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Impacts of Climate Change on Water resources in India and Responsive Adaptations for Future

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Abstract. The Global climate is changing with most rapid rate than ever. Main reason behind it is undoubtedly anthropogenic interventions like Greenhouse Gases emission into environment. This climate change has its impacts on Global as well as regional water resources. This paper aims to elucidate the trend in change of climate with its effect on water resources in India and also illuminates the adaptations to be made for preparedness to climate change.

Keywords: Climate Change, Adaptations, Water Resources, Greenhouse effect.

1. Introduction

Adequate scientific evidence (for example, Intergovernmental Panel on Climate Change [IPCC], 2007) exists that confirms the global climate is changing. Three significant visible signs of climate change are: (i) increase in global average temperature, (ii) change in regional precipitation patterns, and (iii) rise in sea levels.

Projections based on climate models implies that on a global scale, temperatures will keep rising over the next century, causing rise in sea levels and change in circulation patterns that affect precipitation. In terms of impacts affecting normal human life, the biggest impact will be on water—with respect to both water availability and limits of floods and droughts. Increase in atmospheric temperature, for example, is likely to have a direct impact on the runoff in snow-fed rivers and on the water demands of crops and vegetation apart from the indirect impacts on all other phenomena of interest in hydrology and water resources management. Climate change, in conjunction with other changes occurring in the country such as rapid urbanization and industrial growth, has serious implications for policy and infrastructure growth in water and other related sectors. Hence, awareness of the issue and proper adaptations must be taken to deal with the upcoming calamity. [1][3]

2. Climate Changes

Climate in a narrow sense is defined as "average weather", or more precisely, as the statistical explanation in terms of mean and variability of relevant quantities of weather parameters over a period of time. Climate change in IPCC usage denotes to any change in climate over time, either due to natural variability or as a result of human activity. This usage is different from that of UNFCCC which describes climate change as, "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". Climate change is not only a major global environmental problem, but also an issue of great worry to a developing country like India. Some natural factors are changes in the Sun's intensity; the Earth's orbit; Ocean circulation; volcanic eruptions etc. Similarly, Human Factors include changes in the land use pattern, burning fossil fuel and release of GHGs. The earth's atmosphere - the layer of air that surrounds the earth - contains many gases. Short-wave radiation from the sun passes through the earth's atmosphere. Partly this radiation is reflected back into space, absorbed by the atmosphere and what remains reaches the earth's surface, whether it is reflected or absorbed. Consecutively, the earth's surface, emits long-wave radiation toward space. The GHGs available in the atmosphere, which principally include CO_2, CH_4, CFCs, NO_2 and O_3, absorb some of this long-wave radiation emitted by the Earth's surface and re-radiate it back to the surface. Thus GHGs modify the heat balance of the Earth by retaining long-wave radiation that would

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otherwise be dispersed through the Earth's atmosphere to space, this is known as the greenhouse effect. Clearly, GHGs plays major role in controlling the temperature of the earth and an increase in their concentration in the atmosphere would increase the temperature of the Earth. Additionally, presence of surplus quantities of CFCs affects the protective ozone layer which deflects the harmful short wave rays. IPCC also observed that global average air temperature near earth's surface rose to (0.74 ± 0.18) ℃ in the last century. [2]

3. Temperature rise in India and future predictions

Studies have been carried out by National Institute of Hydrology to analyze the trends of variation in temperature over India and the results have been compared with global trend. An analysis of temperature data of 125 stations distributed all over India shows an increase of 0.42^{o} C, 0.92^{o} C and 0.09^{o} C in annual mean temperature, mean maximum temperature and mean minimum temperature respectively over the last 100 years. However, the trends are varying on regional basis. It has been seen that the changes in temperature in India over last century are broadly consistent with global trend of increase in temperature. The temperature is increasing all over the country relatively over northern regions of India. Surface air temperature shows comparable increasing trends by as much as 3 °C to 4 ℃ by the end of the 21^{st} century. [2]

4. Water resources in India

Total precipitation together with snowfall of roughly 4000 km^3 in the country, the availability from surface water and renewable groundwater is estimated to be around 1869 km^3. Due to variations in topography and uneven distribution of resources over space and time, it is estimated that only about 1123 km^3, consisting of 690 km^3 from surface water and 433 km^3 from groundwater resources can be put to use. Table – (i) shows the estimated water resources of the India. Many Indian rivers are perennial, though few are seasonal. The reason is because of precipitation over a large part of India is concentrated in the monsoon season during June to October. Precipitation varies from 100 mm in the western parts of Rajasthan to over 11000 mm at Cherrapunji in Meghalaya. Rivers do not, though, remain at a high stage throughout the monsoon season. It is only a course of heavy rains, which may run for a period of several hours to few days that generates large run-off in the catchments. [2]

