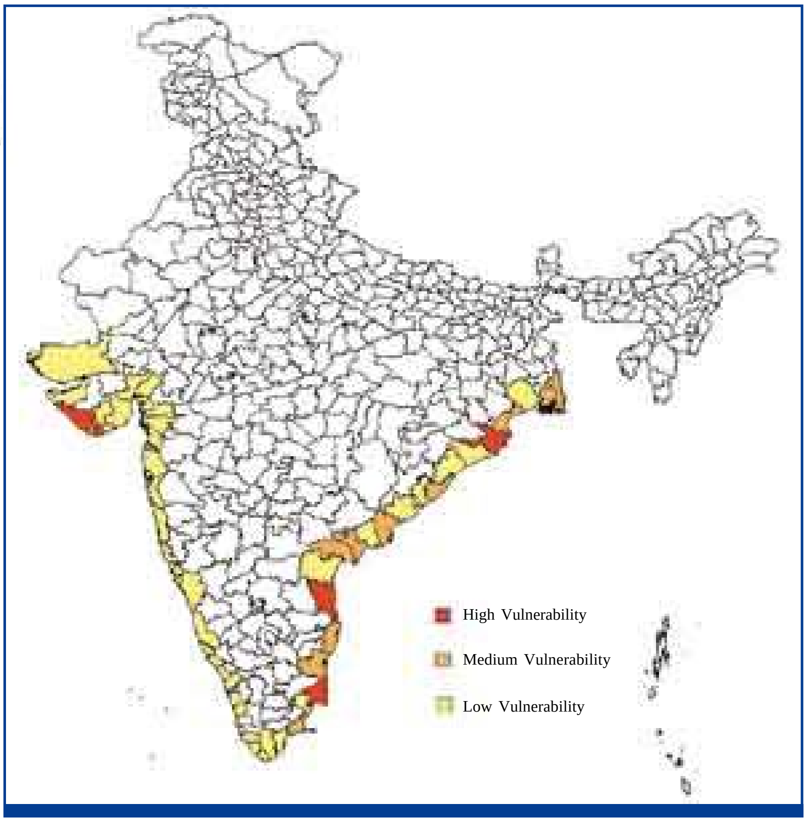


Figure 9: Coastal districts vulnerable to climate change.

climate-related concerns in the context of the Indian coastal zones are erosion, flooding, submergence and deterioration of coastal ecosystems, such as mangroves and salinization. In many cases, these problems are either caused by, or exacerbated by, sea-level rise and tropical cyclones. The key climate-related risks in the coastal zone include tropical cyclones, sea-level rise, and changes in temperature and precipitation. A rise in sea level is likely to have significant implications on the coastal population and agricultural performance of India. A one-metre sea-level rise is projected to displace approximately 7.1 million people in India and about 5,764 square kilometers of land area will be lost, along with 4,200 km of roads.

The diverse impact expected as a result of sea-level rise include land loss and population displacement, increased flooding of low-lying coastal areas, loss of yield and employment resulting from inundation, and salinization. Damage to coastal infrastructure, aquaculture and coastal tourism, due to the erosion of sandy beaches, is also likely. The extent of vulnerability, however, depends not just on the physical exposure to sea-level rise and the population affected, but also on the extent of economic activity of the areas and capacity to cope with impacts (see Figure 9).

Human health: The overall susceptibility of the Indian population to environmental health concerns has decreased in recent years as a result of the improvement in access to health facilities. The extent of access to and utilization of health care varies substantially between states, districts and different segments of society. To a large extent, this is responsible for substantial differences between states in health indices of the population. During the 1990s, the mortality rates reached a plateau, and India entered an era of dual disease burden. Communicable diseases have become more difficult to combat because of the development of insecticide resistant strains of vectors. Malaria is one such disease in India that has been prevalent over the years, despite government efforts to eradicate it. The climate, vegetation and other socioeconomic parameters conducive to its prevalence are consistently present in some regions of India. It is projected that malaria will move to higher latitudes and altitudes in India, with 10 per cent more area offering climatic opportunities for the malaria vector to breed throughout the year during the 2080s with respect to the year 2000 (see Figure 10).

