Climate Change and Its Impact on Natural Disasters in India

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India has witnessed remarkable progress in human and economic development since Independence, however, the path of economic development and growth has been challenging. The concept of sustainable development is buzz word now-a-days which has emerged due to increasing problems of environment and ecology. The inter-related issues emerged from economic growth; environment and ecology are affecting the human population. The human activities are adversely affecting the environment and ecology while the global issues like ozone layer depletion, greenhouse gases affect, global warming, climatic change, etc. cause concern. Even redressing these issues in a systematic and scientific manner have gained momentum and for the first time in the history, Nobel Prize for peace has been given to the persons contributing in the field of addressing climate change. The environmental pollution is posing a serious challenge for the sustainability of the economic growth while the road to sustainable development is a tardy one. There is degradation of natural resources due to over exploitation, unsustainable economic and commercial activities as well as poor governance of environmental regulations, policies and enforcement of environmental legislations. Environmental pollution is one of the major challenges of the present day. The social dimensions of environmental pollutions are of paramount importance. It has been well realized that no programme get success at the desired level without people's active participation and role in its planning, implementation, monitoring and appraisal.

The scope of scientific understanding and technical skills in ecology and environmental science have widened significantly over the years. A greater attention is being paid to global environmental

change, biodiversity conservation, environmental toxics, ecological restoration, and sustainable development with particularly emphasis on human well-being. Most of the global environmental problems fall within the gambit of ecological studies and require a thorough understanding of ecological principles for resolution. The understanding of ecological principles is important for sustainable use of resources and to evolve strategies for mitigation of environmental problems at local, regional and global regions. The ecologists are required to interpret the human induced environmental changes and postulate varied scenarios for alternative policy options for legislative and implementable administrative decisions. Thus, ecology has grown by internalizing different disciplines of natural and social sciences.

The increase in severity of natural disasters and the aided damage is attributed to climate change. The human induced climate change has been caused by the cumulative emissions of greenhouse gases which is the culmination of increasing consumption of fossil fuels. The climate change is likely to affect the future of the country – youth. The decision makers of today will not be able to see the effects of climate change. Thus, the youth has responsibility of addressing climate change in order to ensure their bright, clean and green future.

Climate Change:

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. According to the latest scientific assessment, the earth's climate system has demonstrably changed in both global and regional scales. Most of the warming (of 0.1°C per decade) observed over the last 50 years, is attributable to human activities. The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean

temperature may increase between 1.4 and 5.8 degrees Celsius by 2100. This unprecedented increase is expected to have severe impacts on the global hydrological system, eco-systems, sea level, crop production and related produces (Sathaye, J. et.al., 2006:). The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India. The UN Conference on Environment and Development (UNCED) in 1992 at Rio de Janeiro to Framework Convention on Climate Change (FCCC), which laid the framework for the eventual stabilization of green house gases in the atmosphere, recognizing the common but differentiated responsibilities and respective capabilities, and social and economic conditions. The Convention came into force in 1994. Subsequently, the 1997 Kyoto Protocol, which came into the force in 2005, reasserted the importance of stabilizing green house gases concentrations in the atmosphere and adhering to sustainable development principles. The Protocol laid out guidelines and rules regarding the extent to which a participating industrialized country should reduce its emissions of six green house gases – carbon dioxide, methane, nitrous oxide, chlofluoro-carbon, hydrofluoro-carbons and perfluoro-carbons. The Kyoto Protocol does not require the developing countries to reduce their green house gas emissions. However, the Kyoto reduction, by itself, is inadequate to achieve a stabilization of climate change by 2010.

The global carbon cycle involves interaction among the atmosphere, oceans, soils and vegetation and fossil fuel deposits. The combustion of fossil fuels and other human activities are the primary reasons for increased concentrations of CO_2 and other green house gases. Between 1910 and 1999, an estimated 6.3 G+C/year was released due to the combustion of fossil fuels, and another 1.6 G+C/year was released due to the burning of forest vegetation of the six aforementioned Green House Gases, CO_2 accounted for 63 per cent, methane 24 per cent, nitrous oxide 10 per cent and the other

gases, the remaining 3 per cent of the carbon equivalent emissions in 2000. The industrialized countries have been the primary contributors to emissions of CO_2. According to the estimates, industrialized countries are responsible for about 83 per cent of the rise in cumulative fossil fuel related CO_2 emissions since 1800 (Loske, 1996). In the 1990's, they accounted for about 53 per cent of the 6.3 G+C/year which was released as CO_2 from fossil fuel combustion. Developing countries accounted for only 37 per cent of cumulative CO_2 emissions from industrial sources and land use change during the period 1900 to 1999, whereas industrialized countries accounted for 63 per cent. The contribution of India to the cumulative global CO_2 emissions from 1980 to 2003 was only 3.11 per cent. India's carbon emissions per person are twentieth of those of the US and the tenth of most Western Europe and Japan. India has reasons to be concerned about climate change. A vast population was depends (depending) on climate sensitive sectors like agriculture, forestry and fishery for livelihood in the country. The adverse impacts of climate change, in the form of declining rainfall and rising temperatures and thus the increased severity of drought and flooding, would threaten food security and livelihood in the economy. Poor infrastructure facilities, weak instrumental mechanism, lack of financial resources and vast sectoral and regional variability adversely affect the adaptive capacity of the country to climate change. Climate change could represent additional stress on the ecological and socio-economic systems that are already forcing tremendous pressure due to rapid industrialization, urbanization and economic development (Gupta, 2005).

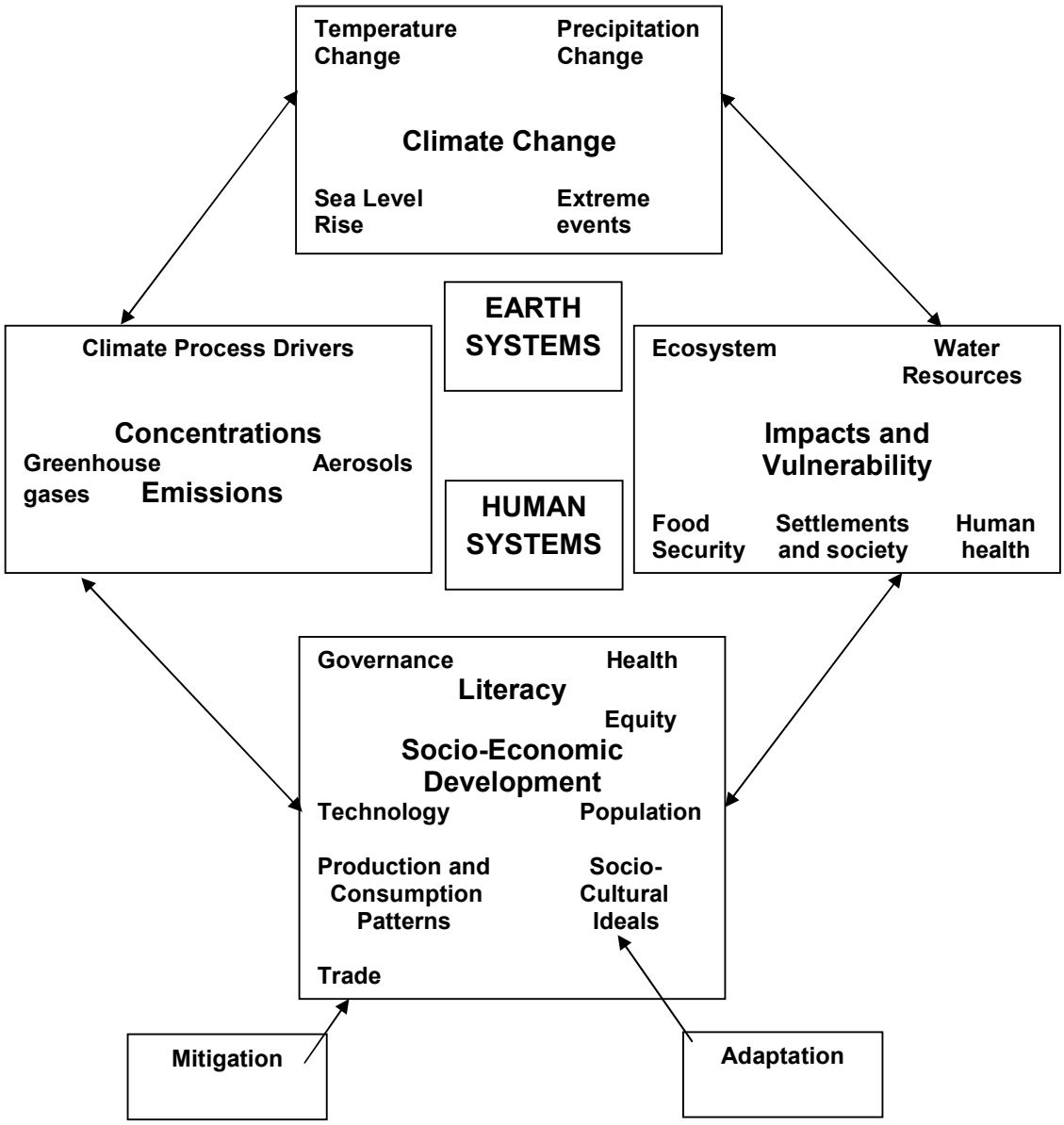
The potential of air pollution on vegetation is also high. Eco-systems are likely to be most at risk if they are on substrates with a low buffering capacity and receive occasional, heavy doses of pollution or contain key species that are vulnerable. The effects of air pollution of materials may include (i) loss of mechanical strength; (ii) leakage; (iii)

failure of protective coatings; (vi) loss of details in carvings; (v) pipe corrosion. Air pollution may also cause damage to built environment, cultural heritage and architecture.

Dr. R.K. Pachouri, the joint Noble Peace Prize winner of 2007 for the significant contribution in the field of mitigation of climate change, has remarked that climate change has the potential to disrupt peace, stability and security across the world. The findings of the Fourth Assessment Report of IPCC (Intergovernmental Panel on Climate Change) have highlighted the impacts of climate change and other serious implications for growth, development and social well-being in some of the most vulnerable regions. There are several dimensions of climate change that bring out the equitable aspects of this problem. The emissions of green house gases which have cumulatively resulted in the problem of human induced climate change have been produced by one set of countries while the worst impacts are going to be felt by the different set of countries and communities. India, the fourth largest an emitter of green house gases, seems to have taken a very bold step towards a sustainable future by starting the process of introducing renewable energy generation and its promotion. It is said that renewable and energy saving credits will be traded on India's power exchanges. This will create a domestic market that may rival India's $ 4-6 billion international trade in carbon credits (Gupta, April, 2010). Thus, Dr. Pachouri is of the view that if the earth's climate system has to be stabilized, mitigation measures will have to be undertaken with urgency. However, mitigation can not be seen as narrow challenge and would require addressing the vary structure of economic growth as the world has come to accept over many decades (Tera Green, December 2007 - January 2008) (Chart 1).

Chart: 1

Climate Change & Its Implications



Source: IPCC. 2007

From 1900 to 2005, precipitation increased significantly in eastern parts of north and South America, northern Europe and northern and Central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally,

the area affected by drought has slightly increased since the 1970s. The rate of global average sea level rise has risen from 1.8 mm/yr to 3.1 mm/yr from 1961 to 1993. This has primarily been due to thermal expansion, melting glaciers, ice caps and polar ice sheets. The projected sea level rise at the end of 21st century will be an alarming 18-59 cm. The Fourth Report on IPCC underlines the impacts of anthropogenic warming that could be abrupt as well as irreversible. Partial loss of ice sheets on ice polar land could imply several meters of sea level rise, major changes in coast lines and inundation of low lying areas, great impact on river deltas and low lying Islands. Approximately 20-30 per cent of species assessed so far are likely to be at increased risk of extinction. Large scale and persistent changes in Meridional .Overturning Circulation will have impacts on marine ecosystem productivity, fisheries and terrestrial vegetation. Report further underlines that by the year 2020, between 75 and 250 million people in Africa will be exposed to increased water stress. In fact, some areas, yields from rain fed agriculture could be reduced by 50 per cent. Conditions in Asia too would not be too different in 2050. Fresh water availability is projected to decrease while coastal areas, especially heavily populated mega delta regions will be at greater risk form sea flooding. Sea level rise is also expected to exacerbate inundation, storm surge, erosion and other coastal hazards threatening vital infrastructure in small island states (Tera Green, December 2007 – January 2008).

