Impact of Climate Change and Adaptation to Green Technology in India

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Abstract— **India is now put into the pressure of reducing the emission GHG (Green House Gases) into the atmosphere due to its climatic change. The responsibility of the reduction of the greenhouse gas emissions 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 survey says that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius (C) by 2100. This unprecedented increase is expected to have severe impacts on the global hydrological system, ecosystems, sea level, crop production and related processes. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India. The impact of the GHG emission on the Climate Change is now worsening than we imagined a decade ago. India being the Developing country was not able to adopt any strategy because it is more concerned to the social economic development. The most effective way is to adopt a sustainable development pathway by shifting to the environmentally sustainable technologies and promotion of water conservation, renewable energy, forest conservation and energy efficiency. It's the responsibility of the Indian Scientists to bring up various sustainable methods and technologies which will be accepted environmentally and globally too. Other than talking about socio economic growth, concentration must be dissipated to the introduction of the green technology into the development of the sustainable technologies for the prevailing problem of the Climate change impact.**

Keywords — Impact; Socio-economic development; Sustainable; Unprecedented; Implications;

I. INTRODUCTION

This work captures and disseminates the impacts and perspectives on climate change from the Indian context. In India, climate change could represent an additional stress on ecological and socioeconomic systems that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. While talks about the reduction of GHG`s between various industrialized countries have not yielded the expected, measures are on the run to put a knot for the problem of Climate Change. Now it is India's one of the major responsibility for cutting down the $CO_2$ and GHG`s emissions. As an effort put forth, India is in the urge to introduce the Green Technology into its industrialized world. Many Environmental Activists have volunteered to bring out a Green Revolution in the industrialized world. However, the efforts of them have ended in vain as it has failed to gain the confidence over their senior officials and the political system of India.

India being a sub-continent, the severity of the climate change is to be measured on a large scale. The climatic change has its adversities in food production, water supply, coastal settlements, forest ecosystems, health, energy security etc. The climatic change is a global concern, but the pressure is upon us as its impact upon us is severe. It is now believed that India being a developing country can be a solution to this global problem. It's now time to mitigate the impacts of the climatic change upon our planet. India has potential to supply substantial mitigation at a relatively low price.

India is a large developing country with diverse climatic zones. The livelihood of vast population depends on climate-sensitive economic sectors like agriculture, forestry and fisheries. The costs of not addressing climate change or to adapt to it are very uncertain, but their welfare consequences are enormous. Adaptation is a private or local public good, whereas mitigation is a global public good. The individuals or communities bear the risk wherever there is undersupply of adaptation measures. Adaptation costs are the insurance payments and the costs of not addressing adaptation are the damages from unmitigated climate risks. There are many ways to pursue sustainable development strategies that contribute to mitigation of climate change. So our responsibility is to find a suitable sustainable strategy.

II. INDIA'S STANCE ON CLIMATE CHANGE?

Agriculture being the backbone of our country has been put to threat in the recent years. In India nearly 700 million rural populations depends upon climate-sensitive sectors such as agriculture, forests and fisheries. Moreover natural resources such as water, biodiversity, mangroves, coastal zones, grasslands and their livelihoods have also been put to threat. Climate change is likely to impact all the natural ecosystems as well as socio-economic systems. The latest high resolution climate change scenarios and projections for India, based on Regional Climate Modeling (RCM) system, known as PRECIS developed by Hadley Center and applied for India using IPCC scenarios A2 and B2 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.

III. Lower agricultural production

The FCCC objective states that GHG concentrations should be stabilised at levels where food production is not threatened (UN, 1992). Thus it is easy for one to foresee the impacts on agriculture caused by the different climate change scenarios. Kumar and Parikh (2001a and 2001b) examined the impact of climate change on agricultural crop yields, GDP and welfare. Based upon the climate change scenarios, which project a temperature rise of 2.5°C to 4.9°C for India, Kumar and Parikh estimated that:

- Without considering the carbon dioxide fertilization effects yield losses for rice and wheat vary between 32 and 40%, and 41 and 52%, respectively;
- GDP would drop by between 1.8 to 3.4%.

