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Editorial

Climate Change and Hydrology in Indian Perspectives

Ansar Khan[1*], Soumendu Chatterjee[2]

[1]*Department of Geography and Environment Management, Vidyasagar University, Midnapore-721 102, India*

[2]*Department of Geography, Presidency University, Kolkata-700 073, India*

**Corresponding author: Ansar Khan, Department of Geography and Environment Management, Vidyasagar University, Midnapore-721 102, India, Email: khanansargeo@gmail.com*

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The global hydrological cycle is a key component of Earth's climate system. A significant amount of the energy the Earth receives from the Sun is redistributed around the world by the hydrological cycle in the form of latent heat flux [1]. Changes in the hydrological cycle have a direct impact on droughts, floods, water resources and ecosystem services. Observed land precipitation [2-4] and global river discharges [5] do not show an increasing trend as might be expected in a warming world [6-11].

In recent times, several studies around the globe show that climatic change is likely to impact significantly upon freshwater resources availability. In India, demand for water has already increased manifold over the years due to urbanization, agriculture expansion, increasing population, rapid industrialization and economic development. At present, changes in cropping pattern and land-use pattern, over-exploitation of water storage and changes in irrigation and drainage are modifying the hydrological cycle in many climate regions and river basins of India. An assessment of the availability of water resources in the context of future national requirements and expected impacts of climate change and its variability is critical for relevant national and regional long-term development strategies and sustainable development. This article examines the potential for sustainable development of surface water and groundwater resources within the constraints imposed by climate change and future research needs in India.

The present simulation results from GCMs are still considered uncertain. Ability of present GCMs in predicting the impact of climate change on rainfall is still not promising. In addition, there are uncertainties involved in predicting extreme flood and drought events by these models. While climate models predict an increase in precipitation by –24 to 15% over India [12], regional changes may be different [13]. Studies on inter-annual and long-term variability of monsoon and annual rainfall have indicated that variation in rainfall for the subcontinent is statistically significant [14-15]. Analysis of observed rainfall data for the 131-yr period (1871–2001) suggests no clear role of global warming in the variability of monsoon rainfall over India [16]. Therefore, it is difficult, at this juncture, to convince the water planner and development agencies to incorporate the impact of climate change into their projects and water resources systems. However, given the potential adverse impacts on water resources that could be brought about by climate change, it is worthwhile to conduct more in-depth studies and analyses to gauge the extent of problems that the country may face. Man-made climate changes, i.e. changes in cropping pattern and land-use pattern, over-exploitation of water storage and changes in irrigation and drainage in the Gangetic basin show a reduction in the Ganges discharge by 60% over 25 years. This has led to about 50% drop in water availability in surface water resources, drop in groundwater table and generation of new surface features having different thermal properties [17]. More studies are needed in different basins, aquifers and agro-climatic regions of India to assess the sensitivity of the basin response to climate change [18]. Considering the inter-annual variability of rainfall in India, assessment of only volume may not be helpful until temporal and spatial variations of climate change and their impacts are assessed. Agricultural demand, particularly for irrigation water, which is a major share of total water demand of the coun-

try, is considered more sensitive to climate change. A change in field-level climate may alter the need and timing of irrigation. Increased dryness may lead to increased demand, but demand could be reduced if soil moisture content rises at critical times of the year [19]. It is projected [20] that most irrigated areas in India would require more water around 2025 and global net irrigation requirements would increase relative to the situation without climate change by 3.5–5% by 2025, and 6–8% by 2075. In India, roughly 52% of irrigation consumption across the country is extracted from groundwater; therefore, it can be an alarming situation with decline in groundwater and increase in irrigation requirements due to climate change. To obtain better quantitative assessment of the climate change impact, it is imperative that more accurate 'damage due to flood' and 'damage due to drought' relationship should be established and updated periodically. This is especially critical in areas where rapid socio-economic development has taken place. During dry spells, supplementing stream water supply from storages solves only part of the problem. Maintaining the water quality is of equal importance to ensure adequate safe water supply not only for anthropogenic consumption, but also for the healthy survival of its habitats and aquatic life. Therefore, serious efforts and commitment are needed to protect the watersheds and their resources, so that water quality deterioration would not become the limiting factor in determining the availability of water supply, thus jeopardizing the progress in social-economic development programmes in future. It is recognized that prudent and integrated water resources development and management for optimum and sustainable water utilization is an important and urgent issue to be taken up seriously, even without the occurrence of climate change impact.