Table-(i) - Water resources of India [2]

Estimated Annual Precipitation(Including Snowfall)	4000km^3
Average Annual potential in Rivers	1869 km^3
Estimated utilisable water	1123 km^3
(i) Surface	690 km^3
(ii) Ground	433 km^3
Water Demand ~ Utilization (Year 2000)	634 km^3
(i) Domestic	42 km^3
(ii) Irrigation	541 km^3
(iii) Industry, Energy and others	51 km^3

5. Impact of Climate Change on Water Resources

Temperature or warmth drives the hydrological cycle, regulating hydrological processes in a direct or indirect way. A warmer weather may lead to intensification of the hydrological cycle, causing higher rates of evaporation and increase of liquid precipitation. These processes in alliance with a shifting pattern of precipitation may affect the spatial and temporal circulation of runoff, soil moisture, groundwater reserves etc. and may increase the frequency of droughts and floods. Figure–1 displays a conceptual model of the effect of GHG and global warming on the hydrological cycle and phenomena affiliated with weather extreme. The future climatic (weather) change, though, will have its wallop globally but likely to be felt severely in developing countries with agrarian economies, such as India. Increasing population, industrialization and

associated demands for freshwater, food and energy would be areas of anxiety in the altering climate scenarios. Surge in extreme climatic events will be of great repercussion owing to the high vulnerability of the region to these changes. The projections show that the warming would vary from region to region, accompanied by increases and decreases in precipitation. Along with this, there would be changes in the variability of climate, and changes in the intensity and frequency of some extreme climatic phenomenon. Flood magnitude and frequency are expected to increase in most regions while low flows are supposed to decrease in many regions. Although there have been very few studies addressing the issue directly, mostly due to difficulties in characterising credible scenarios for changes in flood producing climatic events. [5][7]

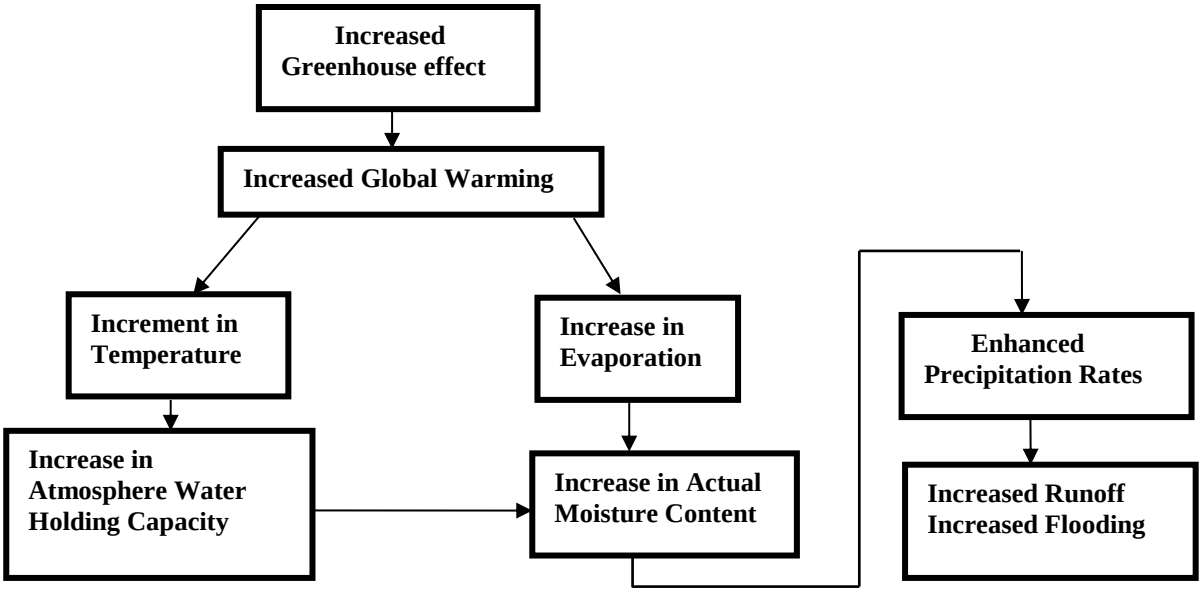

Figure-1- Basic model of the effect of GHG and global warming on the hydrological cycle [2]

5.1Change in Rainfall Patterns

A downturn in monsoon rainfall since the 1950s has been seen. The frequency of heavy rainfall events has also increased. An increase of 2 ℃in the world's mean temperatures will make India's summer monsoon highly unpredictable. At 4 ℃ heating, an acutely wet monsoon that currently has a chance of happening only once in 100 years is projected to happen every 10 years by the end of the century. A sudden change in the monsoon could precipitate a major catastrophe, resulting more frequent droughts as well as larger flooding in large parts of India. India's northwest seaboard area to the south eastern seaboard area could see higher than average rainfall. Dry years are anticipated to be drier and wet years to be wetter. [4]

