CHAPTER 14

WAY FORWARD - CLIMATE CHANGE IMPACT ASSESSMENT ON WATER RESOURCES AND ADAPTATION

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Climate change is said to be the most critical problem in the field of water and environment that the mankind has ever faced. Climate change related risks, in conjunction with other risks are increasing at different paces. Some, such as water availability related risks are increasing gradually while some such as floods and droughts risks are increasing rapidly (Lacombe, 2018). Hence, wide ranging initiatives and actions are needed to tackle this global problem.

An essential requirement to handle climate change problem is a detailed scientific understanding of the causes and past trends behind climate change and its impacts. This will help in initiating necessary actions to mitigate the adverse impacts. Various chapters of this report, have discussed impacts of climate change on different components of hydrologic cycle with special emphasis to the impacts in India.

14.1 Knowledge Gaps in Climate Science

Similar to any other emerging area of research, there are many knowledge gaps or "holes" in our understanding about the behaviour of climate system. Among the other things, this also means that uncertainties are associated with future projections and that future climate changes could be significantly different than the projections. Schiermeier (2010) listed four "problem areas" that need to be addressed by climate scientists. These four areas that require more research are: a) regional climate prediction, b) precipitation forecasts, c) aerosols, and d) palaeoclimate data. He, of course, stated that such "holes do not undermine the fundamental conclusion that humans are warming the climate". It was also noted that in the field of climate science, the most crucial information is the least reliable.

14.1.1 Regional Climate Prediction

The projections of future climate at local and regional levels have large uncertainties. These projections form the basis for taking remedial actions such as adaptation projects. As a number of modeling groups across the world are continuously improving their models, it is hoped that the regional projections made by the next generation of models will have reduced uncertainties and will be useful for planners and policy-makers. Availability of better data and more powerful computers will add to these efforts.

14.1.2 Precipitation

For the hydrologists, precipitation is the most important variable to determine the impact of climate change on water resources. It is well known that precipitation is also the variable that is most difficult to model. A number of modeling centers across the world are applying GCMs and making future climate projections. However, in these studies, projections of precipitation are widely different at all scales: global, regional and local. There are several reasons behind this. Besides inadequate understanding of climate system, we have inadequate data to correctly model processes such as cloud formation, orographic effects, thunder-clouds, etc.

14.1.3 Aerosols

Aerosols are airborne particles. A source of uncertainty in climate science is the inability to properly account for the impacts of aerosols on the climate. Scientists don't have clear understanding of the impacts of particles such as sulphates, black carbon, sea salt and dust on temperature and precipitation. Note that different aerosols have different impacts. Overall, aerosols are known to have cooling impact on climate as they block sunlight. However, estimates of the cooling effect have wide variation; some aerosols produce warming effect. Lack of data is another concern. Space and ground-based sensors are used to measure aerosol impact. Schiermeier (2010) noted that the relationship between aerosols and clouds adds another layer of complication.

14.1.4 Palaeoclimatology Data

Temperature data prior to 1850 are scarce but long-term data are needed in climate studies and researchers must find other ways to reveal earlier temperature trends. Palaeo-climatology uses data obtained from sources such as tree rings, coral reefs, lake sediments, glacial movements, etc. Thickness of tree rings have been related with temperature and rainfall. Tree ring growth at some sites have tracked atmospheric temperatures but have diverged from the actual temperatures during the recent decades. It is likely that the trees grow differently when temperatures exceed a certain threshold. In any case, to improve the usefulness of tree ring data, it is necessary to know how different tree species grow under different climates.

Based on the review carried out and presented in this report, a number of issues have emerged which can be broadly classified in the issues dealing with research and investigations to be carried out and actions to be taken for adaptation and management to overcome adverse climate impacts.

14.2 General Observations

a) Due to geographical location as well as topography and economy and population, India is among the countries that are highly vulnerable to climate change. India has to ensure water food and energy security to its growing population, keeping in view the impacts of climate and other changes. We also need to protect our people from water related disasters which are likely to become more frequent, more intense and more widespread with time.

b) The surface mean temperature anomalies for past 100 years or so for India are consistent with global trends in temperature.

c) Due to changes in climate, extreme temperature events can cause severe adverse impacts on society and it is important to understand the likely patterns of long term changes at different locations across the country so that suitable adaptations and mitigation measures can be taken up.

