CLIMATE CHANGE ADAPTATION IN WATER RESOURCES

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Abstract-Water resources are directly impacted by climate change, and the management of these resources affects the vulnerability of ecosystems, socio-economic activities and human health. Water management is also expected to play an increasingly central role in adaptation. This paper deals with impact of climate change on water resources. It outlines the various policy options for adaptation of water resources in the context of climate change. Thus paper makes a special note on water and climate change adaptation planning, climate change water adaptation technology and developing appropriate action on climate adaptation in water resources. This paper concludes with some interesting findings along with policy suggestions.

Introduction

The IPCC Fourth Assessment Report predicts that as a result of climate change, freshwater resources will decrease by 10 to 30 percent in many mid-latitude and tropical dry regions, and that the projected sea-level rise by the 2080s will result in millions more people experiencing flooding every year. While some regions may benefit from climate change, overall the IPCC predicts that the effects of climate change on water resources will have negative implications. The IPCC Technical Paper on Climate Change and Water (IPCC, 2008) states that: “Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources.

Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks. It is against this technical background that the challenges of the future have to be addressed, although it should be remembered that existing climates are already highly variable and climate change simply adds to the complexity and scale of the challenge of managing this variability. While there is growing confidence about model predictions of changing temperatures and rainfall, the impact of these changes on water availability from rivers, lakes and underground sources is poorly understood. As an example, one effect of temperature increases is to increase evaporation rates. Since the balance between evaporation and rainfall determines whether a climate is humid or arid, aridity will tend to increase where rising temperatures are not matched by rising rainfalls.

Climate change and water resource scenario in India

The intensity of floods and severity of droughts in various parts of India is projected to increase. As per the report by GoI (2004) some river basins might face water scarcity. IPCC (2007) warns that the combination of population growth and climate change is predicted to reduce the availability of fresh water in India from the current 1900 to 1000 cubic meters per capita/year by 2025. GoI (2004)notes that rising sea levels may lead to increased saline intrusion into coastal and island aquifers, while increased frequency and severity of floods may affect groundwater quality in alluvial aquifers. As much as 60 % of the crop area in India is rain fed, with rainfall being largely confined to the southwest monsoon season from June to September. While climate models are relatively consistent in predicting temperature increase, projecting the scope of precipitation changes remains very difficult. However, an overall increase in rainfall intensity, combined with a reduction in the number of rainy days, will have great effects for the majority of the land needed for agricultural production. As per the report by GoI (2004) North Andhra Pradesh and the west coast are already witnessing an increase in monsoon rainfall (+10 % to +12 % above the 100-year normal) and Madhya Pradesh, North East India and parts of Gujarat and Kerala are experiencing a decrease in monsoon rainfall: - 6 % to - 8 % below the 100-year normal.

The impacts of climate change on water resources, such as the increase in extreme weather events like droughts and floods as well as higher rainfall variability, will exacerbate the vulnerability of people’s livelihoods. Incorporating adaptation measures into the management of water resources is vital, particularly in those regions, such as semi-arid to arid areas, which suffer from harsh climatic conditions. Due to the limitation of climate models, projecting the scope of precipitation changes remains a very difficult task. This calls for special attention to prepare for higher rainfall variability.

Climate change and Water Management

During past decades, water managers have already reacted to the changes in climate by adopting a range of practices, uncertain long-term challenges. Aerts and Droogers (2009) and IPCC (2007) report that climate change and socioeconomic trends have not been taken into account. Uncertainty makes it difficult to translate trends, such as higher rainfall variability, into quantitative terms that could serve as a basis to develop concrete water management strategies and measures. However, existing climate data and models have been instrumental in pointing out some general changes in the water cycle that are triggered by climate change. As per the report by IUCN (2003) and Aerts and Droogers (2009) the implication for decision-making is that investments in water infrastructure will have to be made on the basis of unknown and uncertain future risks. It also means that management approaches that deal with existing risk and uncertainty have to be taken into consideration, along with climate scenario analyses and vulnerability assessments.