5.2 Drought

Evidence clearly shows that parts of South Asia have become less wet since the 1970s with a increase in the number of droughts. Droughts have major repercussions. In 1987 and 2002-2003, droughts influenced more than half of India's crop area and led to a gigantic fall in crop production. Droughts are anticipated to be more frequent in some areas, particularly in north-western India, Orissa, Jharkhand and Chhattisgarh. Considerable fall in crop yield is anticipated because of extreme heat by the 2040s. [4]

5.3 Ground Water

More than 60% of India's agriculture is dependent on rain, making the country highly dependent on groundwater. Even without weather change, 15% of India's groundwater assets are overexploited. Although it is difficult to predict future ground water levels, drop in water tables can be expected to reduce further on account of surging demand for water from a growing population, more upscale life styles, as well as from the services and commerce sector. [4]

5.4 Glacier Melt

Glaciers in the north-western Himalayas and in the Karakoram range - where westerly winter winds are the major source of moisture - have remained steady or even more developed. On the other hand, most Himalayan glaciers - where a considerable part of the moisture is provided by the summer monsoon - have been retreating over the past century. At 2.5 ℃ warming, melting glaciers and the loss of snow cover over the Himalayas are expected to threaten the steadiness and reliability of northern India's primarily glacier dependent rivers, particularly the Indus and the Brahmaputra. The Ganges will be less reliant on melt water due to high annual rainfall downstream during the monsoon season. The Brahmaputra and Indus are expected to see increased flows in spring when the snows melt, with flows reducing afterwards in late spring and summer. Alterations in the flows of the Ganga, Brahmaputra and Indus rivers could significantly impact irrigation, affecting the quantity of food that can be produced in their basins as well as the livelihoods of millions of people (209 million in the Indus basin, 62 million in the Brahmaputra basin and 478 million in the Ganges basin, in the year 2005). [4]

5.5 Sea Level Rise

Mumbai is the world's largest populated city exposed to coastal inundating, with large parts of the city built on reclaimed land, underneath the high-tide mark. Fast and unplanned urbanization further increases the risks of sea water intrusion. With India in the vicinity of equator, the sub-continent would see much higher rises in sea levels than higher latitudes. Sea-level rise and storm rush would lead to saltwater intrusion in the coastal localities, contaminating drinking water, impacting agriculture, degrading quality of groundwater and probably causing a rise in diarrhoea and cholera cases, as the cholera bacterium survives more time in relatively more saline water. Kolkata and Mumbai, both being densely populated cities, are particularly prone to the impacts of tropical cyclones and sea-level rise. [4]

6. Preparedness and Adaptations to Climate Change

Impacts of current and future climate change are inevitable. Past emissions are estimated to involve unavoidable warming, even if atmospheric GHG concentrations remain at 2000 levels, with effects transmitted through hydrological and hydrogeological systems, and onto the ecosystems and people that depend on them making certain adaptations a necessity to prepare for the upcoming calamities. They can be practiced on four levels [6]:

(i) Institutional Arrangements

(ii) Development and Management of Water resources

(iii) Warning and Prevention of floods

(iv) Management of droughts.

6.1 Institutional Arrangements

On Institutional level, various practises can adopted such as:

(i) Preparing integrated plans for extreme climatic events at all levels.

(ii) Introduction of a Modern unified legislation for disaster management.

(iii) Establishing National network of all knowledge-based institutions.

(iv) Introduction of weather-indexed insurance.

6.2 Development and Management of Water Resources

(i) Enhance water storage capacity, especially in Himalayan region.

(ii) Enhance water productivity at all levels.

(iii) Improve design standards in disaster prone areas.

(iv) Uplift the traditional institutions at local levels.

6.3 Warning and Prevention of Floods

(i) Promoting Programmes teaching "How to survive the floods".

(ii) Improve flood forecast.

(iii) Community participation in flood management.

(iv) Flood plain zoning, enforcement of regulations.

(v) Area inundation forecasting

6.4 Management of Droughts

(i) Drought management is still an ad-hoc and empirical famine intervention for providing instant relief to prevent starvation.

(ii) Advancement of Vulnerability mapping, community involvement; prevention, mitigation and quick response, use of modern tools and procedures of monitoring, impact documentation and capacity building.

7. Conclusion

With current trends of increasing temperature, climate change has become the problem that should be paid immediate attention. Proper planning and implementations of such plans at all the levels should get started as this arising problem can only be mitigated and minimized to an extent.

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