d) Climate models are the best tools to understand impacts of climate changes. So far India doesn't have an indigenously developed model; it would be better to develop an indigenous model for different regions – scientific growth, possibility of developing future scenario that are constant with the emissions and land use land cover changes in India. Of course considerable scientific and infrastructural resources would be needed to develop a model and it will also take considerable time but a beginning needs to be made.

e) Downscaling of climate projections is the process of transferring general circulation model (GCM) output to a finer spatial and temporal scale. Downscaling techniques have been designed to bridge the gap between the information that the climate modelling community can currently provide and that required by the impacts research community.

f) Downscaling assumes that regional /local climate is conditioned by the climate on larger, for instance, continental or global scales. This is realistic. However, the dependence structures may change in future.

g) Downscaled data are typically bias-corrected to match with the observations but even then they may be unable to reproduce the observed behaviour and the relation between local/regional and continental/global climate may change in the future.

Krishnan and Sanjay (2017) report that CCCR, IITM, Pune have successfully developed IITM-ESMv2, the second version of IITM Earth System Model. IITM-ESMv2 is a radiatively balanced global climate modeling framework that has the capability to address key scientific questions relating to long-term climate change. IITM-ESMv2 would be first climate model from India to contribute to the Coupled Model Intercomparison Project Sixth Phase (CMIP6) for the IPCC sixth assessment report (AR6).

14.3 India Specific Issues and Observations

The various statistical data mentioned in this section have been drawn from published literature including Krishnan and Sanjay (2017), IPCC reports and other sources.

i. The annual average temperatures over the Indian landmass have shown an increasing trend of about 0.6°C/(100 yr) during the period 1901-2010. The highest trend is observed in post monsoon season 0.79°C/(100 yr), and the lowest in the monsoon season 0.43°C /(100 yr).

ii. Annual mean, maximum and minimum temperatures averaged over the country as a whole show significant warming trend of 0.16°C, 0.17°C and 0.14°C per decade, respectively since 1981.

iii. Maximum warming trend is seen during the post-monsoon season. The annual average temperature over the Indian landmass has significantly increased in the region north of 20°N.

iv. The number of warm days and nights has significantly increased over the last 35 years.

v. Overall monsoon rainfall does not show any significant change mainly because the decreasing trend in moderate rain events has been compensated by an increasing trend in heavy rain events.

vi. The annual as well as seasonal (June through September) monsoon rainfall over India shows significant decreasing trend over the core monsoon zone, north-eastern parts and southern parts of west coast.

vii. The total number of consecutive dry days with spell length more than five days has increased significantly, while the total number of consecutive wet days has shown significant decrease.

viii. The Indian region experienced extreme weather events in recent years such as heat waves, cold waves, extremely heavy rain events and many others. These events happen to be more severe and more frequent in recent years, producing devastating impacts on human life, agriculture, water resources, health etc.

ix. The number of warm days averaged over the entire Indian landmass depict significant increasing trend ~ 4.5 days /(35 years) during the period 1981-2015, while the number of warm nights has also increased significantly ~ 3.5 days /(35 years). The number of cold days and cold nights do not show any significant trend. The occurrence of hot days and hot nights, particularly during the pre-monsoon (Mar-Apr-May) season, were significantly more during the recent 35 years as compared to the previous time epoch.

x. Number of consecutive dry-day index [CDD, the number of dry days (days with daily rainfall < 1 mm)] in the spells where consecutive dry days are at least 5 (i.e., days with PR<1 mm) in a year. CDD is showing increasing trend.

xi. Number of consecutive wet day index (CWD) or the number of wet days [days with daily rainfall > 1 mm] in the spells where consecutive wet days are at least 5 (i.e., days with PR > 1 mm) in a year. CWD is showing falling trend.

xii. There are many critical data gaps in water sector in India. The current assessments of surface water availability are old and need to be updated by following sound hydrological principles. Reliable baseline data are necessary to predict the changes.

xiii. Utilization of water in its various uses is rarely measured. Hence, there is considerable uncertainty in the estimates of water utilization. This is hampering, among the other things, optimal water resources utilization.

xiv. Water quality data in India are scanty; limited variables are measured and at sub-optimal frequency. Good baseline data are needed to understand the impacts of global warming on water quality.

xv. Changes in land use and land cover impact hydrologic response of watersheds as well as emission /sequestration of carbon dioxide. Reliable landuse maps at close times should be prepared and made available to study CC impacts.

xvi. Hydrogeological maps are needed for improved assessment of ground water resources, impact of climate change on them, and groundwater contamination.