Tideman and Khatana (2004) note the key priorities for initial action in the water sector include: addressing current and expected water scarcity problems; dealing with floods and other extreme events; expanding the knowledge base on water resources; dealing with exposure to climate change and impacts and strengthening the national capacity for Integrated Water Resources Management and planning Adaptation in water resources management means adjusting well-proven and established measures to the changing conditions. New and innovative approaches to water resources management and its development are vital to reduce the vulnerability and livelihood insecurity among the poorest and facilitate adaptation to the uncertain effects of a changing climate. Climate Proofing constitutes such a new approach. It involves the systematic observation of the current and future risks and opportunities of climate change, leading to the identification of measures to address these issues. In general, adaptation in water management also requires adjustments in policy fields outside the water sector, such as: migration and settlement; transboundary cooperation in the event of disasters; regional and land use planning and agriculture, especially irrigation development.

India's National Water Mission

In order to mainstream climate change issues in the water sector, the Indian Government prepared its National Water Mission under the National Action Plan on Climate Change (NAPCC) in 2009. GoI (2009) notes that the mission highlights as its main objectives: conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through Integrated Water Resources Management. These objectives will be achieved by: establishing a comprehensive water database in the public domain to assess climate change impacts on water resources; promoting civic and state action for water conservation, augmentation and preservation; focusing attention to areas where water is over-used; increasing water use efficiency by 20 % and promoting Integrated Water Resources Management at basin level.

Climate change adaptation options in water resource management

It is evident from the work of IUCN (2003) and Ngigi (2009) that policy analysis and change, and mainstreaming adaptation in water resource management has potential impacts in the form of placing the adaptation issue at the heart of decision-making, securing sufficient financial resources to implement adaptation, creating the flexibility required for coordination between different sectors and administrative levels and providing adequate institutional structures for adaptation.

The policy option on adjustments in water management regulations has potential impacts in the form of establishing appropriate spatial planning and building codes with regard to floods by the way of avoiding high-risk and hazardous areas, specifications for the elevation of the lowest floor level, use of flood-resistant material, promoting water-saving devices in the form of drip irrigation, multiple use systems, compulsory rainwater harvesting tanks for new buildings, improving efficiency of water distribution and use and reusing waste water.

The policy option on development of national, sectoral and regional adaptation strategies has potential impacts in the form of establishing appropriate spatial planning and building codes with regard to floods in the form of avoiding high-risk and hazardous areas, specifications for the elevation of the lowest floor level, use of flood-resistant material, promoting water-saving devices by the way of drip irrigation, multiple use systems, compulsory rainwater harvesting tanks for new buildings, improving efficiency of water distribution and use and reusing waste water.

The policy option on international cooperation has potential impacts reflected in the form of making use of international expertise on climate and climate impact data, formulating adaptation strategies and setting adaptation priorities, building up analytical monitoring capacities, and learning about tools for assessing policies and carrying out cost-benefit analyses. The policy option on capacity building has potential impacts by the way of raising awareness of the effects of climate change on water resources, by introducing climate change into the curriculum for all school levels, and integrating knowledge of expected climate change impacts on the water cycle into water management. The policy option on Incentives for adaptation has potential impacts in the form of involving the private sector in planning and implementing adaptation measures in the form of improving efficiency of water use, gaining the support of civil society and other actors for the development and implementation of adaptation strategies in the water sector.

Water and climate change adaptation planning

It can be done in the following ways. These include develop capacity-building as an initial and inherent component of the adaptation planning process, including in order to: ensure the success of innovative technological interventions at the community level. There is a need to strengthen local capacity to sustain livelihoods and ensuring continuous inter sectoral communication and coordination. Adaptation planning should enhance international cooperation to facilitate access to financial and technical resources, as well as capacity-building for developing countries and international cooperation should aim, in particular, at: establishing national data information systems. There is need to identify the most appropriate international funding mechanism to enable developing countries to comply with established procedures for data collection and management and strengthening technical and institutional capacities in providing high-quality climate services through north–south, south–south and triangular cooperation. Further there is a need to develop demonstration projects; consider innovative local-level financing and revenue options to secure long-term and sustainable investments and trigger cost-effective solutions.

