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IMPACT OF GLOBAL CLIMATE CHANGE ON FRESHWATER AND BIODIVERSITY OF INDIA

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ABSTRACT

Climate change' caused by anthropogenic activities is going to cause a major impact on water, forest, biodiversity, agricultural productivity and human health. A large number of scientific studies and IPCC's (Inter Governmental Panel on Climate Change) fourth assessment reports are now available. According to these documents global climate change is unequivocally proved as a 'reality'. However, the predicted impacts are going to be wildly different in different parts of the world, on different sectors and in different time frames. It is important to understand the precise impact on different sectors to design preventive, mitigative and adaptation strategies. An attempt is made in the present paper to collect and collate the data from all possible sources and critically examine to present a clear and precise picture of climate change effect on two of India's major sectors- water resources and biodiversity (including forests).

INTRODUCTION

Climate change, global warming and Kyoto protocol are becoming household words these days. The looming threat of drastic change in climate in the decades to come has shaken the whole world. Awarding noble prize to Al Gore and IPCC. (Inter Governmental Panel on Climate Change) headed by Dr. R.K. Pachauri has also brought climate change to International focus. Recently concluded Bali summit on climate change has also attracted a very high attention.

Climate change is the most important challenge before Mankind and has serious implications for future water availability, food production, ecosystems health and well being and even the survival of human race. And all these doomsday projections are not for 2400 or 2500 but are very very likely to happen in the next few decades. Even the doubts about existence of any such phenomenon as the climate change have been put to rest and it is now unequivocally and universally proved that current warming of earth is very likely due to anthropogenic activities such as burning of fossil fuels, land use changes and agriculture (IPCC Fourth Assessment Report 2007). Atmospheric Carbon-di-oxide concentration (the main green house gas) is now highest in the last 6.5 lakh years and is constantly increasing since 1960. According to IPCC, the average global temperature is expected to increase by about 0.2^0 per decade over the next two decades (climate projections for India are given later in this article) and is projected to increase overall from 1.8^0 C to 7^0C.

Sea level is expected to rise by 18 to 59 cm by the end of 21st century. Other major changes projected are acidification of the oceans, reduced snow cover and sea ice, more frequent heat waves and heavy rainfall events, more intense tropical cyclones and slower

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oceanic currents. The warming shall continue over centuries and may lead to a complete meltdown of the Greenland ice-sheet increasing global sea level by about 7m.

The regional impact of global climate change shall be different in type and magnitude in the different regions, however, more severe impact is predicted in the tropical areas (mostly developing and poor countries) including India.

India should be seriously concerned about the climate change as it is a very large developing country with significant rural population directly dependent on climate sensitive sectors like agriculture, forests and fisheries and natural resources (such as water, biodiversity, mangroves, coastal zones and grasslands) for their subsistence and livelihood.

This article is not centered only towards providing an answer to all of the above questions. A lot has been written and conveyed by a host of organizations all over the world. The aim of this article is to brifely discuss the latest climate change especially after the IPCC's 4th Assessment report which was released a few months back and that report is so far the most authentic source of information and also discussing the specific effect of climate change on India's freshwaters and biodiversity, two of our pillars for survival and prosperity.

What Is Climate Change ?

Climate change is also a day to day phenomenon but it should best be referred as climate variability. Climate change is the change of climate over a longer period of time ranging from decades to centuries caused both by natural and human induced changes. According to UNFCCC (United Nations Framework Convention on Climate Change) climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability, observed over comparable time periods. Thus UNFCCC uses the term 'climate change' to mean only those changes that are brought about by human activities.

Huge data collected, collated and compiled by UNFCC and IPCC indicate that the globally averaged effect since 1750 has been one of warming and by 2100 the average temperature of the world will rise by 1.8°C to 4.0°C. To understand the phenomenon in a simple way, the concentration of certain gases (called as green house gases or GHGs) is increasing considerably due to human activities mainly burning of coal and petroleum. Carbon di-oxide (CO_2) is the main culprit and other gases are methane, nitrous oxide, sulphur hexa fluoride, hydrofluoro-carbons and per fluorocarbons. These gases trap the heat from sunlight and do not allow it to be reflected back thus the earth is getting gradually warmer. These gases have different warming potential, if carbon dioxide's warming potential is 1, it is 21 for methane, 310 for nitrous oxide, 23900 for sulphur hexafluoride, 11700 for hydrofluorocarbons and 9200 for perfluorocarbons.