Most human activities – fossil fuel combustion for power generation, transport, land use changes and industrial processes – generate emissions of green house gases. Power generation accounted for around 10 Gt CO_2e or around one quarter of the total green house gases emission. Transport is the second largest source of energy related CO_2 emissions. Over the past three decades, energy supply and transport have increased their green house gas emissions

by 145 and 120 per cent respectively (Human Development Report, 2007/2008). Land use changes also play an important role. Deforestation is by far the large source of CO_2 emissions in this context. Rich countries dominate the overall emissions account. Collectively they account for about 7 out of every 10 tonnes of CO_2 that have been emitted since the start of the industrial era. Historic emissions amount to around 1100 tonnes of CO_2 per capita for Britain and America, compared with 66 tonnes per capita for China and 23 tonnes per capita for India. The United States is the largest emitter, accounting for around $1/5^{th}$ of the total. Collectively, top 5 – China, India, Japan, the Russian Federation and the United States – account for more than half; the top 10 for every 60 per cent (Human Development Report, 2007/2008)

CO_2 emissions during 2004 were reported to be 1166 Mt in India with the CO_2 intensity of 478. CO_2. The growth during 1995-2000 was recorded 2.9 per cent while it was reported significantly high upto 3.2 per cent during 2000-2005. CO_2 per capita during 2005 was recorded 1.1 tonne only in India. Carbon dioxide emissions show a steady growth (6.9 per cent) during 1990-2004. India's share in world's total CO^2 emissions was reported 4.6 per cent in 2004 however its share was recorded only 3 per cent in 1990 (Table 1).

Table: 1

Carbon Dioxide Emission in India

Particulars	**India**	**World**
Total (Mt CO_2)		
1990	681.7	22702.5
2004	1342.1	28982.7
Annual Change (Percentage)		
1990-2004	6.9	2.0
Share of World's Total		
1990	3.0	100
2004	4.6	100
Per Capita (t CO_2)		

1990 2004	0.8 1.2	4.3 4.5
Carbon Intensity of Energy CO_2 emissions per unit of energy use (kt of CO_2 per kt of oil equivalent) 1990 2004	 1.89 2.24	 2.64 2.63
Carbon Intensity of Growth CO_2 emissions per unit of GDP (kt of CO_2 per million 2000 ppp US$) 1990 2004	 0.48 0.44	 0.68 0.55
Carbon Dioxide Emissions from forest biomass (Mt CO_2 / year) 1990-2005	 -40.8	 4038.1
Carbon Stocks in forest biomass (Mt Carbon) 2005	2343.0	282650.1

Source: Human Development Report, 2007/2008.

There has been significant increase in carbon dioxide emissions (92.6 per cent) during 1990 to 2005 in India. The per capita carbon dioxide emission has increased from 0.7 mt in 1990 to 1.1 mt in 2005. India's share in global carbon dioxide emissions was reported to be 4.33 per cent in 2005. Cumulative carbon dioxide emissions since 1850 were reported to be 28.6 billion mt in India. Non-CO2 emissions have also increased significantly from 53.1 million tons in 1990 to 89.2 million tons in 2005 (Table 2.).

Table: 2

Carbon Intensity in India

Particulars	**India**	**World**
Total (Mt CO_2) 1990 2005	 597 1149	 20693 26544
Change (Percentage) 1990-2005	 90.2	 28.3
Share of World's Total 1990 2005	 3.0 4.33	 100 100

Per Capita (t CO_2) 1990 2005	 0.07 1.1	 4 4.2
Cumulative Emissions since 1950 (Billions)	28.6	116.1
Non-CO2 emissions (mt) 1990 2005	 53.1 89.2	 1861.0 1978.9
Carbon Intensity of Energy CO_2 emissions per unit of energy use (kt of CO_2 per kt of oil equivalent) 1990 2005	 1.87 2.14	 2.39 2.35

Source: World Development Report, 2010.

The Earth is warming and its climate is changing. Indeed, measurement shows that the earth has warmed by 0.74°C over the last 100 years. Warmer surface temperatures heat the oceans melt ice sheets and alter weather patterns across the globe. The IPCC has estimated the changes in the earth's climate in 20th and early 21st century. The change in earth climate is likely to impact on society, economy and polity as well.

Climate change optimizes the complexity of the development challenge in a globalizing world. Climate change is a development reality. Climate change has the potential to reverse the hard earned development gains of the past decades, and impede the progress towards achieving the Millennium Development Goals, such as eradicating poverty, combating communicable diseases, and ensuring environmental sustainability. Climate change increases the cost of development. There are at least three dimensions to these added development cost: (a) the required economic adjustments to the impacts of global climate policies, including actions that they lead to price increases for various commodities, such as energy and food, or changes in the trade balances; (b) the need for more resilient

infrastructure, disaster relief and preparedness measures, and new agricultural technologies and practices to counter increased risk of climate change impacts; and (c) the accelerated adoption of less green house gases intensive technologies including those with higher costs and risk, as may become necessary in the context of the global climate change regime (IBRD, 2008). Geographically coupled with high level poverty and population density has rendered South Asia especially vulnerable to the impacts of climate change. The region faces daunting climate related development challenges. The region is highly susceptible to natural disasters. The Himalayas are a vital life sustaining resource for South Asia. The retreating glaciers of Himalayas due to climate change could present the most of reaching challenge to the region. The sea level rise due to climate change is a further concern in the region. While vulnerability to climate change in South Asia is high, the region has also emerged as a significant contributor to greenhouse gas emissions. Thus, there is dire need for coordinated regional response to mitigate the adverse impact of climate change.

World Development Report, 2010 has advocated that climate change must urgently be addressed. Climate change threatens all countries, with developing countries the most vulnerable. Estimates are that they would bear 75 to 80 per cent of the costs of damages caused by the changing climate. Most of developing countries lack sufficient financial and technical capacities to manage increasing climate risks. They also depend more directly on climate sensitive natural resources for income and wellbeing (World Development Report, 2010).

Anthropogenic climate change has become visible in the past two decades. The community of nations is required to take actions to reduce the emissions of greenhouse gases which are the main cause

of global warming. UNFCCC and its Kyoto Protocol; several innovative mechanisms are available for enabling countries to meet their target of GHG emissions in the first commitment period 2008-12 based. These mechanisms are referred to as market mechanisms and also provided for transactions between two nations. One of these mechanisms is called the Clean Development Mechanism, in which the government or a company of one of the developed nations having a GHG reduction target can invest in a project developed by an entity in a developing country (National Action Plan for CDM, Planning Commission, 2003).

Increasing scientific evidence of human interference with the climatic system, coupled with growing public concern over global environmental issues, begin to push climate change on to the political agenda in the mid 1980s. Recognizing the needs of policy makers for authoritative and upto date scientific information, world metrological organizations and the UN Environment Programme established the Inter-Governmental Penal on Climate Change in 1988. In 1990, the IPCC issued its First Assessment Report, confirming that climate change was indeed a threat and calling for a global treaty to address the problem. In 1992, UN conference on Environment and Development, called as Earth's Summit, in Rio de Janeiro adopted UN Framework Convention on Climate Change. In 2002, World Summit on Sustainable Development also reviewed the progress of earth summit (Table 3). The Kyoto Protocol targeted to reduce greenhouse gases emissions to 8-10 percent by the year 2012.

Table: 3

A Chronology of the Climate Change Process

Date	Events
1988	WMO and UNEP establish the IPCC. The UN General Assembly takes to climate change for the first time.

1990	The IPCC's First Assessment Report is published. It concludes that international negotiations on a framework convention should start as quickly as possible. The UN General Assembly opens negotiations on a framework convention on climate change and establishes an Intergovernmental Negotiating Committee (INC) to conduct these.
Feb. 1991	The INC meets fro the first time.
9th May 1992	The UN Framework Convention on Climate Change (UNFCCC) is adopted in New York at the resumed fifth session of the INC.
4th June 1992	The UNFCCC is opened for signature at the "Earth Summit" in Rio de Janeiro, Brazil.
21st March 1994	The UNFCCC enters into force.
7th April 1995	The first Conference of the Parties (COP-1) in Berlin launches a new round of negotiations on a "protocol or other legal instrument".
11th-15th Dec. 1995	The IPCC approves its Second Assessment Report Its findings underline the need for strong policy action.
19th July 1996	COP-2 in Geneva takes note of the "Geneva Ministerial Declaration", which acts as a further impetus to the on-going negotiations.
11th Dec. 1997	COP-3 meeting in Kyoto adopts the "Kyoto Protocol" to the UNFCCC.
16th March 1998	The Kyoto Protocol is opened for signature at UN headquarters in New York. Over a one-year period, it receives 84 signatures.
14th Nov. 1998	COP-4 meeting in Buenos Aires adopts the "Buenos Aires Plan of Action", setting out a programme of work on the Kyoto Protocol's operational details and the implementation of the Convention. COP-6 is set as the deadline.
13th-24th Nov. 2000	COP-6 meets in The Hague, but fails to agree on a package of decisions under the Buenos Aires Plan of Action.
4th-6th April 2001	The IPCC accepts the three Working Group contributions to its Third Assessment Report, which

	gave a stronger Evidence of warmer world.
16th-27th July 2001	COP-6 resumes in Bonn. Parties adopt the "Bonn Agreements", registering consensus on key political issues under the Buenos Aires Plan of Action.
29th Oct – 9th Nov. 2001	COP-7 in Marrakesh adopts the "Marrakesh Accords", a set of detailed decisions giving effect to the Bonn Agreements.
26th Aug-4th Sept. 2002	The "World Summit on Sustainable Development" (WSSD) meets in Johannesburg, South Africa, to review progress since the 1992 Earth Summit.
23rd Oct. – 1st Nov. 2002	COP-8 in New Delhi, India; the simplified modalities & Procedures for small scale CDM Projects were adopted.
1st-12th Dec. 2003	COP-9 in Milan, Italy: Kyoto Protocol could not get ratified.

Source: National Action Plan for Operationalizing Clean Development Mechanism in India, Planning Commission, New Delhi, 2003.

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low in developing countries. The efforts made by the UNFCCC and the Kyoto Protocol provisions are clearly inadequate to address the climate change challenge. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy,

forest conservation, reforestation, water conservation, etc. The issue of highest importance to developing countries is reducing the vulnerability of their natural and socio-economic systems to the projected climate change. India and other developing countries will face the challenge of promoting mitigation and adaptation strategies, bearing the cost of such an effort, and its implications for economic development.

The global carbon cycle involves interaction among the atmosphere, oceans, soils and vegetation and fossil fuel deposits. The oceans contain 39,000 giga tonnes of carbon (GtC), fossil fuel deposits about 16,000 GtC, soils and vegetation about 2500 GtC, and the atmosphere about 760 GtC2. Since 1850, land-use change is estimated to have released about 136 GtC and fossil fuel combustion, about 270 GtC. Of this, 180 GtC has ended up in the atmosphere, while 110 GtC has been absorbed by growing vegetation and the remainder by the oceans. It is the increasing concentration of atmospheric CO2 that is the cause for concern about global climate change.

The combustion of fossil fuels and other human activities are the primary reasons for increased concentrations of CO2 and other greenhouse gases. Between 1990 and 1999, an estimated 6.3 GtC/year was released due to the combustion of fossil fuels, and another 1.6 GtC/year was released due to the burning of forest vegetation. This was offset by the absorption of 2.3 GtC/year each by growing vegetation and the oceans. This left a balance of 3.3 GtC/year in the atmosphere3. Controlling the release of greenhouse gases from fossil fuel combustion, land-use change and the burning of vegetation are therefore obvious opportunities for reducing greenhouse gas emissions. Reducing greenhouse gas emissions can lessen the projected rate and magnitude of warming and sea level rise. The

greater the reductions in emissions and the earlier they are introduced, the smaller and slower the projected warming and the rise in sea levels. Future climate change is thus determined by historic, current and future emissions. Of the six aforementioned GHGs, CO2 accounted for 63%, methane 24%, nitrous oxide 10%, and the other gases the remaining 3% of the carbon equivalent emissions in 2000. Thus in addition to CO2, global mitigation efforts need to focus on the two largest and rapidly increasing GHGs.