Developing appropriate action on climate adaptation in water resources

It could be noted that the climate adaptation in water resources could be practiced in the following ways. Developing localized science in order to draw attention to the local impacts of climate change and facilitate decision-making at the regional, national and sub national levels. This might include efforts to develop scenarios downscaled to the level of managing water resources, and methods to develop narrative climate scenarios based on key climate vulnerabilities; Improving the available analytical tools to capture how human interactions with hydrology produce positive or negative outcomes for the economies and ecosystems upon which human communities depend; Developing research on extreme events and long- and longer-term climate change and their transboundary dimensions to raise awareness on the need for transboundary cooperation in adaptation; Assessing water-relevant adaptation policies and aspects concerning sustainable water management, addressing long-term impacts to ensure coherence and prioritizing adaptation actions at the national level; Investing in the appropriate coverage of monitoring systems at different scales; Establishing mechanisms for filling in data gaps in data-scarce areas with advanced tools where needed; Enhancing the establishment of data information systems through data platforms, clearing houses and meta -databases on observational data.

Climate change water adaptation technology

Water allocation can be done through basin level modeling and seasonal forecasting seasonal water rationing and water re-allocation. Water augmentation can be practiced by the way of rainwater harvesting for infiltration urban green spaces, conjunctive use of surface and groundwater, managed aquifer recharge and source water protection. Water efficiency and demand management could be adapted in the form of water efficiency in industry, improved irrigation efficiency, water metering, reducing system water loss and leakages, public water conservation campaigns, progressive pricing, hydrological zoning, water licensing and permits, shifting the timing of use and water savings requirements in building codes.

Climate change adaptation in the form of Water storage can be practiced in the form of construction and improvement of surface reservoirs, multipurpose dams, soil moisture conservation techniques, natural wetlands and rainwater harvesting for storage. Climate change adaptation in the form of alternative water sources can be practiced by the way of Sea water desalination, solar water distillation, fog harvesting, inter basin transfers, groundwater prospecting and extraction, boreholes and tube wells and water recycling and reuse. Climate adaptation in the form of riverine flood protection could be practiced by the way of constructing structural barriers to flooding - dams, dikes, locks, and levees, optimization of reservoir operations, re-connecting rivers with floodplains, flow-through dams, accommodation of flooding in terms of flexible, buildings and infrastructure, ecological river restoration, multipurpose dams, zoning and land development limitations. Climate change adaptation in the form of urban storm water management can be done through urban green spaces, permeable pavements and parking lots, bio swales, optimization of urban drainage systems, runoff control structures to temporarily and store rainwater.

Climate change adaptation in the form of limiting saltwater intrusion can be done through limiting abstraction from shallow aquifers, barriers to fluvial saltwater intrusion, increasing sustainable aquifer recharge, coastal surface water monitoring, and coastal groundwater level monitoring.

Climate change adaptation in form of built infrastructure for shoreline protection can be practiced in the form of revetments, construction of sea walls, and land claim beach nourishment, construction of storm surge barriers and closure dams, construction of breakwaters dikes, groins and jetties in the form of inlet structures. Climate change adaptation in the form of green infrastructure for shoreline protection can be done through creation of artificial reefs, restoration and protection of coral and oyster reefs, cliff stabilization, protection of sea grass beds, coastal wetlands including mangroves and dune construction and rehabilitation. Climate change adaptation in the form of accommodation and management can be practiced by the way of creating coastal zoning developing, floating agricultural systems, flood proofing, managed coastal realignment, coastal setbacks and fluvial sediment management.

Climate change adaptation in the form of flood proofing for water quality can be practiced in the form of flood-proof wells and flood-proof sanitary latrines. Climate change adaptation in the form of early warning can be practiced in the form, of developing flood forecasting systems, drought forecasting systems, early warning systems for floods, Landslide and mudflow warning systems, decentralized community run early warning systems, drought early warning systems, flash flood guidance systems, real-time monitoring networks. Climate change adaptation in the form of disaster response can be done by the way of Stacking of sandbags combined with the use of ground improvement technology, flood disaster preparedness indices, communication protocols, flood shelters, social media applications for disaster, response and mapping national and community disaster, management plans. Climate change adaptation in the form of improved water treatment capacity can be done by the way of advanced domestic wastewater treatment tanks, constructed wetlands for water treatment, improved efficiency of centralized water treatment systems and improved point-of-use water treatment.