Indian Climate and Water Scarcity

The major impacts of climate change in India would be on the hydrology, water resources and agriculture of the country. A rise in sea level due to thermal expansion of sea water and melting of ice from high altitudes and latitudes is also expected. Climate variability and climate change assume great importance for the Indian sub-continent because its economic performance and social progress are dependent on rainfall and climate change is likely to affect rainfall. India possesses a great variety and diversity of climate, varying from extremely hot to extremely cold, from extremely arid regions to extremely humid regions, from drought-prone areas to flood-prone areas. Climatic conditions govern to a great extent the operation of water resources in the country. The Himalayan Rivers of India are ice-fed rivers and thus are very vulnerable to climate change. Rainfall is governed by the southwest and northeast monsoons. The distribution of Indian rainfall shows great temporal and spatial variations. About 80% of the total rainfall occurs during four monsoonal months (June to September) and is not spread uniformly over the country, creating pockets of scarcity in some regions. Thus, large storages of water are required to meet the demand during the lean periods.

Agriculture is the dominant sector in the economics of a developing country like India and is the major source of employment, income and sustenance for the majority of the population of the country. Out of the 342×10^6 ha of land area in India, 142×10^6 ha are cultivated, out of which 31.4% is irrigated. Two main crop seasons, "kharif" or monsoon (July-October) and "rabi" or post-monsoon (November-March), provide almost all food grain production. The intra-regional variability in climatic change induced by greenhouse warming together with the inter-regional heterogeneities due to differences in spatial factors (soils, topography, length of crop growing season, major rainfed crops in a given area, runoff harvesting possibilities, ground water potential) might make the picture more complicated. When considering the increasing demand for water for various activities, it also becomes essential to know with sufficient accuracy the future availability of water, considering the probable effects of climate change, so as to plan and manage the resources and requirements.

There is an urgent need to view the various projected climate change scenarios in a balanced way. An accurate appraisal of the water resources of India is therefore of the utmost importance for the planning, development and utilization of water. A focused and careful examination of the different components of the prevailing agricultural systems in different regions should be done in order to provide potential options for adapting to climatic changes.

From the above, it can be concluded that the Indian region is highly sensitive to climate change. The elements/sectors currently at risk are likely to be highly vulnerable to climate change and variability. It is urgently required to intensify in-depth research work with the following objectives:

• Analyze recent experiences in climate variability and extreme events, and their impacts on regional water resources and groundwater availability.

• Study on changing patterns of rainfall, i.e. spatial and temporal variation and its impact on run-off and aquifer recharge pattern.

• Study sea-level rise due to increased run-off as projected due to glacial recession and increased rainfall.

• Sea-water intrusions into costal aquifers.

• Determine vulnerability of regional water resources to climate change and identify key risks and prioritize adaptation

responses.

• Evaluate the efficacy of various adaptation strategies or coping mechanisms that may reduce vulnerability of the regional water resources.

It has been the venture of this study to summarize some important vulnerability issues associated with the present and potential future hydrological responses due to climate change and highlight those areas where further research is required. The National Environment Policy [21] also advocated that anthropogenic climate changes have severe adverse impacts on India's precipitation patterns, ecosystems, agricultural potential, forests, water resources, coastal and marine resources. Large-scale planning would be clearly required for adaptation measures for climate change impacts, if catastrophic human misery is to be avoided.

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