The result of this warming which is already being felt in many parts of the world shall be heat waves, increased frequency of heavy precipitation, increased frequency of tropical cyclones, water and food scarcity, increased abundance of Malaria, dengue and other diseases, severe loss of biodiversity which will have serious social, economic, political and environmental consequences.

Geographical Sketch and climate of India

India falling in the tropical belt of Asia is world's seventh and Asia's second largest Nation. Indian mainland falls in 8'4' to 37° 6' latitude and 68° 7' to 97° 25' E longitude. It has a land frontier of some 15,200 km and a coastline of 7516 km. The current population of India occupies only 2.4% of world's geographical area but supports 16.2 percent of the human global population. Population density in India is 325 per sq.km. and India's population is 1.081 billion (2004 census).

The country is divided into four well defined regions - the Himalayan mountains, the Gangetic River plains, the Southern (Deccan Plateau) and the islands of Lakshadweep, Andaman and Nicobar.

The climate of India is monsoonic, rains come mainly from south-west monsoon between June and October and from north between December and February. The climate is drier and hot in rest of the period. The monsoons are thus the most critical climate factor for drinking water supplies and rain-fed agriculture for India. India is however prone to annual floods and droughts. Key-information on India is given in Table 1.

Climate Change Projections for India

Climate change projections for India are not the same as for the whole world. As such very few studies have been carried out on climate change in India, most of the information is available from the reports of Indian Meteorological Department (IMD), other

studies available on this aspect are of Kriplani *et al*. (1996); Lal *et al*. (1996); Lal *et al*. (2001b); Singh and Sontakke (2002) and Lal (2003). Climate abnormalities in India are reported by Webster *et al*. (1998); Lal (2003) IMD (2006); De and Mukhopadhyay (1998) and IMD (2002-2006). The projections for India are summarized in Table 2 and 3.

One of the most authentic study on possible climate change on India was carried out at the British Hadley Centre for climate prediction and Research called PRECIS. The findings are :

General increase in precipitation and surface air temperature for the country as a whole for the period 2071-2100. The annual mean increase in SAT ranges from 2 to 5 ^{0}C. The warming shall be more pronounced over northern India. The all round warming seen in the mean is also reflected in the extreme temperature, and both nights and days will get warmer in the future.

Water is the most important element and the driver of survival, growth and sustainability all over the world. Even before negative impact of climate change on water resources were talked, it has been a matter of debate for decades as water is also affected by non-climate drivers like population changes, industrialization, urbanization, agricultural patterns and change in affluence level. However, climate change is going to further complicate the problems in water sector and may perhaps force the planners to not only intensify the water management practices but also to devise new strategies on urgent basis.

India (where 85% of water is used for agriculture, 10% for industry and 5% for domestic use) is already facing a water crisis. According to world watch institute, India will be highly water stressed country from 2020 onwards. The definition of water stress is less than 1000 cubic meters (10 lakh liters) of water per person per annum.

Dr. A.K. Gosain of Indian Institute of Technology, New Delhi, undertook a study of 12 river basins of India under a global warming scenario and found a general reduction in the overall quantity available run-off. The study also predicted that the Luni-basin with its westward flowing rivers, Kutch and Saurashtra which constitute about one-fourth of the area of Gujarat and 60% area of Rajasthan will face situations of acute water scarcity. Other basins likely to face shortage according to the study are Mahi, the Pennar, the Sabarmati and the Tapi. Seasonal or regular water stressed conditions are predicted for the Cauvery, the Ganga, the Narmada and the Krishna. Severe floods are predicted for the basins of Godavari, the Brahmani and the Mahanadi (Ramchandran, 2007).

Table 1. Key-information on India (Socio-economic and Natural Resources)

Sr. No.	Parameter	Value
1.	Total Population (2004)	1081229000.00
2.	2004 GDP (US$)	538.00
3.	Land Area 2002 (ha)	297319000.00
4.	Arable land and permanent crops (ha)	169800000.00
5.	Arable land (ha)	160000000.00
6.	Total Forest Area (2005) (ha)	67701000.00
7.	Percent of Forest cover (FAO 2005)	22.8
8.	Natural Renewable Water Resources 2002, per capita m^3	1822.00
9.	Water resources (Total renewable per Capita actual) m3/inhab/yr. 1998 to 2002.	1807.00