India is a large developing country with nearly 700 million rural population directly depending on climate-sensitive sectors (agriculture, forests and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Further, the adaptive capacity of dry land farmers, forest dwellers, fisher folk, and nomadic shepherds is very low (Ravindra Nath & Sathaye, 2002). Climate change is likely to impact all the natural ecosystems as well as socio-economic systems as shown by the National Communications Report of India to the UNFCCC (GoI, 2004). The latest high resolution climate change scenarios and projections for India, based on Regional Climate Modelling (RCM) system, known as PRECIS developed by Hadley Center and applied for India using IPCC scenarios A2 and B2 (Rupa Kumar, et.al, 2005)) shows the following:

- An annual mean surface temperature rise by the end of century, ranging from 3 to 5°C under A2 scenario and 2.5 to 4°C under B2 scenario, with warming more pronounced in the northern parts of India.
- A 20% rise in all India summer monsoon rainfall and further rise in rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu, which show a slight decrease.

- Extremes in maximum and minimum temperatures are also expected to increase and similarly extreme precipitation also shows substantial increases, particularly over the west coast of India and west central India.

Natural Disasters Vulnerability

South Asia is most vulnerable to climate change. The region faces daunting climate related development challenges. The impacts of climate change in the form of higher temperature, more variable precipitation and more extreme weather events are already felt in South Asia. The region is already marked by climate variability and a higher incidence of natural disasters. The region has also a long and densely populated coast line with low lying islands that are vulnerable to sea level rise. Urbanization poses an additional challenge in the region. Women, poor and indigenous people are most vulnerable to climate risk.

The Working Group II of IPCC concluded with high confidence (90 per cent probability) that “climate change is projected to impinge on the sustainable development of most developing countries of Asia, as it compounds the pressures placed on natural resources and the environment that are associated with rapid urbanization, industrialization, and economic development”. While vulnerability to climate change is high in South Asia, the region has also emerged as a significant contributor to Greenhouse Gas Emissions. The Greenhouse gas contributions by country in South Asia show that India’s share is significantly high. South Asia is extremely vulnerable to natural disasters. During 1990 and 2008, over 750 million people of the region were affected by the natural disasters (Table 4). The worst affected countries were reported to be India, Bangladesh and Pakistan. The proportion of population affected by natural disasters is

reported to be significantly high in Bangladesh and India. The climate change is also likely to intensify the events of natural disasters.

Table: 4

Natural Disaster Impacts in South Asia (1990–2008)

Country	Population ('000)	Deaths ('000)	People affected ('000)	Population affected (%)	Damage in US$ ('000)
Afghanistan	22,615	6.1	5,410	23.9	69,060
Bangladesh	143,990	155.3	145,713	101.2	12,984,000
Bhutan	602	0.2	66	11.0	3,500
India	1,071,608	53.4	885,244	82.6	25,743,100
Maldives	279	0.0	2	0.7	500,100
Nepal	25,278	4.6	2,796	11.1	245,100
Pakistan	162,662	9.4	27,943	17.2	3,573,054
Sri Lanka	19,258	0.5	6,331	32.9	1,670,070
Total	1,368,327	**229.5**	1,073,504	78.5	**44,787,984**

Source: **www.em-dat.net) and United Nations World Population Prospects (http://esa.un.org).**

The Indian subcontinent is vulnerable to droughts, floods, cyclones and earthquakes. Land slides, avalanche and forest fires also occur frequently (Table 5).

Table: 5

Major Disasters in India Since 1970

S.No.	Disaster	Impact
	Cyclone	
1.	29 October 1971, Orissa	Cyclone and tidal waves killed 10,000 people
2.	19 November 1977 Andhra Pradesh	Cyclone and tidal waves killed 20,000 people
3.	29 and 30 October 1999	Cyclone and tidal waves killed 9,000

	Orissa	and 18 million people were affected
	Earthquake	
4.	20 October 1991 Uttarkashi	An earthquake of magnitude 6.6 killed 723 people
5.	30 September 1993 Latur	Approximately 8000 people died and there was a heavy loss to infrastructure
6.	22 May 1997 Jabalpur	39 people dead
7.	29 March 1997, Chamoli	100 people dead
8.	20 January 2001, Bhuj, Gujarat	More than 10,000 dead and heavy loss to infrastructure
	Landslide	
9.	July 1991, Assam	300 people killed, heavy loss to roads and infrastructure
10.	August 1993, Nagaland	500 killed and more than 200 houses destroyed and about 5 kms. Road damaged
11.	18 August 1998, Malpa, Uttarakhand	210 people killed. Villages were washed away
	Floods	
12.	1978 Floods in North East India	3,800 people killed and heavy loss to property
13.	1994 Floods in Assam, Arunachal Pradesh, Jammu and Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, Goa, Kerala and Gujarat	More than 2000 people killed and thousands affected
14.	2004 Tsunami, Coastal areas of Tamil Nadu, Andhra Pradesh, Andaman Nicobar Islands and Pondicherry.	More than 10,000 people were killed and damage of $1068 million to properties.

Source: Natural Hazards and Disaster Management, Text Book in Geography for Class XI CBSC, Delhi.

The loss from natural disaster in India is shown in Table 6. About 7 per cent population of the country was affected by the natural disasters during 1971-2008. The economic losses due to natural disasters accounted for 2.5 per cent of GDP. The coastal zones are likely to be affected badly due to climate change. During 2000, population in low elevation coastal zones was reported to be 6.3 per cent while 2.5 per cent geographical area is reported to be low elevation coastal zones. This area and population is likely to be affected due to climate change. Projected physical impact of climate change by 2050 also demonstrates that there will be increased in 1.6 centigrade temperature and 1.9 per cent precipitation with 2.7 per cent precipitation intensity during 2000-2050 (Table 6).

Table: 6

Loss for Natural Disaster in India (1971–2008)

Particulars	Numbers
Mortality	
Drought (Number of People during 1971-2008)	8
Floods and Storms (Number of People during 1971-2008)	2489
People affected	
Droughts (Number of people '000' affected during 1971-2008)	25294
Floods and Storms (Number of people '000' affected during 1971-2008)	22314
Share of Population affected (1971-2008)	7.2
Economic losses	
Droughts ($ thousand) (1971-2008)	61608
Floods and Storms ($ thousand) (1971-2008)	1055375
Percentage of GDP (1961-2008)	2.5

Coast Line	
Kelometres (2008)	7000
Population in low elevation coastal zones (%) (2000)	6.3
Area in low elevation coastal zones (%) (2000)	2.5
Projected physical impact by 2050	
Change in temperature (2000-2050)	1.6
Change in heatwave duration (Number of days) (2000-2050)	10.8
Change of precipitation (2000-2050)	1.9
Precipitation intensity (2000-2050)	2.7

Source: **World Development Report, 2010.**

Among the 32 states and Union Territories in the country, 22 are multi-disaster prone. About 40 million hectares of land in the country has been identified as flood prone and on an average 18.6 million hectare of land is flooded annually. About 57 per cent of area of the country is vulnerable to seismic activity. About 18 per cent of country's total area is drought prone, approximately 50 million people are annually affected by droughts and about 68 per cent of total sown area of the country is drought prone. India has a long coastline of 8040 km. which is exposed to tropical cyclones arising in the Bay of Bengal, the Arabian Sea and Indian Sea. The Indian Ocean is one of the six major cyclonic prone regions of the globe (Jain, 2004:61). The Coromandal coastline is more cyclones prone, with 80 per cent of the total cyclones generated in this region. Risk to the existing housing stock in various states and union-territories had been estimated by Expert Group Set up by the Ministry of Urban Affairs and Employment, Government of India. About 3.9 million houses are susceptible to earthquakes of very high intensity, about 20 million houses are susceptible to damage due to winds and about 9.3 million houses are susceptible to damage due

to floods. Besides the risk of earth quakes, cyclones and floods are liable to very high damage and destruction of vulnerable houses under heavy rains. (Jain, 2004:61). Some 49 per cent of the total housing stock is liable to very high damage from natural hazards, while about 1 per cent of the total housing stock gets destroyed every year. It is to be noted that in earth quake, 80 per cent of the casualties are due to collapsing buildings. Brick and stone buildings without proper support are liable to collapse. Non-engineered buildings continue to be built in the areas prone to natural disasters. Unemployment, poverty backwardness, migration from rural areas and increasing price of land and construction, million of people are occupying disaster prone areas. Thus about 6 per cent increase in disaster affected population has been reported.

The changing topography due to environmental degradation has also increased the vulnerability in the country. In 1988, 11.2 per cent of total land area was flood prone, but in 1998 floods inundated 37 per cent geographical area. Three major disasters that India have experienced in the recent past are the super cyclone in Orissa (1999), earthquake in Gujarat (2001) and Tsunami (2004) in Tamil Nadu, Pondicherry, Andaman Nicobar Islands and parts of other southern states. Frequent disasters lead to erosion of development gains and restricted options threatened by hazards.

The continent of Asia is particularly vulnerable to disasters strikes. Between the years 1991 to 2000 Asia has accounted for 83 per cent of the population affected by disasters globally. Within Asia, 24 per cent of deaths due to disasters occurred in India, on account of its size population and vulnerability. Floods and high winds account for 60 per cent of all disasters in India. Many parts of the Indian sub-continent are susceptible to different types of disasters owing to the unique topography and climatic characteristics. About 54 per cent of

the sub continent's landmass is vulnerable to earthquakes while about 4 crore hectares is vulnerable to periodic floods. The country has suffered four major earthquakes in the span of last 50 years along-with a series of moderate intensity earthquakes that have occurred at regular intervals. Since 1988, six earth quakes have struck different parts of the country. Tsunami in India killed 10749 persons while $1068 million loss or damage to properties was reported.

The Indian sub-continent lies upon the Indian plate which is moving northward and collides with the Eurasian Plate. Due to this collision, the Himalayas are generated in the process. This is the main cause of earthquakes from Himalayas to the Arakan Yoma. The same process, results in earthquakes in Andaman and Nicobar Islands. Sometimes earthquakes of different magnitudes occur within the Indian Plate. As per the latest seismic zoning map of India, the country is divided into four Seismic Zones. Zone V marked in red shows the area of very high risk zone, Zone IV marked in orange shows the area of high risk zone, Zone III marked in yellow shows the region of moderate risk zone and Zone II marked in blue shows the region of low risk zone. Zone V is the most vulnerable to earth quakes, where historically some of the country's most powerful shock has occurred. As per India's Seismic Vulnerability Atlas, 58 cities of India fall within seismic vulnerability Zones. Out of which 13 cities are located in Zone V, 16 Cities in Zone IV AND 29 cities are situated in Zone III.

Geographically, Zone V includes the Andamand and Nicobar Islands, all of North Eastern India, parts of north western Bihar, eastern parts of Uttaranchal, Kangra Valley in Himachal Pradesh, Srinagar area in Jammu and Kashmir and Rann of Kutchh in Gujarat. Earthquakes with magnitudes in excess of 7.0 have occurred in these areas, and have had intensities higher than IX. Most of the

earthquakes which occurred were rated at 5-6 scale (60 per cent) while more than one third earthquakes were in between 6-7 Richter scale. Again, about half of the earth quakes have occurred in North East India alone. During the earthquakes, majority of losses is due to collapse of buildings and damage to infrastructure. More than half of the houses are built with stone walls and 35 per cent have burnt brick units which are highly vulnerable to sustain damage of seismic intensities namely VII, VIII and IX.

Tsunami Disaster in the Indian Ocean was one of the worst natural disasters in modern times. Over 200,000 people died and more than 1.5 million people lost their homes and their livelihoods. If the earthquake is under water and land movement is near the coast then tsunami may strike suddenly and if the earth movement is far in the sea then it may take few minutes to hours before striking the coast. The onset is extensive and often very destructive. The general causes of tsunamis are geological movements.

The recent tsunami strike in December 2004 severely hit the coastal states of Tamil Nadu, Kerala, Andhra Pradesh and union territory of Andaman Nicobar Islands. According to Government reports, 10739 people in India lost their lives and 6913 were injured. It was reported that 5640 persons are still missing. The highest human losses were in the Andaman Nicobar Islands and the state of Tamil Nadu. Overall damages were estimated at about $660 million and losses to $410 million (UN, 2005).

Landslides are slippery masses of road, earth or debris which make by force of their own weight down mountain slopes or riverbanks. Though, they occur gradually, however, sudden failure can often bring toll and heavy losses to humankind and property. Erosion, intense rainfall, geological weak materials, human excavation,

earthquake shaking and volcanic explosion are some of the factors for land sliding.

Cyclonic disturbances of varying intensities originate in the Bay of Bengal and the Arabian Sea mainly during the April-December period. A scrutiny of cyclones in nearly 100 years (1891-1989) reveals that a few districts were hit by cyclones more often than other districts. These districts are Junagarh, 24 Parganas, Midnapur, Balasore, Cuttack, Puri, Srikakulam, Vizag. East Godavari, Krishna, Nellore and Tanjore while the coastal areas of Orissa and West Bengal were affected, by a large number of cyclonic storms during post 1949 period (Subhiah, 2004). The cyclone of 1977 caused death toll of over 14000 while recent cyclone in December 2000 severely hit three districts of Tamil Nadu.