Their study also showed that even with carbon fertilization effects, losses would be in the same direction but somewhat smaller. For a developing country, these are very large changes which can cause much human misery. From India's point of view, a 2°C increase would be clearly intolerable.

According to the scientists it is believed that if the global climate keeps on increasing at the current rate, there are high risks of extreme events such as drier tropics, wildfires and possible decline in the agricultural production in the world's most densely populated area. Increases or decreases in vegetation growth can be determined by measuring the ratio of two different oxygen isotopes in air. Moreover the current shift in the monsoon trend of our nation proves that there is more rainfall in the ocean instead of the land which resulted in the lowering vegetation level.

Various studies reveals those climate changes can affect the Earth's capacity to grow vegetation. Oxygen levels and its isotopic composition in the atmosphere are stable; it takes a major terrestrial change to affect it very much. These changes were huge. The drop in vegetation growth must have been dramatic. Ocean circulation patterns also can heavily influence climate, and shift in ways that are not completely understood. However, the study still points to monsoon behavior being closely linked to climate change. Findings highlight the sensitivity of low-latitude rainfall patterns to abrupt climate change in the high–latitude north

IV. Risk of Sea Level Rise

Lives of large population in the coastal areas are now put to threat due to the sea level rise and prone to sub-mergence. This will lead to the migration in large scale especially from the low-lying delta regions in the developing countries. Intrusion of sea-water in the ground water and changes in temperature can reduce agricultural and fishing too. The situation is even worse in the developing countries like India where a large part of the country is dependent upon the coastal fishery and agriculture. If a one-meter sea level rise were to take place today, it would displace 7 million persons in India (ADB, 1995). If this situation prevails in future, the number would be more and there are chances that 35% of the land in Bangladesh would be submerged by a one-meter rise.

V. Forests

Climate change, resulting from increase in greenhouse gases such as CO2 and methane, and other anthropogenic emissions into the atmosphere, can be expected to have significant impacts on forest ecology, forest distribution, and productivity. The projected impacts of climate change on forests also have implications for forest product flows and trade and forest management. It is important to make assessments of likely impacts of climate change on forests in different countries and regions to allow respective governments and communities to adapt these impacts. Such assessments are all the more important in tropical countries in which the local communities depend significantly on forests for their livelihoods, and where rates of deforestation are high. Indeed, the issue on climate change impacts on forests maybe less relevant if the anthropogenic impacts can be expected to be of much greater magnitude.

The forests in southern India are mainly in two distinctive belts, one along the Western Ghats and the other along the Eastern Ghats. The former tract is biologically more diverse and has been much more extensively studied than the latter. The Western Ghats rise to over 2000 m asl, and their complex topography contribute to a wide spectrum of tropical vegetation types, from wet evergreen forest along the western slopes receiving high rainfall (typically > 2000 mm/annum) and montane stunted evergreen forest and grassland (at altitudes > 1800 m asl), through semi-evergreen, moist deciduous, and dry thorn forest in areas of lower rainfall to the east of Ghats.

Increased temperatures of 2-3.5°C during winter and summer would potentially stress vegetation through increased evapotranspiration. The increased rainfall, however coupled with elevated CO_2 increasing water use efficiency, could compensate for this loss. In the balance, the marginal increase in soil moisture projected for this region could result in increased productivity in all forest types. Further, a shift in vegetation type boundaries could be expected along a west-east gradient (with moist forest types expanding farther east) and along an altitudinal gradient (with species adapted to the warmer, lower elevations migrating to higher altitudes). An increase in dry season length could also place forest types such as dry and moist deciduous forests at increased risk of dry season fires.