Table 2. Key observed past and present climate trends and variability of India

S. No	Changes in Temperature	Change in Precipitation	References
1.	0.68^{0}C increase per century, increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter.	Increase in extreme rains in north-west during summer monsoon in recent decades, lower number of rainy days along east coast.	Kripalani *et al*. 1996; Lal *et al*. 1996; Lal *et al*. 2001 b; Singh and Sontakke, 2002 and Lal, 2003

Table 3. Observed changes in extreme events and severe climate anomalies observed in India

S.No.	Key-trend	Intense rains and Floods	Droughts
1.	Frequency of hot days and multiple day heatwave has increased in past century; increase due to heat stress.	Serious and recurrent floods in North-east states of India during 2002-04, a record of 4.4m rainfall in Mumbai on 26 to 27th July 2005 Floods in Barmer, Surat and Srinagar 2006.	Consecutive droughts in 1999 to 2002 led to sharp decline in water Table; consecutive drought between 2000 & 2002 in deaths caused crop failures, mass starvation affected 11 million people in Orissa. Droughts in N.E. India during summer monsoon of 2006.

(Source : Webster *et al.* 1998; Lal 2003 IMD 2006) De & Mukhopadhyay, 1998, IMD 02-06.

Table 4. Water Resources of India

Sr. No.	Items	Quantity (cubic kilometers)
1.	Annual precipitation volume (Including snowfall)	4000
2.	Average annual potential flow in River	1869
3.	Per Capita water availability (1997)	1967
4.	Estimated utilizable water Resources (i) surface water resources 690 cu.km (ii) ground water resources 432 cu.km	1122

Source: Ministry of Water Resources, Govt. of India, New Delhi.

Goswami *et al*. (2006) using daily rainfall data set show a significant rising trends in the frequency and magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000 which is attributed to climate change. They have predicted a substantial increase in hazards related to heavy rains over central India in future.

The Glacial melt phenomenon

There has been a lot of hue and cry over Himalayan glacial meltdown in the last few years. Even Fourth Assessment Report of IPCC has taken a serious cognizance of this phenomenon. A number of studies are carried out on this aspect in India.

Important north Indian rivers like Ganga, Brahmputra are dependent on Himalayan glaciers for maintaining adequate flow even in the lean season. Frontline (A leading Indian monthly) reported way back in 2001 that Gangotri one of the largest glaciers of Himalayas is receding at an alarming rate subsequently a study carried out by Mr. Anil Kulkarni of Space Application Centre in Ahmedabad of 466 glaciers in the chenab, the Parbati and the Basapa basins using data from the Indian remote sensing satellite and field expeditions and comparing them with the 1962 topographic surveys have shown an overall 21% reduction in the glacier surface area. The process of deglaciation also led the fragmentation of larger glaciers. The mean area of glacial extent also declined from 1 sq.km to 0.32 sq.km during 1962-2004. The study further concluded that large glaciers may take 15 to 60 years than small glaciers (less than 1 sq km) which take 4-11 years to melt. The study found that in the Himalayan region the smaller glaciers have deglaciated by almost 38% in this 40 year period. As the global warming increases this fragmentation will have a profound impact on the water resources in the Himalayan region and the Gangetic plains. There are already strong evidences of snow-accumulation pattern in the Himalayas.

According to WWF (2005) glaciers in Himalayas are receding faster than any other part of the world and if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the earth keeps warming at the current rate. Its total area will likely shrink from the current 500,000 to 100,000 km2 by the year 2035.

According to Stern (2007) climate change related melting of glaciers could seriously affect half a billion people in Himalaya - Hindukush region.

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Source: Ministry of Water Resources, Govt. of India, New Delhi.

Table 5. The annual per capital availability of water (in terms of annual water renewable resources)

1900	-	8192 m^3
1950	-	5694 m^3
1990	-	1953 m^3
2010	-	1704 m^3
2050	-	1235 m^3

Table 6. Present and Projected Water demand (after 3 decades) for various uses in India (BCM)

Purpose	Present level	After 3 Decades
Domestic use	33	52
Irrigation	630	770
Energy	27	71
Industrial use	30	37
Other purposes	30	37
Total	750	1050
Surface water	500	700
Ground water	250	300

(Source: Ministry of Environment and Forests, Govt of India)

Water Quality

In India the major Freshwater ecosystems have been stressed upon by land use and land cover change, recreational activities and pollution and the flows of major rivers have been affected by hydroelectric and industrial development projects down the river including that in the estuaries. The changes in aquatic habitat have also affected fisheries in lower valleys and deltas, the absence of nutrient rich sediments has a detrimental effect on fish productivity, reduced flows in the lower valley catchments have also resulted in eutrophication and poor water quality.