Infrastructure and energy: Large investments are being committed to new infrastructure projects, such as improving drinking water availability, construction of roads and highways, the cost of which runs into billions of US dollars. Infrastructure being long-life assets are designed to withstand normal variability in climate regime. However, climate change can affect both average conditions and the probability of extreme events, temperatures, precipitation patterns, water

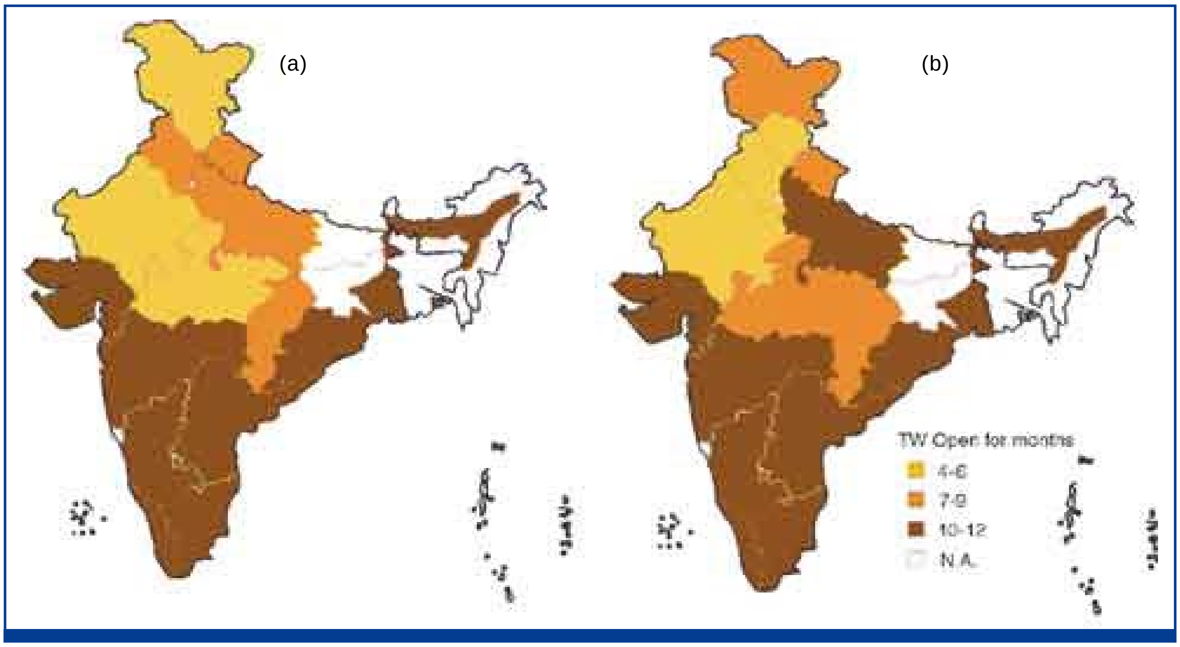


Figure 10: Transmission window of malaria in different states of India.
(a) for 2000 and (b) under projected climate change scenario during the 2080s.

availability, flooding and water logging, vegetation growth, land slides and land erosion in the medium and long-run which may have serious impacts on infrastructure. These are likely to lead to huge monetary losses, if not taken into consideration while planning. Studies indicate that increased temperatures would increase space-cooling requirements, while enhanced groundwater demand would increase water-pumping requirements. These will enhance the electricity demand and add costs to the consumers for maintaining their lifestyles, as well as to the electricity production systems.

The projected variability in precipitation can impact the irrigation needs and consequently increase electricity demand in agriculture sector. This would result in the need for higher power generation capacity. Also, about 1.5 per cent additional power generation capacity would be required for enhanced space cooling requirements as a result of increase in temperature. These additional power requirements are likely to be partly offset by adoption of various energy conservation measures in these areas as the projected energy saving potential in these sectors is very high. However, implementation of energy conservation measures would require substantial investments.