The montane regions of the Western Ghats featuring a mixture of stunted evergreen forest and grasslands with sharp ecotones are a sensitive indicator of past climate change. With an increase in temperature and reduction in incidence of frost, the montane forests dominated by Lauraceae and Rubiaccae could potentially expand into the grasslands. It is more likely, however, that anthropogenic disturbances such as fires and the raising of plantation of Australian Wattle (Acacia spp.) and

eucalypts (Eucalyptus spp.) in recent decades would set the stage for a further spread of these exotic plants (of C3 photosynthetic type) especially the weed-like wattles-into the grasslands in the absence of management to restore the grasslands. The central Indian forests in the states such as Madhya Pradesh and Maharashtra are mostly moist deciduous forests. Increase in rainfall and soil mixture during the Southwest monsoon could potentially transform these to moister vegetation types.

Thus, there may be no scope for any significant changes in forest type or productivity. Northeast India again has a wide spectrum of tropical and subtropical forests and grasslands associated with the flood plains of rivers. The climate change scenario for northeast India is not very clear. There seems to be much greater variability in the various climatic parameters over even a small area. This region alreasy experiences very heavy rainfall, and any changes in rainfall may not be of much consequence for vegetation. The projected increase in temperature, however, in all the seasons, is likely to result in shifts of lower altitude tropical and sub-tropical forests to higher altitude temperate forest regions, resulting in contraction or die-off of some temperate vegetation types.

VI. CLASICAL RETREAT

Earlier studies on selected glaciers of Indian Himalaya indicate that most of the glaciers are retreating discontinuously since post-glacial time. Of these, the Siachen and Pindari Glaciers retreated at a rate of 31.5m and 23.5m per year respectively (Vohra, 1981). Gangotri Glacier is retreating at an average rate of 18m per year Thakur et al. (1991). Shukla and Siddiqui (1999) monitored the Milam Glacier in the Kumaon Himalaya and estimated that the ice retreated at an average rate of 9.1m per year between 1901 and 1997. Dobhal et al. (1999) monitored the shifting of snout of Dokriani Bamak Glacier in the Garhwal Himalaya and found 586m retreat during the period 1962 to 1997. The average retreat was 16.5m per year. Matny found Dokriani Bamak Glacier retreated by 20m in 1998, compared to an average retreat of 16.5m over the previous Thirty-five years. (Matny, L., 2000). Geological Survey of India (Vohra, 1981) studied the Gara, Gor Garang, Shaune Garang, and Nagpo Tokpo Glaciers of Satluj River Basin and observed an average retreat of 4.22 - 6.8 m/year. The Bara Shigri, Chhota Shigri, Miyar, Hamtah, Nagpo Tokpo, Triloknath and Sonapani Glaciers in Chenab River Basin retreated at the rate of 6.81 to 29.78 m/year. The highest and lowest retreat was in the Bara Shigri Glacier and Chhota Shigri Glacier respectively. During the period 1963 - 1997, Kulkarni and others found the retreat of Janapa Glacier by 696m, Jorya Garang by 425m, Naradu Garang by 550m, Bilare Bange by 90m, and Karu Garang by 800m and Baspa Bamak by 380m (Kulkarni et al 2004).

In their studies they observed an overall 19 percent retreated in glaciated area and 23 percent in glacier volume in last 39 years. Based on the field survey carried out in 1999, the snout of Shaune Garang Glacier was marked at an elevation of 4460 masl in contrast to the Survey of India 1962 topographic map, which marked the snout at an altitude of 4360 masl (Philip and Sah 2004). This is indicating a vertical shift of 100m and horizontal shift of 1500m within a span of 37 years.