The Bangladesh cyclone of 1991 hit India too and caused death of 1.32 lakh persons. The coastal bet plantation (green belt plantation along the coastal line in a scientific interweaving pattern) can reduce the adverse impact of hazards of cyclone, tsunami, and flood. However, the frequent cutting of plants, trees and clearance of forest and mangroves, the cyclone and tsunami waves trend freely in land. The lakh of productive forest cover allows water to immediate large areas and cause destruction. Thus, community based mitigation strategies are to be introduced.

Climate change poses potentially devastating facts on India's agriculture. The Eastern India is already suffering severely from the consequences of illegal migration from Bangladesh. About 20 million Bangladeshis are estimated to have crossed into India. The Bangladeshi influx into India is mainly due to natural disasters in Bangladesh and subsequently its impact on agricultural productivity. If climate change is added to the natural disasters, the rise of sea level and consequential submergence of swaths of Bangladesh is likely to

pressurize the Bangladeshi influx into India. Over exploitation of the Indus in its upper reaches has begun to cause extensive salination of the soil in the Sindh. Slower development in Pakistan as well as uncertainties that bed evil the country have already begun to cause migrants to cross over the Indian border (Kohli, 2010). If ecological deterioration continues, India will be faced with an influx from the west to compound the problems arise today influx of illegal migrants from Bangladesh.

Floods are a recurring phenomenon in chronically flood prone regions in India. Floods affect around 7.56 million hectares of area (2.30 per cent of country's area) and 3.3 million hectares of crop lands every year (4 per cent of the cropped area). Eastern India, comprising Uttar Pradesh, Bihar, West Bengal, Assam, and Orissa account for about 70 per cent of the flood impacts in the country.

The flood of 2000 alone killed about 1300 persons in Gujarat, Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Uttar Pradesh and West Bengal. Even, floods have adversely affected economy and society of major metropolitan cities like Mumbai, Surat, Ahmadabad, Raipur, and Pune etc. in the recent past.

In 2001, 122 districts were hit by floods and affected 21.110 million populations. Mapping of flood prone areas; land use regulation and control; construction of engineered structures; flood management; and community based mitigation such as sedimentation clearance, reforestation, etc. may reduce the adverse impact of floods in vulnerable areas.

Drought prone area programme was initiated during 1970-71 to focus solely on drought prone areas. Presently the programme is being implemented in 972 blocks of 185 districts in 16 states. A large number of districts are covered under the programme in the states of

Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Gujarat and Uttarakhand. Similarly, desert development programme was started in the states of Rajasthan, Gujarat, Haryana, Jammu & Kashmir and Himachal Pradesh during 1977-78. The coverage of the programme has been extended to a few more districts in Andhra Pradesh and Karnataka. Drought is an insidious natural hazard that results from a departure of precipitation from expected or normal that is insufficient to meet the demands of human, plant and animal activities. Almost 35 per cent of the country's area, receiving annual average rainfall of less than 750 mm is prone to drought once in three years. In these areas, almost 200 million people are affected in varying degrees by drought. In the arid and the semi arid regions, seasonal periodicities can affect the pattern of livelihood system of farmers.

Endangering Biodiversity

Biodiversity, encompassing variety and variability of all life on Earth, is the product of evolutionary history. Biodiversity benefits human societies in myriad of ways by providing wide range of ecological, economic, social, cultural, educational, scientific and aesthetic services. Extensive anthropogenic interventions and climatic change in the natural eco-systems have been resulting in loss of biodiversity. South Asia is endowed with an exceptional array of biodiversity. The region’s biodiversity is reflected in varied biomass and the wide range of habitats within its ecosystems. The rich ecological landscape has been integral to the lives, wellbeing and livelihoods of the millions of people. The biodiversity profile of South Asia region is shown in Table 7. Climate change will increase the threat the ecosystems and biodiversity. It will also affect the vegetation, productivity and biodiversity. In India, climate change is projected to lead the severe loss to the vegetation cover in various

ecosystems. Fresh water and inland wetlands will be affected by the likely impacts of sea level rise, glacial melt and extreme weather events.

Table: 7

Biodiversity Profile of South Asia

	Afghanistan	Bangla-desh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Forest Area (% of land area)	1.3	6.7	68	22.8	3.3	25.4	2.5	29.9
Deforestation (average annual %; 1990-2005)	2.7	0.1	-0.3	-0.4	0	1.9	1.9	1.3
Conservation Status								
% Threatened Animal Species	5.71	12.11	5.72	19.54	7.73	15.82	9.51	35.12
Critically Endangered (all species)	3	10	3	72	1	4	8	129
Endangered (all species)	5	28	12	161	3	18	16	127
Vulnerable (all species)	22	51	32	240	7	52	50	159
Endemic (all species)	1	1	3	276	0	2	3	361
Globally Threatened Species Present in the Country								
Mammals	14	23	22	86	0	31	18	21
Birds	12	23	16	73	0	27	25	15
Reptiles	1	21	0	25	2	6	9	8
Amphibians	1	1	1	66	0	3	0	52
Fish	0	11	0	35	9	0	20	29
Invertebrates	1	0	1	22	0	0	0	52
Plants	1	10	7	166	0	7	2	238
Protected Areas								
Nationally Protected Area (% of land area)	0.3	0.5	25.6	5.3	0	18.6	9.5	27.3
Total Protected Areas[a] (number)	9	26	9	718	25	30	234	278

Sources: The World Bank's The Little Green Data Book 2008; 2008 International Union for Conservation of Nature (IUCN).

India is rich in biodiversity resources. It represents large bio-geographic zones ranging from Himalayan region to the coastal areas. India ranks 7th in mammals, 9th in birds, and 5th in reptiles. India has 23.39 per cent of its geographical area under forests and tree cover. Of the 34 globally identified biodiversity hot spots, India harbours 4 hot spots i.e. Himalya, Indo-Burma, Western Ghats, and Sri Lanka and Sundaland. The global estimates as per IUCN Red List, 2008 suggest that 10 per cent of the vertebrate and 0.2 per cent of invertebrate described fauna is threatened. The population trends in threatened Indian species are shown in Table 8. Out of 1296 species, 648 species were recorded as threatened.

Table: 8

Population Trends in Threatened Indian Species

Group	Threatened	No change or stable	Upwards or improving	Downwards or decreasing	Indeter-minate	Trends not available
Mammals	213	4	1	47	87	74
Birds	149	2	-	80	10	57
Reptiles	033	-	-	2	2	29
Amphibia	148	5	-	68	73	2
Pisces	75	-	-	21	42	12
Crustacea	12	-	-	-	-	12
Mollusca	5	-	-	-	1	4
Hymenoptera	5	-	-	-	-	5
Lepidoptera	4	-	-	-	1	4
Odonata	3	-	-	-	1	3
Anoplura	1	-	-	-	-	1
Total	**648**	**11**	**1**	**218**	**217**	**201**

Source: Red List of Threatened Species, IUCN, 2004.

In terms of plant diversity, India ranks 10th in the world and 4th in Asia. With over 45500 plant species, India represents nearly 11 per cent world's known floral diversity (MoEF, 2009). India has significant share in the plant species of the globe however; a larger proportion of the plant species in India are endemic (Table 9). India has 246 globally threatened floral species which constitute approximately 2.9 per cent of the world's total number of threatened floral species.

Table: 9

Endemism in Different Plant Groups of India

Plant groups	Number of Species in India		% of Endemic Species
	Total Number of Species	Number of Endemic Species	
Virus/Bacteria	850	--	--
Algae	7175	1925	26.8
Fungi	14,500	3500	24.0
Lichens	2223	527	23.7
Bryophytes	2500	629	25.1
Pteridophytes	1,200	193	16.0
Gymnosperms	67	7	14.9
Angiosperms	17,527	6200	35.3

Source: Ministry of Environment and Forest, New Delhi, 2009.

India has 1.8 per cent of the global forest area with per capita forests of 0.0.8 hectare. The total forest and tree cover of the country is estimated to be 23.39 per cent of the geographical area. Protected areas are the corner stones of biodiversity conservation efforts. India has created a network of protected areas and other conservation areas which include a total of 661 units, besides identifying a number of wet lands under NWCP for conservation interventions. The area

covered under protected areas and other conservation sites accounts for around 9 per cent of the total geographical area of the country. Out of 27 biogeographic provinces, 19 are adequately represented in the protected areas network (Table 10).

Table: 10

National Parks & Wildlife Sanctuaries in India

Zone Name	% of India's Geographic Area	No. of NPs	% of Biozone Area	No. of WLS	% of Biozone Area	No NPs of + WLS	% of Biozone Area
Trans Himalaya	5.62	3	3.14	4	5.65	7	8.79
Himalaya	6.41	12	3.50	65	7.63	77	11.12
Deserts	6.51	1	1.48	5	6.03	6	7.51
Semi-Arid	16.41	10	0.28	81	2.30	91	2.58
Western Ghats	4.02	16	2.78	47	7.58	63	10.36
Deccan Peninsula	41.99	24	0.70	127	3.21	151	3.92
Gangetic Plain	10.79	6	0.67	32	1.54	38	2.21
Coasts	2.78	5	1.90	20	3.24	25	5.14
North East	5.21	13	1.56	36	2.00	49	3.56
Islands	0.25	9	14.02	96	4.72	105	18.75
Grand Total	**100**	**99**	**1.19**	**513**	**3.60**	**612**	**4.79**

Source: National Wildlife Database, Wildlife Institute of India, 2009

Besides, National Parks and Wildlife Sanctuaries, 15 biosphere reserves have been created in India which represent many states and serve the purpose of biodiversity conservation (Table 11).

Table: 11

Biosphere Reserves – A profile

S. No.	Name of BR	Total Geographical Area (Km^2)	Representative States
1.	Niilgiri	5520	Tamil Nadu, Kerala & Karnataka
2.	Nanda Devi	5860.69	Uttarakhand
3.	Nokrek	820	Meghalaya
4.	Manas	2837	Assam
5	Sunderban	9630	West Bengal
6.	Gulf of Mannar	10500	Tamil Nadu
7.	Great Nicobar	885	A& N Islands
8.	Simlipal	4374	Orissa
9.	Dibru-Saikhowa	765	Assam
10.	Dehang –Debang	5111.5	Andhra Pradesh
11.	Kangchendzonga	2619.92	Sikkim
12.	Pachmari	4926.28	Madhya Pradesh
13.	Agasthymalai	3500.36	Tamil Nadu & Kerala
14.	Achanakmar Amarkantak	3835.51	M.P. & Chattisgarh
15.	Kachchh	12,454.00	Gujarat

Source: Ministry of Environment and Forest, New Delhi, 2009.

India has a long history of legislation relevant to biodiversity conservation. The Constitution of India contains specific provisions for environmental conservation. Numerous legislations (Acts, Rules, Circular and Orders), related to environmental protection as well as specific laws relating to forests, wildlife and biodiversity have been

passed taking into account governmental and civil society concerns (Box 1).

Box-1

Legislations of Biodiversity Conservation

Wildlife (Protection) Act, 1972
Indian Forest Act, 1927
Forest (Conservation) Act, 1980
Biological Diversity Act, 2002
Biological Diversity Rules, 2004
Protection of Plant Varieties and Farmers' Rights Act, 2001
The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006
National Forest Policy, 1988
National Conservation Strategy and Policy Statement for Environment and Sustainable Development, 1992
National Agricultural Policy, 2000
National Seeds Policy, 2002
National Wildlife Action Plan (2002-2016)
Comprehensive Marine Fishing Policy, 2004
National Biodiversity Authority (2003)
National Environment Policy, 2006
National Forestry Action Programme (2000-2020)
National Biotechnology Development Strategy (2007)
National Forestry Commission Report (2006)
National Biodiversity Strategy and Action Plan (2005)
National Action Plan on Climate Change (2008)

Source: Ministry of Environment and Forest, New Delhi, 2009.