Though the Government of India has taken many policy decisions that reduce risks and enhance the adaptive capacity of the most vulnerable sectors and groups by promoting sustainable development, considerable scope exists for including more measures to cover the entire range of impacts due to the present climate variability. Currently, income disparities and high population growth constrain the opportunities and equitable access to the existing social infrastructure. The projected climate change could further accentuate these conditions. The challenge then is to identify opportunities that facilitate the sustainable use of existing resources. Faster economic development with more equitable income distribution, improved disaster management efforts, sustainable sectoral policies, careful planning of capital intensive and climate sensitive long-life infrastructure assets, are some measures that will assist India in reducing its vulnerability to climate change.

RESEARCH AND SYSTEMATIC OBSERVATION

India’s observational and research capabilities have been developed to capture its unique geography and specific requirements, and also to fulfil international commitments of data exchange for weather forecasting and allied research activities. Modernized meteorological observations and research in India was initiated more than 200 years ago, in 1793, when the first Indian meteorological observatory was set up at Madras (Chennai). A network of about 90 weather observatories was established in 1875, when the India Meteorological Department was set up. Many data and research networks have since been established for climate dependent sectors, such as agriculture, forestry and hydrology, rendering a modern scientific background to atmospheric science in India. Inclusion of the latest data from satellites and other modern observation platforms, such as automated weather stations, ground-based remote sensing techniques, and ocean data buoys has strengthened India's long-term strategy of building up a self-reliant climate data bank.

Indian researchers have contributed significantly to the global knowledge on climate change by undertaking research and through participation in international scientific processes, especially in the preparation of various assessment reports of the IPCC. The Government of India, under its various programmes, promotes and supports numerous multidisciplinary studies on climate change and related issues, both in the national and international context, such as understanding climate variability, sectoral and sub-regional vulnerability and impact assessments due to climate change, climate modelling, measurement of atmospheric trace constituents, GHG, and integrating climate change concerns into national planning.

The Government of India also makes investments for the promotion of research and development on a continuous basis in various aspects of environmental conservation, including research in climate change and development of new technologies, e.g., renewable energy, afforestation, replacement of hydrocarbons in surface transport by alternative fuels, such as compressed natural gas (CNG) and ethanol. The government has also allowed the mixing of ethanol to the extent of 5 per cent with petrol. However, an understanding of the national circumstances is important for a comprehensive treatment of climate change issues, concerns and opportunities.

Despite the fact that there is growing literature on climate change science and policy, there is a considerable gap of material on developing countries. There is a great need to bridge this gap to enhance understanding on diverse dimensions of climate change problems, and to facilitate global, national and local policy making, keeping in mind the problems of developing countries.

EDUCATION, TRAINING AND PUBLIC AWARENESS

The Government of India has created mechanisms for increasing awareness on climate change issues through outreach and education initiatives in recent years. The Environmental Information System (ENVIS) centres have been set up throughout the country to generate and provide environmental information to decision makers, policy planners, scientists, researchers and students, through web-enabled systems.

The Ministry of Environment and Forests (MoEF) is the coordinating agency in India for Global Learning and Observations to Benefit the Environment (GLOBE). Students collect data on various environmental parameters related to atmosphere, water, soil and vegetation, and report their data to the GLOBE website.

India hosted the Eighth Conference of Parties (COP-8) to the UNFCCC during 23 October to 1 November 2002 in New Delhi. The event helped in generating awareness about climate change among various stakeholders in India. Apart from this, considerable

Students recording temperature data at a GLOBE school's weather station.

awareness has been generated through the process of the initial national communication executed and implemented by the MoEF. It followed a broad-based participatory approach, involving 131 research teams drawn from premier research institutions, universities, government ministries and departments, and non-governmental organizations (NGOs) of repute across the country. The activities included a preparation of the GHG inventory, assessment of vulnerability to climate change and development of adaptation responses, assimilation of information relating to national circumstances, research and systematic observation, education, training and public awareness, and the creation of a data centre and website. While undertaking these activities, 27 sectoral thematic and training workshops and conferences at national and sub-regional levels were organized across the country for capacity building. For dissemination of activities related to India's initial national communication and climate change issues, a website (www.natcomindia.org) has been launched.