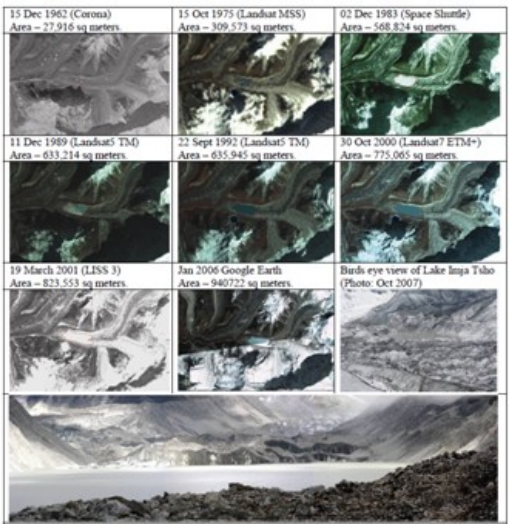

Figure 1: View and aerial Expansion of Imja Glacial Lake from 1962 to 2007 in different satellite images and field observation in Oct 2007.

VII. WEEKEND MONSOON

Purdue University research group found that climate change could influence monsoon dynamics and cause less summer precipitation, a delay in the start of monsoon season and longer breaks between the rainy periods. Almost half of the world's population lives in areas affected by these monsoons, and even slight deviations from the normal monsoon pattern can have great impact. Agricultural production, water availability and hydroelectric power generation could be substantially affected by delayed monsoon onset and reduced surface runoff. Alternatively, the model projects increases in precipitation over some areas, including Bangladesh, which could exacerbate seasonal flood risks. The summer monsoons are responsible for approximately 75 percent of the total annual rainfall in major parts of the region and produce almost 90 percent of India's water supply.

General circulation models have been used for projections of what may happen to monsoon patterns for this region, but the models have disagreed as to whether precipitation will increase or decrease. So in terms of topography playing a role in climate and weather, this region of the world is where we expect to see a large impact. Global models like the ones featured in the Intergovernmental Panel on Climate Change reports can resolve large-scale interactions but have difficulty capturing some of the more subtle atmospheric processes. The research team used a high-resolution climate model believed to have the greatest detail currently available for this region.The model projected a delay in the start of monsoon season from five days to 15 days by the end of the 21st century and an overall weakening of the summer monsoon precipitation over South Asia. Increasing temperatures in the future strengthen some aspects of large-scale monsoon circulation but weaken the fine-scale interactions of the land with the moisture in the atmosphere, which could lead to reduced precipitation over the Indian subcontinent.

Even with a strong monsoon system, if circulation changes enough to change where and when rain is delivered, then that could have an impact that has not been captured in the large-scale evaluations. The atmospheric conditions that lead to reduced precipitation also can lead to intensification of extremely hot conditions. These circulation changes decrease moisture flow over the land, and we see longer periods without rain, along with hot conditions. The model shows an eastward shift in monsoon circulation, which would mean more rainfall over the Indian Ocean, Bangladesh and Myanmar, and less over India, Nepal and Pakistan. Less moisture over the land in combination with the ambient dry summer air would lead to less moisture in the clouds and reduced rainfall. Monsoon moisture flow comes from ocean to land. In the summer, the land warms faster than the ocean. This creates a pressure gradient that draws air masses from the ocean to the continent, bringing moist air that promotes formation of a large-scale monsoon system.

Monsoon season, which starts in early June and ends in late September, begins at the southeast tip of India and moves northwest to the rest of India and Pakistan. The climate model used by the research team accurately recreated the monsoon season of past years, and its future projections are consistent with what has been seen in recent drought years over this region.

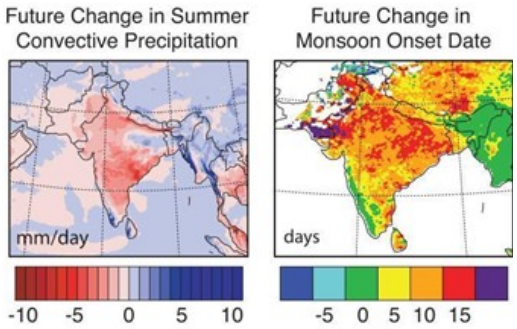

Figure 2. These maps show projected future changes in South Asian summer precipitation and monsoon onset date. A Purdue-led team found that rising future temperatures could lead to less rain and a delay in the start of monsoon season by up to 15 days by the end of the 21st century. (Credit: Diffenbaugh lab image)