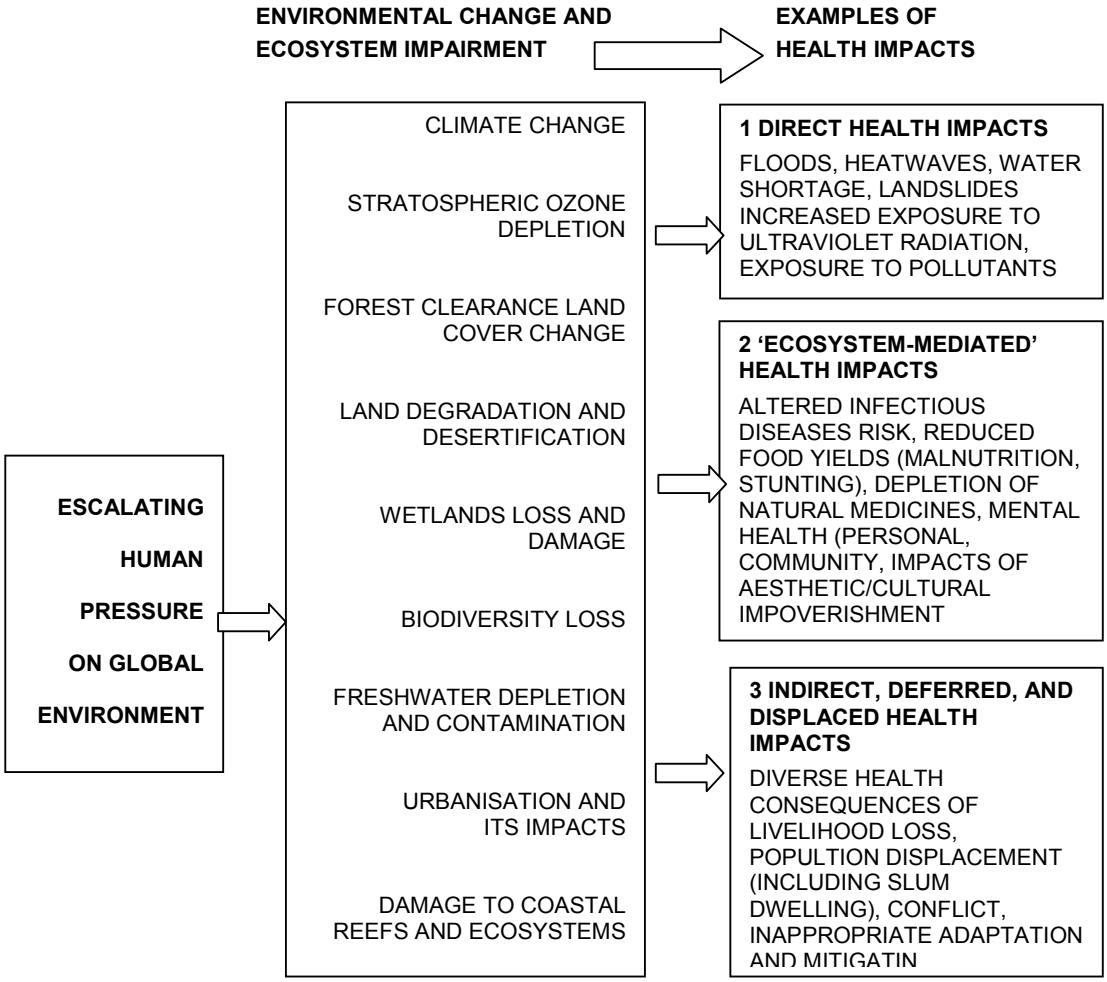
Impact of Climate Change on Human Well-being

Climate change will affect the basic determinants of health. WHO has estimated that in the year 2000, climate change accounted for the loss of 1.5 lakh lives globally and 77000 lives in Asia Pacific region. Rising in vector born diseases such as malaria, dengu and chikan guina is a major upshot of climate change. The natural disasters not only lead behind a trail of destruction in terms of lives lost or injured, but also displaced population, often without access to health services and the omni present danger of infectious diseases outbreaks like diarrhea and malaria. Most obvious impact of global warming is heat stress; the impact of heat stress may result in the increase in heat stroke, cardiovascular collapse and respiratory complications. The poor and vulnerable are the main victims of climate change and its health impact (Dogra, 2009).

It is becoming increasingly clear that population growth and economic development are leading to rapid changes in our global eco-systems. Ecosystems are the planet's life support systems for the human species and all other forms of life. Human biology has a fundamental need for food, water, clean air, shelter and relative climatic constancy. Other health benefits include those derives from having a full complement of species, intact water sheds, climate regulation and genetic diversity. Stress on fresh water sources, food producing systems and climate regulations could cause major adverse health impacts (Chart 2).

Chart: 2

Effects of Ecosystem Change on Health

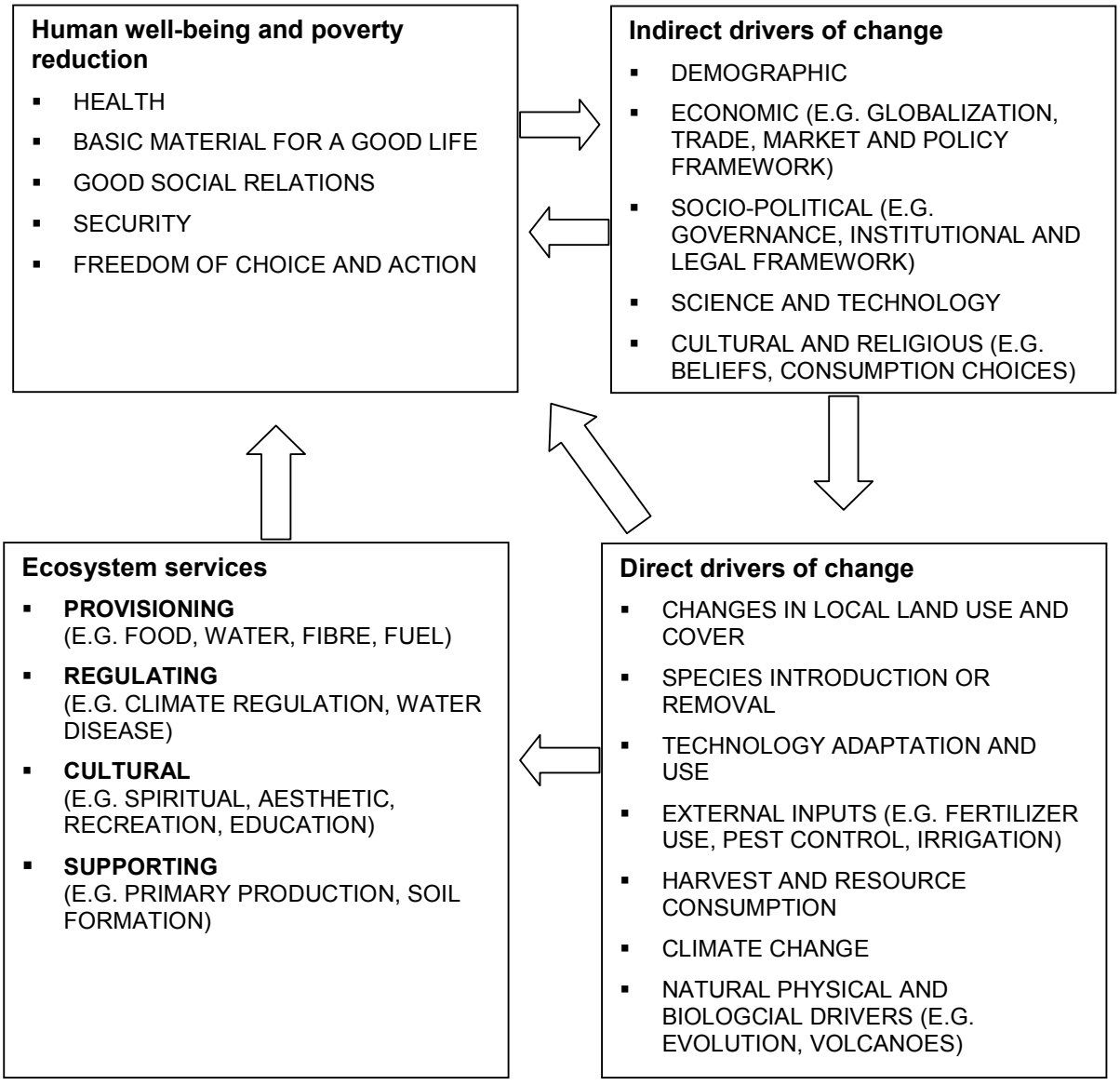


Source: Ecosystems and Human Wellbeing, A Report Millennium Ecosystem Assessment, 2005.

The ecosystems are essential to human wellbeing and especially to human health as defined by World Health Organization (2005). Chart 3 shows linkages between human wellbeing and ecosystems.

Chart: 3

Linkages Between Ecosystem & Human Wellbeing



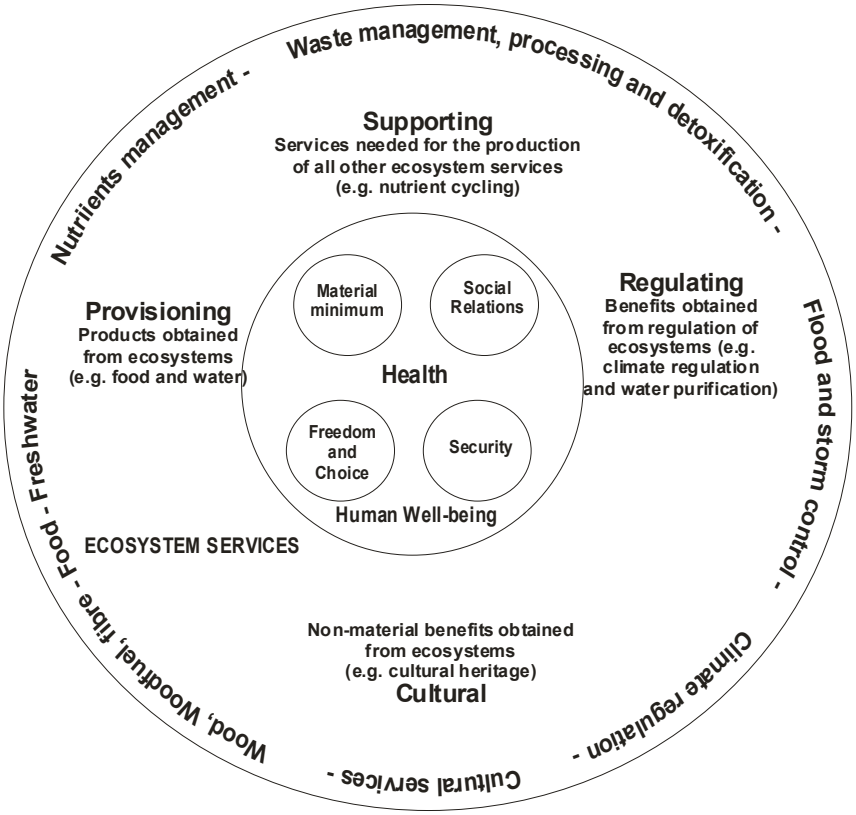
Source: Ecosystems and Human Wellbeing, A Report Millennium Ecosystem Assessment, 2005.

In many respects, human health is a bottom line component of wellbeing, since changes in economic, social, political, residential, psychological and behavioural circumstances all have health consequences. Basic determinants of human wellbeing may be defined in terms of security, adequate supply of basic materials for livelihoods, personal freedom, good social relations and physical

health. By influencing patterns of livelihoods, income, local migration and political conflict, ecosystem services impact the determinants of human wellbeing (WHO, 2005:14) (Chart 4).