Government initiatives, such as the diffusion of renewable energy technologies, joint forest management, water resource management, agricultural extension services, micro financing, web-enabled services for farmers and rural areas, petroleum conservation research and consumer awareness, energy parks for demonstration of clean energy technologies, establishment of the Technology Information, Forecasting & Assessment Council, environmental education in schools and higher education, represent a broad spectrum of initiatives for education, training and public awareness on climate and related issues.

The media, industry associations and civil society have also played active roles. A recent study indicated that out of 50 large Indian corporate houses, more than three-quarters had an environmental policy, sixty per cent had an environment department, and four out of every 10 had formal environment certification (ISO 14001). All the major industry associations have a climate change division and have taken initiatives to conduct training and generate awareness in key areas, such as energy efficiency and other environment friendly projects.

Several civil society initiatives have sought to build capacity and create awareness about climate-friendly issues. Grassroots-level activities are undertaken that seek to improve the ability of communities to manage their natural resources, generate sustainable livelihoods, develop infrastructure, and participate in decision making, thereby improving their capability to cope with climatic stresses.

In addition, numerous capacity-building initiatives have been undertaken in India. A vital aspect of this process has been the participation by the central and state government agencies, research institutions, NGOs and industry. The Government of India has instituted consultative processes for climate change policies. Indian researchers have made significant contributions to international scientific assessments. Awareness workshops and seminars on issues concerning climate change have been conducted across the country over the last decade. However, in the wake of the complexity of climate change issues, the task is far from complete, and assessments in a range of areas and analyses of uncertainties and risks remain to be undertaken.

PROGRAMMES RELATED TO SUSTAINABLE DEVELOPMENT

India's development plans are crafted with a balanced emphasis on economic development and environment. The planning process, while targetting an accelerated economic growth, is guided by the principles of sustainable development with a commitment to a cleaner and greener environment. Planning in India seeks to increase wealth and human welfare, while simultaneously conserving the environment. It emphasizes the promotion of people's participatory institutions and social mobilization, particularly through the empowerment of women, for ensuring environmental sustainability of the development process.

The past few years have witnessed the introduction of landmark environmental measures in India that have targetted conservation of rivers, improvement of urban air quality, enhanced forestation and a significant increase in the installed capacity of renewable energy technologies. These and similar measures, affirmed by the democratic and legislative processes, have been implemented by committing additional resources, as well as by realigning new investments. These deliberate actions, by consciously factoring in India's commitment to the UNFCCC, have realigned economic development to a more climate friendly and sustainable path.

The principal objective of the national development strategy is to reduce the incidence of poverty to 10 per cent by 2012 and provide gainful employment. The target GDP growth rate of 8 per cent during the current decade, therefore, aims to double our per capita income during this period. Achieving these development priorities will require a substantial increase in energy consumption both at macro and micro levels, and consequent rise in GHG emissions. Coal, being the most abundant domestic energy resource, would continue to play a dominant role. The per capita emissions, which are currently a fifth of the world average, can therefore be expected to rise. Even so, our per capita emissions will remain significantly below the current world average during next several years.

India is endowed with diverse energy resources, wherein coal has a dominant share. Therefore, the Indian energy system evolved with a large share of coal in the energy consumption. This, coupled with the rising energy consumption, led to a rising carbon emissions trajectory in the past. However, India's per capita CO_2 emission of 0.87 t-CO_2 in 1994 is still amongst the lowest in the world. It is 4 per cent of the US per capita CO_2 emissions in 1994, 8 per cent of Germany, 9 per cent of UK, 10 per cent of Japan and 23 per cent of the global average. India's energy, power, and carbon intensities of the GDP have declined after the mid-nineties, due to factors such as increased share of service sector in the GDP, and energy efficiency improvements. India has also taken some initiatives to enhance penetration of low carbon-intensive fuels like natural gas and carbon-free sources like renewable energy. The programmes and institutions to promote energy efficiency, energy conservation and renewable technologies were initiated over two decades ago in India. The recent reforms in the energy and power sectors have resulted in accelerated economic growth, improvements in fuel quality, technology stocks, infrastructure, management practices, and lowered the barriers to efficiency.