14.4. Research and Development Issues

a) It would be helpful to develop a reference climate data network of stations which can provide good quality long term data for improved understanding of the changes in meteorological and hydrological variables across the country (Jain, 2015).

b) As the water quality data are scarce in India, we do not have adequate understanding of the extent of pollution in various water bodies across the country. Hence it would be necessary to strengthen the water quality data networks by deploying required instruments to monitor all the desired parameters. At the same time, detailed modeling should be carried out so that management tasks for restoring good water quality in the natural water sources could be implemented. Additional stresses arising due to global warming and climate change need to be factored in the water quality management programs.

c) In view of lack of data on hydrologic, economic and other sectors, there is considerable uncertainty in the future climate projections for the country. Specifically, the uncertainty may arise due to the use of GCMs for climate projections, use of downscaling techniques, and hydrologic models. Each of these causes of uncertainties need to be addressed so that the uncertainties in projections as well as in decisions based on them could be minimized. This will require wide range of studies.

d) Although the literature has a large number of publications on downscaling from GCM results but very few studies consider impact on climate change on hydrological response of catchments and present qualitative results. Even when studies have an applied element, consideration is seldom given to how results might enable stakeholders and managers to make more informed, robust decisions on adaptation in the face of uncertainty about the future. In fact, studies on climate change and water adaptation with real-life applications are rare. Paradoxically, the rhetoric has become much more confident about projected changes in temperature and even precipitation at regional scales. Somewhere along the line there has been a disconnection between the suppliers and users of regional climate change scenarios for adaptation and resource planning.

e) We need to develop future projections of max temperature, min. temperature and mean temperature, and precipitation at fine spatial and temporal resolutions for different concentrations of greenhouse gases, such as RCP 4.5, 6.0 and 8.5.
f) It would be necessary to understand how the crop water requirements are going to change across various agro climatic zones in the country in the future and how the warming will impact crop yields at various locations.
g) As food security in the country critically depends on ground water it is necessary to understand the impact of changes in precipitation, temperature and other hydrometeorological variables as well as land use on recharge to ground water. For this purpose, existing mathematical models need to vigorously applied and the parameters use should be based on field assessments.
h) A substantial part of river flow in the lean season comes from ground water contribution. Hence, it is necessary to understand the interaction between river and aquifers in different hydrogeological settings across the country and how this may change with change in climate and other drives.
i) Studies would be required to identify areas where managed aquifer recharge can be practiced to conserve monsoon runoff as well as control decline of ground water tables.
j) A crucial gap in ground water modeling in India is lack of data on sub surface geology and aquifer properties. Some initiatives have been taken recently to address this issue and these need to be replicated to cover larger areas in the country.
k) Understanding the evolution of the Himalayan snowpack and glaciers under future climate change scenarios and their contribution in snow and glacier melt runoff in the Indus, Ganga, and Brahmaputra basins.
l) Himalayas are prone to soil erosion and this process may accelerate if the rainfall intensities increase. A better understanding of soil erosion and land slide mechanism will be needed for taking appropriate remedial measures.
m) Focused attention is needed for reservoir sediment management. Experience from other countries with similar geology and climate, particularly China, will be useful.

14.5 Water Resources Management Issues

a) As the extreme events are going to be more frequent and intense, it will be necessary to develop and strengthen infrastructure to deal with increasing variability.
b) We need to develop ways and means to store water made available during high flow (may be shorter duration) periods so that it does not cause damages in these periods and also can be used beneficially in dry periods.
c) Based on the results of ground water investigations, suitable mitigation measures and regulatory framework needs to be put in place urgently for checking ground water depletion before the situation deteriorates further.

d) A related issue though not arising very much due to climate change is contamination of aquifers due to recharge of polluted municipal and industrial waste in to sub surface zones. In many areas, hand pump water is highly polluted which an evidence that the upper soil layers are already filled with contaminated water which is likely percolate deeper with time. This problem should be addressed immediately before it goes out of control.
e) To manage climate change related risks, both short- and long-term interventions are needed. In short-term, climate adaptation is to be integrated with disaster risk reduction and utilization of natural resources. For the longer-term, plans are to be prepared keeping in view the impact of climate change experienced so far and the future projections.
f) A society which is knowledgeable and aware is more resilient and can better manage the risks. Hence, the society should be made aware and their understanding about climate change risks need to be enhanced.