A lot has been talked and written about water availability related impact of climate change but water quality issues are ignored at the moment. IPCC's

Table 7. Water Availability in India at Present and estimated availability after 3 decades (per capita thousand litres - m^3)

State	Present Level	After 3 decades
Andhra Pradesh	138	52
Arunachal Pradesh	30318	8882
Assam	1095	322
Bihar	283	202
Delhi	0	0
Goa	4732	2718
Gujarat	285	127
Haryana	0	0
Himachal Pradesh	8562	4558
Jammu & Kashmir	3909	2073
Karnataka	3125	1570
Kerala	3542	2113
Madhya Pradesh	2411	941
Maharashtra	277	101
Manipur	3768	1301
Meghalaya	20237	7950
Mizoram	9566	2519
Nagaland	4386	760
Orissa	0	0
Punjab	30	10
Rajasthan	0	0
Sikkim	36662	15084
Tamil Nadu	224	113
Tripura	1206	399
Uttar Pradesh	954	397
West Bengal	243	102243
Union Territory		
Andaman & Nicobar	50112	12325
Chandigarh	0	0
Dadra & Nagar Haveli	5098	1826
Daman & Diu	1620	659
Lakshadweep	78	25
Pondicherry	129	44

(Source: Ministry of Environment and Forests, Govt of India)

4th assessment report has taken it into cognizance and cites several studies carried out outside. India where climate change impact on water quality are highlighted. Major fears are raised due to thermal pollution and pathogens response to elevated temperatures. Intense precipitation events have also been linked to increase in pathogens, especially viruses. Surprisingly though India has been experiencing events of flooding, drought and excessive precipitation, no study has ever been carried out on water quality impacts of these events.

The amount and type of chemicals in wastewater are going to increase considerably with modernization of society and industrial development. Current

Table 8. Major predicted impact on biodiversity worldwide as per IPCC 4th Assessment Report

Sector	Major impact(Impact increases with increasing temperature)
Water	
Increased water availability in moist topics and high latitudes Decreasing water availability and increasing drought in mid latitudes and semi-aid low latitude Hundreds of millions of people exposed to increased water stress.	
Biodiversity	
Upto 30% of all species at increased risk of extinction upto 30°C rise with further rise significant extinction ground the globe widespread coral mortality	
Global mean temperature rise predicted to increase upto 5°C	

wastewater treatment practices (especially those adopted in India) are incapable of taking care of these pollutants and climate change especially the episodes of intense precipitation are going to complicate this issue further.

Higher surface water temperatures will promote algal, blooms which are otherwise very common due to the high rate of Eutrophication; higher surface water temperatures shall only aggrvate the situation. The total microbial content of water shall increase and episodes of bad odour and the occurrence of toxins shall increase (Kundzewicz *et al*. 2007). It is going to be a major problem in India as phosphorus removal is not practiced all in Indian sewage treatment plants (Trivedy, 1994). Besides, during the period of intense rainfall pollutants like heavy metals, pesticides and organic matter shall be increasingly washed away to water bodies. It is natural that water borne diseases shall increase especially in the area of extreme precipitation.

An Indo-Japan study coordinated by Dr, Murari Lal of IIT, Delhi found that by 2080 winter rainfall might experience a 5 to 25% decline even as monsoon rainfall shows a 10-15% increase. A fall in winter rainfall shall cause a greater stress during peak demand summer season. Intense rain during monsoon will only lead the run-off and lesser recharge of groundwater.

Groundwaters

Groundwaters constitute an important water resource in India and even without climate change depletion of groundwaters by over use and pollution of groundwaters are major issues in India. This coupled with increased use of groundwater and impact of climate change are going to make groundwater a major area of focus in time to come. Groundwater recharge rates are going to be affected by climate change, however even the Fourth Assessment Report laments that there is very little research available on groundwaters both in the developed and the developing countries. It is however, certain that since climate change shall bring about a major change in precipitation pattern, vegetation and also the flow in the rivers, the groundwater recharge is going to be affected in a major wars, it could be positive in arid and semi-arid areas where increased rain-fall is forecast.