TABLE I TEMPERATURE CHANGE PROJECTIONS FOR INDIA BASED ON AN ENSEMBLE OF FOUR GCM OUTPUTS

Year	Precipitation change (%)			Sea Level Rise (cm)
	Annual l	Winter	Monsoon	
2020s	1.36±0.19	1.61±0.16	1.13±0.43	4–8
2050s	6.7±8.9	–2.9±26.3	6.7±8.9	15–38
2080s	11.0±12.3	5.3±34.4	11.0±12.3	46–59

SOURCE: Aggarwal, D and M Lal (2001), *Vulnerability of Indian Coastline to Sea-level Rise*, Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi.

TABLE II PRECIPITATION CHANGE PROJECTIONS FOR INDIA BASED ON AN ENSEMBLE OF FOUR GCM OUTPUTS

Year	Temperature change (°C)		
	Annual l	Winter	Monsoon
2020s	1.36±0.19	1.61±0.16	1.13±0.43
2050s	2.69±0.41	3.25±0.36	2.19±0.88
2080s	3.84±0.76	4.52±0.49	3.19±1.42

SOURCE: Aggarwal, D and M Lal (2001), *Vulnerability of Indian Coastline to Sea-level Rise*, Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi.

VIII. DISAPPEARING MANGROVES

Large forest areas of Sunderban have turned into forest villages with heavy with carbon dioxide in the environment. Local people destroy mangrove forest of the region unknowingly; they do not know the concept of climate change and global warming. India is experiencing some of the very real effects of climate change. Sunderban is losing 100 square kilometers every year. Sagar islands- one of the first inhabited islands in the world that has been submerged by the rising seas. Vanishing of other two big islands - Bedford and Lohachara, has displaced thousands of climatic refugees and their inward migration is responsible for mangrove deforestation. There exist no rehabilitation programme for them; there is extremely poor participation of the majority of the people in decisions that affect their lives. This region is one of the world's remotely challenged geographical regions with a population density of more than 1100 person per square kilometers. There occurred change in local weather, the frequency of the cyclone has decreased but their severity has increased, rainfall has become more erratic within a span of ten years.

Sunderban mangrove forests provide an average of 6000t/ha mangrove litter which produce huge amount of organic material for the whole ecosystem. Studies shows establishment of fodder and fuel wood plantations in the villages as a livelihoods option is expected to lead to decrease the pressure on mangroves. Other adaptation options include agro-forestry methods, include plantation of mangroves along freshwater canals and ponds are recently done by the village communities. Sunderban Development Board under state and central government, since its inception in 1980s has brought several changes for the development of the region. Sunderbans are still at a controllable stage. Continuous monitoring, policy change and management interventions must be triggered for mangrove restoration. Scientist say that the Sunderbans, South Asia's largest carbon sink which mops up carbon dioxide must survive to help prevent global warming. Out of 60 varieties of mangrove species that are found in India, Sunderban accounts for 50, many of which are

rare. It has a seemingly unlimited capacity to absorb pollutants from air and water. Though the economic and social benefit arising from this mangrove rehabilitation would be more meaningful to the local communities of this region but it acts as an eye opener to the whole world to understand the concept of forest conservation in mitigating climate change. All constitute part of this complex ecosystem depending upon each other. Any damage to one part will damage and change the whole constitution of the ecology of this area; Sunderban reveals the extreme consequences of climate change and global warming, therefore mangrove plantation is the ultimate solution to this problem.