Chart: 4

Associations Between Health, Other Aspects of Human Well-Being and Ecosystem Services

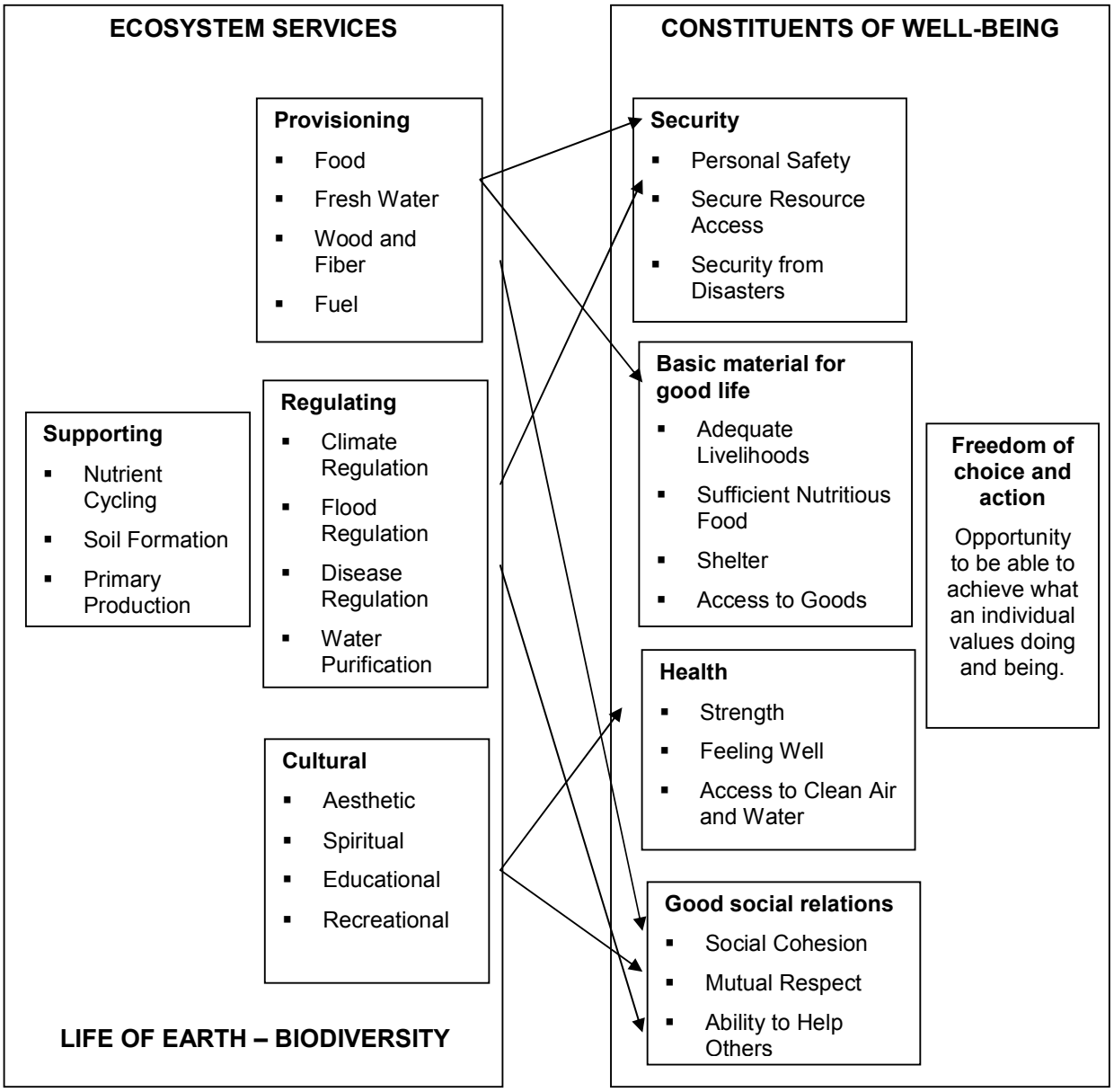


Source: Ecosystems and Human Well being, WHO, 2005.

Ecosystem services have implications of human wellbeing. The benefits obtained from ecosystems include food, natural fibres, steady supply of clean water, regulation of pests and diseases, medicinal substances, recreation and protection from natural hazards (Chart 5).

Chart: 5

Categories of Ecosystem Services



Source: Ecosystems and Human Wellbeing, A Report Millennium Ecosystem Assessment, 2005.

The infectious diseases of the major public health importance require special attention due to ecosystem changes. These also have the greatest potential for risk reduction by planned interventions. Malaria, dengue, schistosomiasis, filariasis, leishmaniasis, cholera, cryptosporidiosis, encephalitis, etc. are some of the diseases which are associated with the changes in ecosystems (WHO, 2005:25). The emergence of these diseases is associated with deforestation, urbanization, poor housing, forest encroachment, agricultural development, habitat fragmentation, urban sprawl, climate variability, mining, industrial food production, etc.

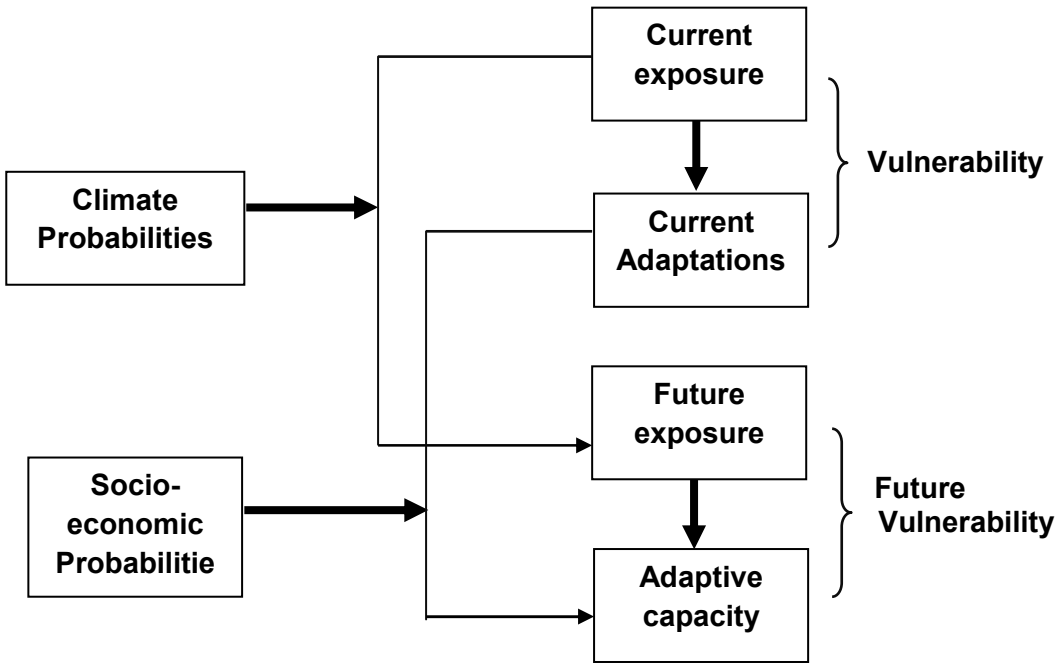
Vulnerability and its causes play essential roles in determining impacts (Handmer, et.al., 1999). The evolution of vulnerability assessments has been stimulated by changing stakeholder needs, and has been aided by increasing scientific knowledge in a range of relevant disciplines. The assessment starts with engaging the community to assess current vulnerabilities, which includes identifying conditions or exposures that are pertinent to the community and assessing the adoptive capacity of the community to deal with these exposures. The analytical framework for vulnerability assessment looks at what systems, places and people are vulnerable and why, and in the process identifies what types of adoption strategies will be most effective (Chart 6).

Adoption to climate change in the context of sustainable development is shown in Chart 7. There are several impacts of climate change and their assessment is imperative in order to adopt strategies to cope with them.

Chart 8 shows adaptation policy framework approach. Five basic framework components are linked by two cross cutting components, represented by the arrow adaptive capacity, and the larger frame, the stakeholder context, within which all the components are played out.

Chart: 6

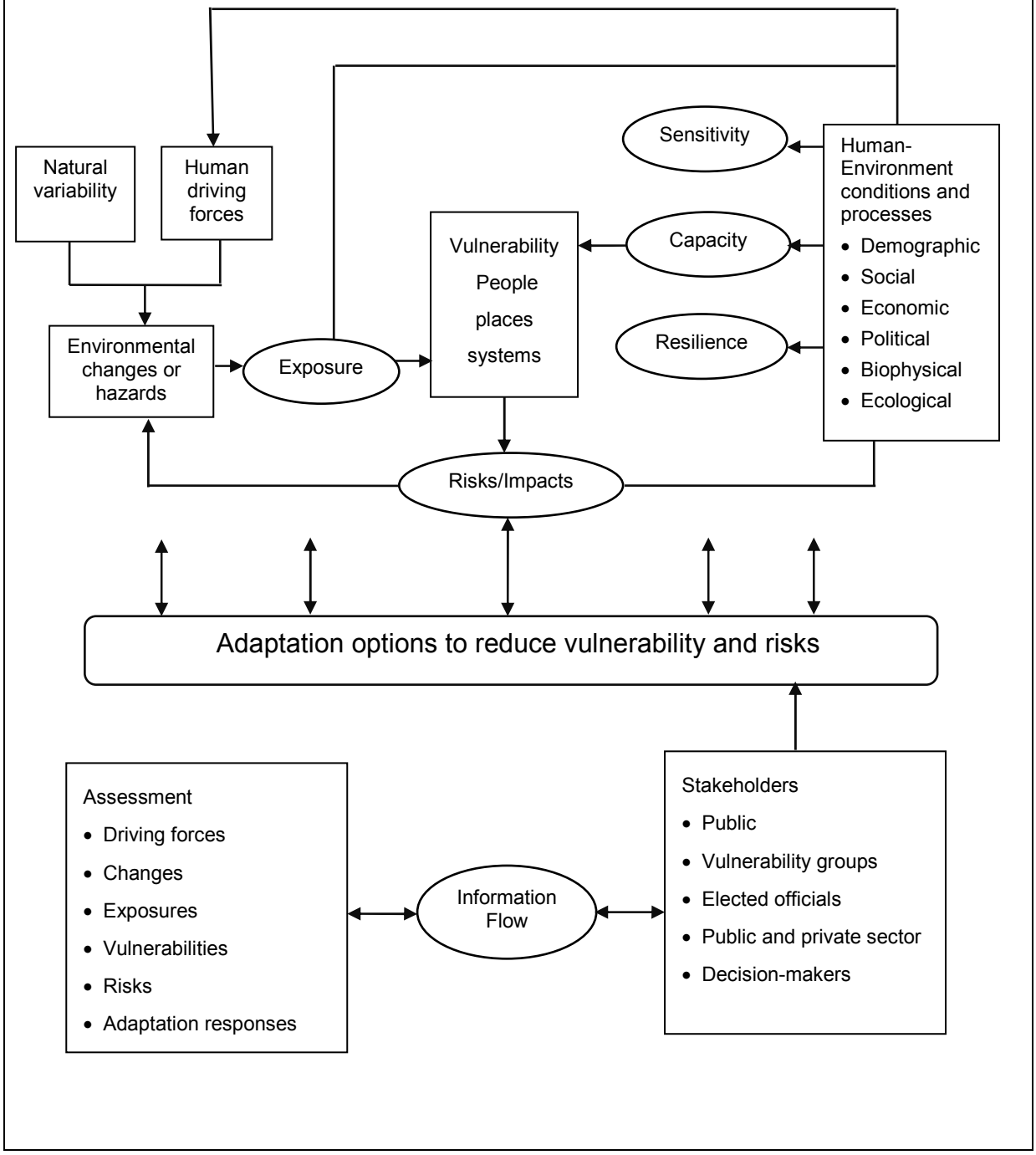
Analytical Framework for Vulnerability Assessment



Source: TERI, New Delhi.