Overexploitation of groundwater in many parts of India has resulted into lowering groundwater level and leading to ingress of sea water in coastal areas making the sub surface water saline. According to cruz *et al.* (2007) India is susceptible to increasing salinity of their groundwater as well as surface water resources especially along the coast due to increase in sea level as a direct impact of global warming (Han *et al.* 1999).

Impcat of climate change on Forests & Biodiversity

Biodiversity is the total genetic pool, all organisms available in all ecosystem, plants, animals and microbes which play an integral part in Man's surviaval, sustenance and well being on this earth.

Indian Biodiversity

Salient Features of Biodiversity Habitats in India

Forests

- About 21% of land area in India is covered by forests,
- Main forest types are :
  - Evergreen tropical rain forests
  - Dry Alpine scrub
  - Semi ever green rain Forest
  - Deciduous monsoon forests (Lal, 1989)

India is already facing deforestation, encroachment of forest land, poaching of wild life and loss of biodiversity due to developmental activities.

Wetlands

Table 9. World Scenario on Water and Biodiversity Impact of global climate change

Sr. No.	Climate change caused phenomenon	Likelihood	Water	Biodiversity
1.	Warmer and fewer cold days and night, warmer and more frequent hot days and nights	Virtually certain	Effects on water resources relying on snow melt	Increased insect outbreak
2.	Warm spell/heat waves	Very likely	Increased water demand, water quality problems, e.g. algal blooms	Increased danger of wild fires
3.	Heavy precipitation events	Very likely	Adverse effects on quality of surface and ground waters contamination of water supply: water scarcity may be relieved	-
4.	Area affected by drought increases	Likely	More widespread water stress	-
5.	Intense tropical cyclone activity increases	Likely	Power outages causing disruption of public water supply	Damage to coral reefs
6.	Increased incidences of extreme high sea level	Likely	Decreased freshwater availability due to saltwater intrusion	Salinization of fresh water Ecosystems - shift in species

(source: IPCC 4th Assessment Report 2007; Projections for 21st century)

Table 10. Indian Biodiversity in comparison to the world's biodiversity

Sr. No.	Group	No. of Spieces in India (SI)	No. of the Species in the World (SW)	SI/SW %
1.	Mammals	350	629	7.6
2.	Birds	1.224	9,702	12.6
3.	Reptiles	408	6,550	6.2
4.	Amphibians	197	4,522	4.4
5.	Fishes	2,546	21,730	11.7
6.	Flowering plants	15,000	250,000	6.0

(Source: www.ces.ernet.in)

Total wetland area in India is 58,286,000 ha or 18.4% of the country, 70% of which is under paddy cultivation.

- A total of 1193 wetlands covering an area of about 3,904,543 ha were recorded by scolt (1989).
- Indian wetlands face severe ecological problems due to human activities and face increasing pollution, loss of species to total extinction.

Marine Environment

- The coastline is about 7560 km
- The area is extremely rich fishing ground
- Coral reefs are an important part of Indian marine biodiversity. They occur principally in the Gulf of Kutch of the Southern mainland coast and around a number of islands opposite Sri Lanka. They are also found in Andman Nicobar and Lakshadweep islands.
- The coastal ecosystems have rich biodiversity due to the presence of estuaries, mangroves & coral reefs.
- Global warming, sea level changes, minining activities and natural hazards like floods, tsumani and earthquake are the major threats to coastal ecosystems.

Current rapid urbanization; industrialization and economic development have led to increasing pollution, land and water degradation and loss of biodiversity. Biodiversity in India is already under threat and is projected to decline in future due to multiple pressures such as increased land use intensity.

Projected Impact on Forest and Biodiversity

In India the species in high elevation ecosystems are projected to shift higher. In the higher elevated areas, the rates of vegetation changes are expected to be slow and colonization success would be constrained by increased erosion and overland flows such as in the highly dissected and steep terrains of the Himalayan mountain range.

Weedy/invasive species with a wide ecological tolerance will have an advantage over others.

Mangroves (e.g. those in the Sundarbans) and coral reefs are particularly vulnerable to climate change. The sundarbans support a diversity of wildlife and is at great risk due to rising sea level. These coastal mangrove forests provide habitat for species such as Bengal tigers, Indian otters, spotted deer, wild bores, estuarine crocodiles, fiddler crabs, mud crabs, three marine lizard species and five marine turtle species.

- With the rise in sea level, the sundarbans will disappear which will spell the demise of the Bengal tiger and other wildlife and could adversely affect human populations.