India had experienced a warming trend of 0.6°C per century with the southern Indian State of Andhra Pradesh recording a highest temperature of 49°C in May 2002 (National Oceanic and Atmospheric Administration, 2002). Andhra Pradesh is home to the magnificent Godavari (as described earlier) and Krishna mangroves. With an evident increase in average temperature and threat of global warming this ecosystem is vulnerable to climate change. The mangrove ecosystem of the east coast of India has been identified as one of the most vulnerable regional habitats to be exposed to sea-level rise (Alongi, 2007). Increasing salinity and precipitation patterns also affect distribution of salt-tolerant mangroves such as A. spp. and Rhizophora spp. The seedlings of all species require very low salinity for their growth; hence, a rise in salinity could affect their survival, growth and productivity (Jagtap and Nagle, 2007). Rising sea-level brings in salts and sulphates; diminution of rainfall reduces mudflow and nutrient influxes. Increased frequency of tropical cyclones with inundation of low-lying areas and salt-water incursion is also not ruled out. Increasing temperature could also cause decreased tree height and leaf size in mangroves (Singh, 2002).

XI. Adaptation to Green Technology

Green technology is a technology that is environment-friendly and ensures that natural resources are conserved. Green technology is the 'future' at large, and the main aim of this innovative technology is to avoid any deterioration to the environmental resources. In a way, green technology helps in reducing the amount of pollution that is being emitted during the process of production and even while consuming the products. It talks about the relationship between human beings and natural resources, and the irreversible hazard that is being caused to the nature and the environment because of the economic activities. One can quote some examples of environmental hazards such as pollution of rivers, global warming resulting in depletion of ozone layer etc.

India is essentially a country that needs to implement green technology because of its vast geographic area and huge population, and also for the reason that India has been identified as one of the emerging and ever-growing markets for the world's producers. Both the production and consumption are so massive that one can witness the tremendous amount of damage that is being caused to the environment and natural resources every second. If the trend continues, then one day we may have to zero in on what we have achieved and get into the shoes to rectify our unpardonable mistakes, which are irreparable. Green technology is not only essential for sustainable development in the long-run but there are also short-term advantages of using eco-friendly fuels. India can use 'cradle to cradle' technology, rather than 'cradle to grave', that can be fully re-used. But the question is how can India develop and tap green technology? There are certain crucial issues that need to be focused upon while introducing green technology. For instance, a social awareness about the need for environment-friendly goods and services for production and consumption at a larger scale is required. And, for this, a massive campaign on this issue has to be undertaken.

Green technology as a subject needs to be made mandatory in academics. The industrial segment needs to be pushed forward to come out with more environment-friendly production and consumption processes. Various incentives need to be given to the industrial sector, which is ready to innovate and implement green technology. Also, the government can work towards encouraging people to come out with agricultural plots within or near the cities so that the distance the food has to travel may be reduced. This can be done either by the small farmers or by large-scale farming undertakers. For a country like India, that's the right approach, since we are inefficient in many ways in our use of energy. It would not be difficult for India to reduce up to this level because we would be using efficient processes also and because of growth.

X. Conclusions

Thus based upon the current impacts of the climate change, it is very clear that the controversies to be created in the future would be really aggravated than thought. Hence, it is now in our hands to take up the responsibility of shaping the planet as it was before. Maybe it is now late in taking decisions but there is very little time to implement it. We have exploited our mother nature to the maximum as we could and now we are being repaid. Adhering to the latest technologies available in the market, we have the capability to advance easily into the industrial practices. Indian industry is quite adept at absorbing technology. Most of the technologies are already available. In fact, if you are talking about steps on climate change, almost 90 per cent of the technologies are available and Indian companies can easily bring them in, unless you are talking about clean coal technologies or carbon sequestration, it's not an issue. And intellectual property rights for technology should also not be an issue in India.

ACKNOWLEDGEMENT

I would really like to thank my college staffs who lent me a helping hand in finishing up this work. I would convey my hearty thanks to the authors of the reference who indirectly helped me in preparing this paper. And I would like to reveal my immense pleasure to the peer reviewers and the paper invigilators for spending time in evaluating my paper.

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