Chart: 7

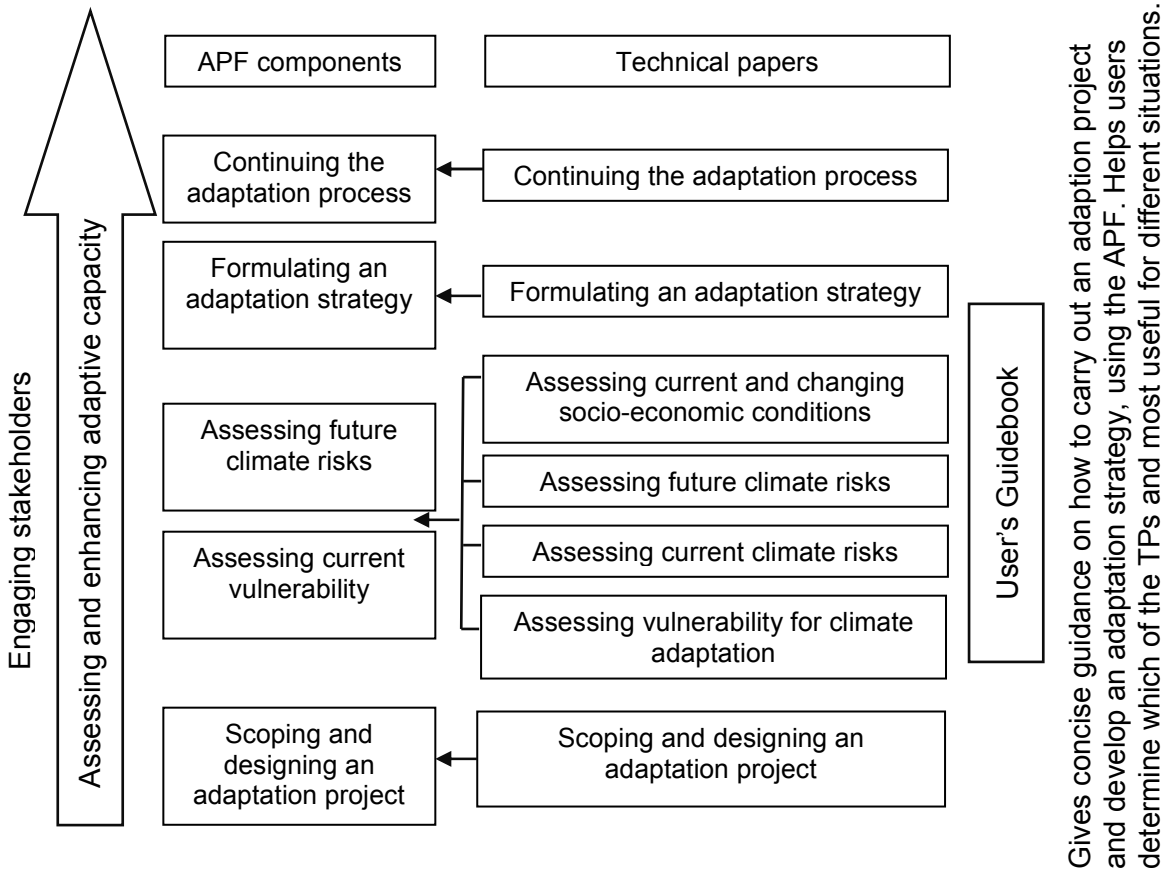
Framework for Vulnerability Assessment



Source: www. Aiaccproject.org

Chart: 8

Adaptation Policy Framework (APF)



Source: www.undp.org./gef

Climate change impacts and vulnerability index are shown in Table 11. The adverse impacts of climate change are likely to happen in various ecosystems. However, the severe impacts may threat to the sustainability of water resources.

Table: 11

Climate Change Impacts and Vulnerability Index

Ecosystems	Threats
Coastal (mangroves, mudflats, estuaries)	Inundation, salination, storms, species loss.
Coral reefs	Bleaching, acidification, loss of ecological and protective services, reduction in species diversity.
Inland wetlands	Desiccation, drainage and diversion, degradation and service loss.
Forests	Loss of forest cover and species, altered composition and structure, enhanced evapo-transpiration.
Mountain (temperate, subtemperate, temperate	Altitudinal shifts in vegetation disrupting species types.
Mountain (subalpine, alpine)	Loss of vegetation cover.
Glaciers	Loss of coverage.
Desert	Expansion.
Rangelands & grasslands	Regime shift, degradation due to overgrazing and increased incidence of fire.
Freshwater (rivers, lakes)	Desiccation, increased salinity at coast, degradation due to increased demand.
Species diversity (floral & faunal)	Loss of diversity and habitat, changes in species composition and food web.

Key: Locations particularly vulnerable to impacts of climate change.

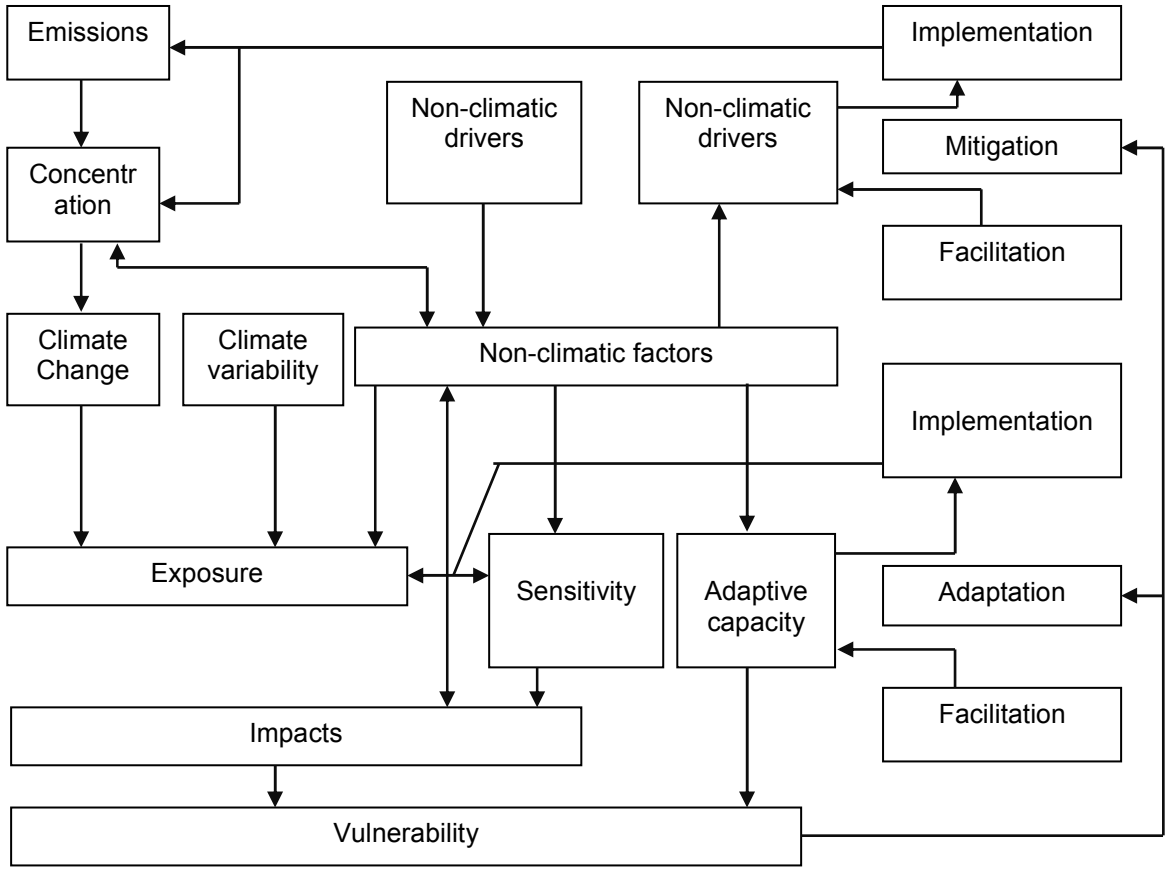
Two types of adaptation are distinguished in the framework (Chart 9): Facilitation and Implementation. The former encompasses activities that enhance adaptive capacity thereby improving conditions for implementation of adaptation measures. Implementation refers to those activities which help in avoiding adverse impact of climate change.

Elements of vulnerability to climate change in rural areas are shown in Chart 10. The majority of the population of India lives in rural area and therefore, there is imperative need to evolve strategies to reduce vulnerability

of climate change in those areas. About 1/3rd geographical area of the country is drought and flood prone. Climate change may increase the intensity of drought and flood both. The economy of rural India is predominantly based on agriculture which is land based economic activities. The climate change is likely to reduce the agricultural productivity and livelihood.

Chart: 9

Adaptation Policy Assessment



Source: Kalein & Fussel, 2002.

India is faced with the challenge of sustaining its rapid economic growth while dealing with global threat of climate change. This threat emanates from accumulated greenhouse gas emissions in the atmosphere, anthropogenically generated through long term and intensive industrial growth and high consumption life styles in developed countries (GoI, 2009). National Action Plan on Climate Change has been setup by Government of India which addresses the urgent and critical concerns of the country through a directional shift in the development pathway, including through the enhancement of the current and planned programmes. In order to deal with the challenge of climate change, there is imperative need to focus on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation. There are 8 National Missions which form the core of the National Action Plan, representing multipronged, long term and integrated strategies for achieving key goals in the context of climate change. These Missions include (1) National Solar Mission, (2) National Mission for Enhance Energy Efficiency, (3) National Mission on Sustainable Habitat, (4) National Water Mission, (5) National Mission of Sustaining Himalayan Ecosystem, (6) National Mission for Green India, (7) National Mission for Sustainable Agriculture, (8) National Mission on Strategic Knowledge for Climate Change.

The most important strategy is related to increasing energy efficiency. There is vast potential of renewable energy resources. The exploitation of renewable energy resources will drastically reduce the high rate of consumption of fossil fuel and will result in high deduction in global warming. Energy efficiency opportunities and measures are shown in Table 12.

Table: 12

Energy Efficiency Opportunities and Measures in Key Consuming Sectors

Sector	Energy efficiency improvement opportunities
Buildings	Integrated building design and measures such as better insulation, advanced windows, energy-efficient lighting, space conditioning, water heating, and refrigeration technologies plus energy efficient brick manufacturing and wall paneling.
Industry	Industrial processes, cogeneration, waste heat recovery, preheating, efficient drives (motor, pump, compressors).
Cities and municipalities	District heating systems, combined heat and power, efficient street lighting, efficient water supply, pumping, and sewage removal systems, solid waste management (methane capture to generate electricity).
Agriculture	Efficient irrigation pumping and efficient water use, such as drip irrigation.
Power supply	New thermal power plants: Combined cycle, supercritical boilers, integrated gasification combined cycle (IGCC), etc. Existing generation facilities: Refurbishment and repowering (including hydro), improved operation and maintenance practices, and better resource utilization (higher plant load factors and availability) Reduced transmission and distribution losses: High-voltage lines, better insulated conductors, capacitors, efficient and low-loss transformers, and improved metering systems and instrumentation.
Transport	Efficient gasoline/diesel engines, urban mass transport systems, modal shifts to inter- and intra-city rail and water transport, improved fleet usage, compressed natural gas (CNG) vehicles.
Households	Efficient lighting, appliance efficiency, improved cook stoves, solar panels for heating and cooking.

The Fourth Assessment Report of the Inter-governmental Penal on Climate Change has predicted the serious challenge due to climate change. The report highlighted the increasing level of anthropogenic greenhouse gases emissions which could lead to impact on fresh water availability, oceanic acidification, food production, flood of coastal area and increase

burden of vector born and water born diseases associated with extreme weather events. It has been estimated that there will be at least 1 per cent of GDP to address the issues of climate change and mitigating the adverse impact of it in India alone. Government of India has already set up National Action Plan for Climate Change with creation of Eight National Missions to assess the impact of climate change and evolving strategies to address the implications of climate change.

Sustainable Urban Development

Sustainable development means attaining a balance between environmental protection and human economic development and between the present and future needs. It means equity in development and sectoral actions across space and time (Cruz, et.al., 2007). It requires an integration of economic, social and environmental approaches towards development. Sustainable urban development refers to attaining social equity and environmental protection in urbanization while minimizing the costs of urbanization. Sustainable urban development specially means achieving a balance between the development of urban areas and protection of the environment within eye to equity in employment, shelter, basic services, social infrastructure and transportation in urban areas. Ensuring environmental sustainability involves (a) integration of the principles of sustainable development in the policies and programmes of the country; (b) reversal of loss of environmental resources; (c) reduction of the proportion of people without sustainable access to safe drinking water, and (d) improving the lives of slum dwellers. In the context of climate change, human influences can be increase in CO_2 levels due to combustion of fossil fuels, aerosols, cement manufacture etc. Other factors like ozone depletion, animal, agriculture and deforestation also change climate. The effect of climate change can be found

on among other things, on rising sea level that may accelerate coastal erosion, on increase in temperature, on increase in intensity of natural disaster, and very importantly on vector borne diseases. Thus, it is likely that climate change will hamper sustainable development of India as it increases the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development. In order to reduce the effect of climate change, we need to include climate proofing concept in national development initiatives.

Sustainable management of urban basic services such as water supply, waste management, management of energy resources, etc. needs new approaches and strategies in the context of climate change. Conservation of old water bodies like lakes, ponds can be made for increased and sustainable water supply. The rainwater harvesting and regulation of building byelaws in the urban centres are likely to improve the rainwater harvesting, water conservation and water recharging. Waste management practices should be started from the production and distribution stages of economic activities through reuse and recycling. Similarly, energy management practices should be encouraged in the planning of buildings and city form. Experiences around the world strongly suggest that densely populated cities produce lower demand for energy – indicating that India's urbanization has the potential to help the efforts to cut carbon emissions. India could achieve deep cuts in GHG emissions if the cities manage their demand for energy proactively rather than simply focusing on building the infrastructure necessary to keep pace with demand. Urban India may reduce upto 28 per cent green house gases emissions, or 440 million tons CO_2 emissions per year by 2030 (McKinsey, April, 2010). McKinsey report has suggested 7 key levers that has potential impact on reducing urban carbon emissions (Table 13).