Biodiversity hotspots like the western Ghats are an important resource because of their high degree of endemism, biodiversity and productivity. Warming could put their stability at risk since they cannot move to higher altitudes.

Ecosystems that cannot move northwards at a rate dictated by global warming will be most at risk. These include glacial ecosystems, coral reefs and Himalayan ecosystems.

Forests

According to N.H. Ravindranath, a Senior Scientist with Indian Institute of Science, Bangalore eighty five percent of the forest grid will undergo drastic changes in the forest type (www.rediff.com/news/2005/Dec.05), the higher impact will be on the savannah biomes. Teak and Sal forests of central and east India and temperate biomes of the Himalayas. Moist and dry savannahs are likely to be replaced by tropical dry forests and seasonal forests. By 2050 we will feel a significant impact.

The impact will be lower on the evergreen rain forests of the Western Ghats and the north east.

According to Dr. Ravindranath composition of species and their dominance could also be altered and large scale forest depletion and loss of biodiversity shall take place.

An augmentation in timber production in the short and medium term is expected but there would be disruption in timber supply in the long run. Loss of biodiversity will result in loss of livelihood for forest dependent communities.

Climate change, however, can cause an irreversible damage to unique forest ecosystems and biodiversity rendering several species extinct. Some species which are currently classified as "critically endangered" could become extinct with a quarter of the species estimated to be at the risk of extinction. It is important to mention here that a detailed study carried out by Prof. Peter Mayhew of the University of York (Indian express Oct. 3,2007) has already predicted that half of the world's plant and animal species shall become extinct due to climate change by the end of the present century.

Another important fact to be remembered here is that not only climate change affects Biodiversity, the loss of biodiversity actually contributes to climate change (www.ukindia.com) . As the biodiversity is degraded or lost through human activities, we may be losing some of our best tools for coping with global climate change as well.

According to Sodhi *et al*. (2004) natural resource utilization could intensify in several parts of Asia due to increasing demand to cope up with developmental activities. In South-East Asia which includes India intensification of forest utilization can intensify deforestation that could lead to the loss of much of its original forests and biodiversity by 2100.

Broader Impact of Climate Change on India

An Article published in a leading English daily (Indian Express October 2006) cites a study sponsored by British Government. Accoding to the report a 100 cm rise in sea level could lead to a loss of US $ 1259 million or the equivalent of 0.36% India's GNP. Some of the key predictions(for the next 100 years) with regard to water resources and biodiversity from this study are :

1. Regional climate models suggest a 2.5 - 5^0C rise in mean surface temperature. Within India northern India will become warmer.
2. A 20% increase in summer monsoon rainfall and instances of extreme temperature and precipitation are expected to rise.
3. Within India northern India will become warmer.
4. All Indian states will experience increased rainfall, except Punjab, Rajasthan and Tamil Nadu where rainfall will decrease.
5. Extreme precipitation will increase particularly along the western coast and west central India.

6. The country's hydrological cycle will most likely be altered. Drought and flood intensity is likely be altered. The Krishna, Narmada, Cauvery and Tapi river basins will experience severe water stress and drought conditions, and the Mahanadi, Godavari and Brahmani will experience enhanced flooding.

According to IPCC Fourth Assessment Report hundreds of millions of people who rely on glacier melt from the Himalayan Hindukush mountains for their water supply will be affected. Water flows in the Ganga, Brahmaputra and other rivers will be impacted by glaciel melt and water availability be affected by rising global temperatures. Water availability in India is expected to fall from 1820 million cubic meter in 2001 to 1140 million cubic meters in 2050 There will be water shortages because of deficient rains. Glacial melt and reductions in the recharging of groundwater because of run-off during floods.

The Mumbai water, especially groundwater will become more saline and drainage system would bear the burnt. There was serious damage to life and property during July 26, 2005 rain as all the drains were clogged. According to Dr. R.K. Pachauri one measure to combat flooding would be to conserve and plant more mangroves and re-design drainage.

CONCLUSION

It is proven without doubt and with very stong confidence by IPCC that India's is going to be severely hit by climate change. Freshwater resources and Biodiversity are the two pillars on which our survival and sustenance is dependent. Both these are going to be seriously affected by climate change, mostly negatively affected. The adverse impact of climate on freshwater systems shall aggravate the impacts of other stresses, such as population growth, economic activities, land use and urbanization. Impact on Forests shall be negative on balance, although some positive effects may be seen in the short run – biodiversity, which is already under constant threat due to developmental activities shall be further stressed by climate change and possibly half of the species shall disappear in next 50 years. Implications of such a major loss of biodiversity are perhaps not estimated yet, but certainly the impact on our economy, and well being and sustainability of our ecosystems shall be very high.