14.6 India's National Action Plan on Climate Change (NAPCC)

Reports of IPCC and discussions on international forums have been urging the nations to initiate actions tackle challenges arising due to climate change. In response, the Indian government developed a National Action Plan on Climate Change (NAPCC) in 2008 as well as asked all states to prepare State Action Plans on Climate Change (SAPCC). The NAPCC has eight missions that deal with different facets of climate change adaptation and mitigation. Among these, the missions relevant to water sector are: National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for Sustainable Agriculture, and National Mission for Strategic Knowledge on Climate Change.

Rattani (2018) reviewed the progress of the missions and reported that "Even though NAPCC has been in existence for close to a decade, … for most missions it has only been three to four years since they came into effect. It is also clear that progress has been almost uncertain for most of the missions". It was found that "institutional, systemic and process barriers — including financial constraints, inter-ministerial coordination, lack of technical expertise and project clearance delays — stand as major challenges in the efficient implementation of the missions. The most obvious source of financing for climate change action is currently the limited government budgetary support". Also, the mission-mode approach for dealing with cross-cutting subjects has not worked (Rattani 2018). Lack of adequate and trained manpower to dedicatedly work on the Missions is another reason that the Missions have not been able to achieve the desired results. A new approach needs to be devised to mainstream the climate agenda in the cross-cutting sectors.

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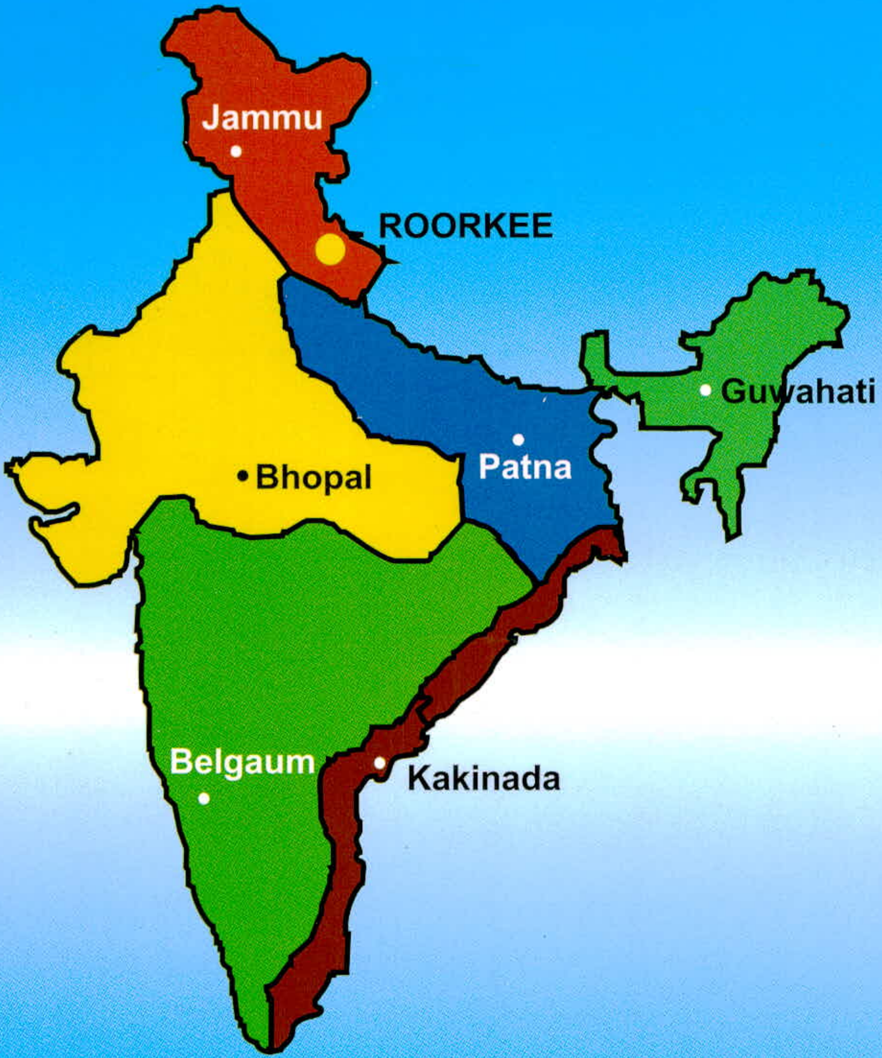

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