Table: 13

Reducing GHG Emissions in Urban India

Emission Type		Lever		Description	Potential Impact MIICO$_2$e[1]
A	Vehicular emissions	A1	Reduce vehicle usage through public transport	• Introduction of buses, bus rapid transport, and metro systems in urban areas	-45
		A2	Improve vehicle fuel efficiency	• Penetration of fuel economy bundles in cars, buses, and trucks	50
		A3	Electric vehicles	• 50 per cent of two-wheelers will be electric; 60 per cent of all projected two-wheelers will be in urban areas	-5
B	Building/ public areas energy consumption	B1	Building envelope (residential and commercial)	• Maximum insulation and highest efficiency appliance to reduce HVAC2 consumption by 55 per cent	150
		B2	Appliances and lighting	• Penetration of high-efficiency devices and one-watt standby standard for all electric appliances and use of CFL[2]	140
		B3	Street Lighting	• Replace 80 per cent of 250W sodium vapor streetlamps with solar power LED[2] lights	20
C	City design	C1	Selective densification of core	• Cluster design will result in more people walking to work and reduce the need for vehicle travel. Assumes 20 per cent reduction in car travel	-30

Note: 1. Metric ton carbon dioxide equivalent.

2. Heating ventilating and air-conditioning, compact fluorescent lighting, light emitting diode.

Source: McKinsey, Global Institute, April, 2010.

In 1992, William Rees developed the concept of ecological footprint to assess the reliance of the planet on its natural resources in ecological assets. Ecological footprint is the measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes, and to absorb the waste it generates using prevailing technology and practices. At a macro level, India appears to be doing well on this measure with an average per capita ecological footprint of 0.8 global hectares. India's relatively small ecological footprint is mainly due to low standards of living (WWF, 2009).

The idea of compact city is quite relevant in the context of sustainable urban development. This necessarily means a high density, mixed land use and efficient public transport planning, which encourages pedestrian oriented habitation. The benefits of compactness of city may include (1) protection of the countryside, green space and biodiversity; (2) reduction of travel distance, emission, green house gases and thus global warming; (3) reduction of materials for construction of infrastructure; (4) economies of scale in providing social institutional services like hospital, banks, etc. and (5) better interactive community life.

Cities occupy less than 3 per cent of the global terrestrial surface, but account for 78 per cent of carbon emissions, 60 per cent of residential water use and 76 per cent of wood use for industrial purposes. In the context of climate change, adaptation and mitigation actions for cities in India are critically require where the urban population is likely to grow. FAO has suggested that a minimum availability of 9 sq.mt. green open space per city dweller is required (Kuchelmeister, 1999). However, in most of the urban centres in India, there is no concrete effort to develop and promote urban green spaces or urban forestry. Three main components of urban forests and green spaces are: patch (urban domestic gardens, public and private parks,

gardens, urban forest patches, etc.), corridor (roadside avenues, walk ways and urban green ways etc.), and network structure (layout of all the patches and the corridors connecting the patches). In India, except for a few cities, urban forests are not well studied. However, Bhopal, Delhi, Chandigarh, Bangalore, Nagpur and Jaipur have paid attention towards development of open green spaces and conservation of biodiversity in urban centres. Trees in urban systems provide a variety of eco-system services including biodiversity conservation, removal of atmospheric pollutants, oxygen generation, noise reduction, mitigation of urban heat island effects, micro climate regulation, stabilization of soil, groundwater recharge, prevention of soil erosion and carbon sequestration (Bolund and Hunhammar, 1999). Biodiversity in urban green spaces and water bodies can be large if the concrete efforts for conservation of eco-systems are made. Similarly, strengthening the network of urban green spaces through linkages between various components; sequential restoration of existing urban forests and developing them into a multi-functional eco-system; integrating urban forest planning into regular master plans and urban development projects; and designing and implementing programmes for local monitoring and local enforcement of rules for the management of urban forests and open green spaces may enhance the environmental quality and conservation of environment.

Way Forward

- There is a need to prepare a comprehensive, flexible and user friendly framework for planning and policy analysis under climate variability and uncertainty scenario.
- It is imperative to develop inter-ministerial and inter-departmental coordination for vulnerability analysis, mitigation and addressing of climate change challenges both at the state and centre level.

- Integrated Energy Policy, introduced in 2006, should be effectively enforced to promote energy efficiency in all sectors with emphasis on mass transport, renewable energy resources development and clean energy technologies.
- A comprehensive legislation on biodiversity conservation should be promulgated. There is need for formulation of policies for protection of wetlands, grasslands, secret groves, natural heritage, etc. from the point of view of biodiversity.
- Promotion of cleaner technologies, strengthening of emission standards, introducing economic incentives and strengthening of monitoring and reporting system is imperative in order to control the industrial pollution.
- Environmental taxes can potentially be levied in a wide range of settings for effluent/emission charges for industrial pollution, and user fees for municipal solid waste, to taxes on the use of agricultural inputs such as fertilizers and pesticides and carbon taxes. The small scale industries may also be imposed taxes in accordance with polluter pays principle.
- An integrated, multi-pronged and multi-dimensional strategy is required to promote biofuel programme for employment generation, poverty alleviation, income generation and social empowerment of poor farmers.
- It is imperative to develop and evaluate adaptation strategies in all the major hydro geological environments to mitigate negative impacts of climate change and variability.
- Integrating climate change adaptation considerations into policy process and decision making across a range of sectors and skills is critical in managing the impacts of climate change. There is need to

develop, disseminate and implement the knowledge, tools and technologies required to effectively engaging in an integrated approach.

- A long term national programme for supporting public participation in environmental management including climate change adaptation measures aimed at educating and building capacity of all stakeholders is imperative. The most serious attention should be given to building civil society's capacity to understand the environmental issues and linkages to sector activities, to effectively engage in public participation forums; and promoting innovative and more interactive approaches to public participation that increase public ownership of environmental action.
- It is the need of hour to strengthen the regulatory framework and enforcement mechanism for effective implementation of environmental legislations, monitoring environmental quality and mitigating environmental pollution.
- A comprehensive urban air quality management strategy should be formulated that includes information related to urban planning, ambient air quality, emission inventory, and air quality dispersion models.
- Capacity building and institutional strengthening for environmental management including climate change adaptation measures is called for. There is need to improve the overall quality of governance, particularly at the state and local levels in order to effectively implement the environmental policies and legislations.
- Vehicular pollution control in metropolitan cities and other cities deserve top priority. A practical strategy should be devised that reduces both emission and congestion.

- Enhancing public and private investments for raising plantations for enhancing the cover and the density of forest is called for. Effectively implementation of Greening India Programme is to be ensured to increase the forest cover and vegetation. In-situ and ex-situ conservation of genetic resources, especially of threatened flora and fauna may be adopted for conserving biodiversity.
- Urban India can achieve significant GHG mitigation through urban planning and energy efficiency standards. Our focus should be on optimizing energy consumption and minimizing GHG emission from India's urban centres. Shifting towards public transport could reduce carbon dioxide emissions to the greater extent. There is scope for significant fuel efficiency improvement in cars, trucks, buses and two-wheelers. Shifting to electric vehicles may also reduce green house gas emissions significantly.
- India could also take advantage of the higher energy efficiency that comes with density by selectively incorporating compact city centres within urban design. Cluster design can result in more people walking to work and reduce the need for vehicular travel. Energy efficient building construction in urban centres and equally focus on promoting non-conventional energy resources may also reduce green house gas emissions significantly.
- It is imperative to develop institutional mechanism for skill development at all levels, specially related to (1) new biotechnologies; (2) benefit sharing mechanisms; (3) contemporary tools in monitoring biodiversity and environmental sustainability; (4) bio safety protocol procedures; and (5) sets of methodologies for evaluating ecosystem services.

:References:

Bolund, P. & Hunhammars (1999), Ecosystems Services in Urban Areas, Ecological Economics, 29.

CII (2008), Building Low Carbon Indian Economy, Confederation of Indian Industry, New Delhi.

Cruz, R.V. et.al. (2007), Asia Climate Change: Impacts, Adaptation and Vulnerability, Contribution of Working Group-II to the 4th Assessment Report of IPCC, Cambridge University Press, U.K.

Dogra, N. (2009), Global Warming and Its Impact on Human Health, TERRA GREEN. Vol. II, Issue, 3, June.

Government of India (2004), *India's Initial National Communications to the United NationsFramework Convention on Climate Change*, Ministry of Environment and Forests, New Delhi.

Government of India (2009), National Action Plan on Climate Change, Prime Minister's Council on climate Change, Govt. of India, New Delhi.

Gupta, R. (2010), Renewable Credits: A Way to Profit from Clean Energy, TERA Green, Vol. III, Issue 1, April, 2010.

Gupta, V. (2005), Climate Change and Domestic Mitigation Efforts, Economic & Political Weekly, March.

Handmer, et.al. (1999), Societal Vulnerability to Climate Change and Variability, Mitigation and Adaptation Strategy for Global Change, Vol. IV, Issue 3 & 4.

IBRD (2008), Development and Climate Change: A Strategic Framework for the World Bank Group, International Bank for Reconstruction and Development/ World Bank, Washington DC.

IPCC (2007), Fourth Assessment Report on Climate Change, Cambridge University Press, New York.

IPCC (2007), Report of Inter-governmental Penal on Climate Change, World Meteorological Organization and UNEP, Geneva.

Jain, A.K. (2004), Emergency Planning for Natural Disasters, paper presented in World Congress on Nature Disaster Mitigation, organized by World Federation of Engineering Organization, at Delhi, dated 19-22 Feb.

Klein, R.J.T. et.al. (2005), Integrating Mitigation and Adaptation into Climate and Development Policy, www.sciencedirect.com.

Kohli, H.S. (2010), Environmental Quality for India Citizens: Meeting Needs and Expectations of a More Affluent Society, IN India 2039: An Affluent Society in One Generation, Edited by H.S. Kohli and Anil Sood, Sage Publications, New Delhi.

Kuchelmeisster, G. (1998), Urban Forestry: Present Situation and Prospects in Asia and Pacific Region, FAO Working Paper, Rome.

Loske, R. (1996), Scope of the Report: Setting The Stage Climate Change and Sustainable Development, Third Assessment Report, Group III, PCC.

McKinsey (2010), India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth, McKinsey Global Institute, Seoul.

MoEF (2009), India's Fourth National Report on The Convention on Biological Diversity, Ministry of Environment & Forest, Govt. of India, New Delhi.

Planning Commission (2003), National Action Plan for Operationalizing Clean Development Mechanism in India, Planning Commission, Govt. of India, New Delhi.

Rai, N. & Singh, A.K. (2008), Disaster Management in India, New Royal Book Company, Lucknow.

Ravindranath, N. H. and Sathaye, J. (2002), *Climate Change and Developing Countries*, Kluwer Academic Publishers, Dordrecht, Netherlands.

Rupa Kumar, K. et al. (2005), High-resolution climate change scenarios for India for the 21st century. *Current Science.*

Sathaye, J. et. al. (2006), "Climate Change, Sustainable Development and India: Global and National Concerns", Current Science, Vol. 90, No. 3, February 10.

Singh, V.S., et.al. (2010), Urban Forests and Open Green Spaces: Lessons for Jaipur, Rajasthan, India, RSPCB Occasional Paper, Rajasthan State Pollution Control Board, Jaipur.

Subbiah, A.R. (2004), Natural Disaster Management, Vol. 21, State of Indian Farmers, Academic Foundation, Delhi.

TeraGreen (2007-2008), TERI, New Delhi, December and January.

TERI, Adaptation to Climate Change in the Context of Sustainable Development, Background Paper, TERI, New Delhi.

UN (2005), Recovery Frame Work in Support of government of India for a Post Tsunami Rehabilitation and Reconstruction Programme, United States, March.

UNDP (2007-2008), Human Development Report, 2007-08, UNDP, New York.

Vivien, F.D. (2008), Sustainable Development: An Overview of Economic Proposals, Sapiens, Vol. I, Issue -2, Institute Veolia Environment, France.

WHO (2005), "Ecosystems and Human Wellbeing", WHO, Geneva.

World Bank (2009), South Asia Climate Change Strategy, World Bank, Washington.

World Bank (2009), South Asia Climate Change Strategy, World Bank, New Delhi.

World Bank (2010), Development and Climate Change, World Development Report, 2010, World Bank, Washington, DC.

WWF (2009), Urbanization and Sustainability in India: An Independent Agenda, Thomson Press, New Delhi.