A number of conclusions are drawn from this limited period study, however, they should be viewed in the light of uncertainties projected by even IPCC in their 4th Assessment report. These uncertainities as per IPCC are due to two reasons : Till 2020 the uncertainities are due to selected climate models, as all projections are based on their reliability. We do not know the exact emission scenario beyond 2020 and hence the uncertainity. However, following important conclusions can be drawn from the various reports with a high level of confidence.

According to IPCC's 4th Assessment Report there is overall net negatve impact of climate change on freshwater resources and Biodiversity of India.

Major conclusions with regard to water

1. Climate change shall bring about an increase in the extreme rains in north-west India during summer monsoons.
2. Kutch and Saurashtra which constitute about 1/4th area of Gujarat and also 60% area of Rajasthan shall face a situation of acute water scarcity.
3. Manyother river basins shall face serious shortage of water.
4. Severe floods are predicted for the basins of Godavari, the Brahmani and Mahanadi basins.
5. Thirty eight percent of Himalayan glaciers have already disappeared. By 2035, the total glacial area may shrink from 5, 00,000 km^2 to 1, 00,000 km^2.
6. Half a billion people in Himalaya- Hindukush region shall be affected by climate change.
7. Increased salinity of surface and groundwater's is predicted especially in coastal areas.
8. Incidents of excessive precipitation of the like of July 2005 rain of Mumbai shall increase, this coupled with low in rivers/other water bodies shall lead to a rise in water pollution of both organic and toxic kin. This will affect water usage further bringing down availability of water. A rise in water borne diseases is also predicted by many studies.
9. Groundwater recharge in several river basins shall be reduced to a significant level.
10. The annual per capita availability of water in India shall decline from 1990 m^3 in 1990 to 1235 m^3 in 2050.
11. Decreased water supply is predicted from snow-caps for major small holder irrigation systems particularly in the indo-gangetic plains.
12. Sea-level rise shall extend areas of salinization of groundwater's and estuaries resulting in a

decline in freshwater availability for humans and ecosystems in coastal areas.

13. Increased precipitation intensity and variability is projected to increase the risk of flooding and drought in many areas.
14. Overall, the impact on water resources shall be myriad and complex. The population dependent on glaciers or snow-melt fed river basins shall be severally hit.
15. The adverse impact of climate change on freshwater systems aggravates the impact of other stresses such as population growth and increased affluence.
16. The current water management practices are likely to be inadequate to reduce the negative impact of climate change.

Forests and Biodiversity

1. Climate change will cause drastic changes in 85% of the forest grids in India.
2. The impact shall be very high on savannah biomes & Teak and Sal forests of central and east India and temperate biomes of Himalayas.
3. Moist and dry savannahs are likely to be replaced by tropical dry forests and seasonal forests.
4. Major impact on forests shall be felt around 2050.
5. The impact shall be lower on the evergreen rain forests of the Western Ghats and the north-east.
6. Large scale forest depletion and losss of biodiversity is predicted.
7. Loss of biodiversity in turn shall contribute to climate change further.
8. Timber production in the coming five six decades is likely to increase. Acceding to the IPCC 4th assessment report by 2020 +5 to +15% growths in timber is expected. Further growth shall be +20 to +40.0 % by 2050 and +20.0 to 60.00 % by 2080 with regional variations.
9. Higher timber growth may lead to more deforestation and shall discourage forestation activities.

Gaps in Knowledge and areas of future research/ action

1. It is obvious and also commented upon in IPCC's 4th assessment report that very few studies are available from India on impact of climate change on water resources and biodiversity.
2. Major conclusions with regard to India are drawn from a handful of Indian studies and a few internationally funded collaborative studies. More Indian studies are urgently required.
3. Impact of climate change on water quality, pollution status and spread of water borne diseases is not all studied in India.
4. More research is urgently needed on forest productivity, behavior of different species and productivity under differenet climate change scenarios.
5. India needs to take its water management practices very seriously. More research/action is needed on wastewater management, wastewater recycling and rainwater harvesting and irrigation water management.
6. A policy on groundwater usage is urgently needed to save this resource from overexploi-tation.

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