CONSTRAINTS AND GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

The Initial National Communication exercise offered an opportunity to enrich and enhance India's experience in identifying constraints, gaps and related financial, technical and capacity needs to adequately fulfill our obligations under the UNFCCC, including the continuing need for improving the quality of national GHG inventories, regional and sectoral assessment of vulnerabilities and adaptation responses, and the communication of information on a continuous basis.

The data needs for continuous reporting have been identified, taking into consideration the data gaps and constraints experienced during the preparation of the initial national communication (Table 3). Measures for improving the future national communication would include designing consistent data reporting formats for continuous GHG inventory reporting, collecting data for formal and informal sectors of the economy, enhancing data depths to move to a higher tier of inventory reporting, and conducting detailed and fresh measurements for Indian emission coefficients.

Several thematic and specific projects are identified for building the research capacity and implementing the climate change project in the country as a part of the preparatory process for national communication. These are representative projects only and do not present an exhaustive elucidation of India's financial and technological needs and constraints. With enhanced scientific understanding and increased awareness, further areas of investigation will be identified.

Capacity building, networking and resource commitment form the core of institutionalizing Indian climate change research initiatives. This involves a shared vision for cooperative research for strengthening and enhancing scientific knowledge and understanding, institutional capacity (instrumentation, modelling tools, data synthesis and data management), technical skills for climate change researchers, inter-agency

Table 3: Key Gaps and Constraints for Sustained National Communication Activities.

Gaps and constraints	Description	Potential measures (Illustrative examples)
Data organization	Published data not available in IPCC friendly formats for inventory reporting.	Design consistent reporting formats.
	Inconsistency in top-down and bottom-up data sets for same activities.	Data collection consistency required.
	Mismatch in sectoral details across different published documents.	Design consistent in reporting formats.
Non-availability of relevant data	Time series data for some specific inventory sub-categories, e.g., municipal solid waste sites.	Generate relevant data sets.
	Data for informal sectors of economy.	Conduct data surveys.
	Data for refining inventory to higher tier levels.	Data depths to be improved.
Non-accessibility of data	Proprietary data for inventory reporting at Tier III level.	Involve industry and monitoring institutions.
	Data not in electronic formats.	Identify critical datasets and digitize.
	Lack of institutional arrangements for data sharing.	
	Time delays in data access.	Awareness generation.
Technical and institutional capacity needs	Training the activity data generating institutions in GHG inventory methodologies and data formats.	Arrange extensive training programmes.
	Institutionalize linkages of inventory estimation with broader perspectives of climate change research.	Wider dissemination activities.
Non-representative emission coefficients	Inadequate sample size for representative emission coefficient measurements in many sub-sectors.	Conduct more measurements.
Limited resources to sustain national communication efforts	Research networks.	Collaborative research, GEF/ international funding.
	India-specific emission coefficients.	Conduct adequate sample measurements for key source categories.
	Vulnerability assessment and adaptation.	Sectoral and sub-regional impact scenario generation, layered data generation and organization, modelling efforts, case studies for most vulnerable regions.
	Data centre and website.	National centre to be established

collaboration and networking, and medium to long-term resource commitment.

Capacities thus strengthened and enhanced can be effectively used for the refinement of GHG inventories, development of climate change projections (with reduced uncertainties and at higher resolutions), long-term GHG emission scenarios, detailed impact assessments and formulation of adaptation strategies, developing the capability to undertake integrated impact assessments at sub-regional scales and the diffusion of climate-friendly technologies

Given the magnitude of the tasks, complexities of technology solutions and diversity of adaptation actions envisaged for an improved and continuous reporting of national communications in the future, the incremental financial needs would be substantial for addressing and responding to the requirements of the Climate Change Convention.