Integrated Water Resources Management

According to GWP (2000) 'Integrated Water Resources Management is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.' These include better water management makes it easier to respond to changes in water availability, basin planning allows for risk identification and mitigation, involvement and participation of stakeholders such as authorities, institutions, the public and private sector as well as civil society helps in mobilization for action and in risk assessment and good management systems allow the right incentives to be passed on to water users.

Adaptive Water Management

Due to the uncertain effects of climate change, identifying effective interventions is particularly challenging. Climate projections are often inconsistent and lack accuracy – especially at the regional and local level. This has guided climate adaptation research towards new – adaptive – approaches in water management that enable water managers to cope with future uncertainties. The concept of Adaptive Water Management aims at more institutional flexibility and provides stakeholders with a central role in an iterative social learning process. Hence adaptive management is about flexibility, about adjusting water management strategies so that they become more resilient under a wide range of future conditions. Aerts and Droogers (2009) and Pahl-Wostl et al. (2005) note that various methods, such as forecasting, risk mapping and insurance systems, especially for drought and flood events, have been established to help develop such strategies. Wider stakeholder involvement and transparency are also required to enhance political support for sharing the burden and possible benefits of the impacts of climate change.

Watershed Management

Watershed management aims to manage water supply, water quality, drainage water runoff and water rights. It also incorporates overall planning processes for watersheds. It comprises the planned, coordinated and sustainable use of: water resources, agricultural resources, grazing land, forests, and areas with other uses such as domestic water supply, irrigation, industrial water use, navigation.

The Indian Government has been supporting the development of watersheds since 1973, when the Drought-Prone Area Programme was introduced. Since then it has evolved with increased experience and knowledge to find answers to two major challenges: soil and water conservation and improvement of livelihoods in rural areas. At first, making significant changes in the original planning and implementation processes was considered too rigid and top-down.

Watershed development in India is working towards developing watersheds to create sustainable livelihood opportunities. Building on participatory approaches, increasing water availability, improving degraded environments and choosing sustainable agricultural activities are key features. Watershed development is thus directly dependent on climate parameters like rainfall, temperature or evapotranspiration. On the one hand, watershed development in India contributes significantly to increasing adaptive capacity and reducing the vulnerability of communities and farmers to climate change. On the other hand, unless it is included in development planning processes, the success of watershed development may itself be at risk from climate change. A systematic consideration of observed and expected changes in climate parameters through climate proofing can contribute to optimising watershed development to take account of climate change.

Climate proofing India's Watershed Development Fund

The National Bank for Agriculture and Rural Development (NABARD) initiated the Watershed Development Fund (WDF) in 2001. The Watershed Development Fund is replenished annually and is set to continue for many years to come. This fund has been set up to cover an area of 1.42 million hectares of land. Main activities include drainage line treatment, water harvesting structures, and livelihood interventions. NABARD and GIZ are starting a process of climate proofing the Watershed Development Fund. Climate proofing should ensure that the activities supported through Watershed Development Fund continue to be appropriate and sustainable, taking into account our changing climate. The exercise of climate proofing could identify possible modifications or additional Watershed Development Fund activities to further increase the adaptive capacities of people living in watershed areas. As many known and well-proven watershed management measures are already in place in India, it is necessary to first look at the existing measures and activities and evaluates their adaptation potential.

Agricultural water management

In addition to the first chapter of this publication, the following paragraphs describe and evaluate water management techniques associated with agricultural production systems. Agricultural water management is not exclusively concerned with irrigation, but encompasses diverse approaches to increase the effectiveness and efficiency of water management for rain-fed agriculture irrigation. As per the report by Narayanamoorthy (2006) India has net irrigated area of 54 million hectares, and it is the largest area of irrigated land in the world. The extraordinary importance of irrigation for Indian agriculture is bound to increase in the future: due to increasing rainfall variability in the wake of climate change, the demand for irrigation as a means of risk minimisation in agriculture will rise. At the same time, however, water scarcity in many parts of the Indian subcontinent will become more pronounced and competition between the water using sectors will intensify. According to Net Indian News Network (2010) the main reason for this is the fact that demand for food grains will continue to rise. The most prevalent form of irrigation in India is groundwater irrigation. Already 70 % of Indian crop production is dependent on groundwater irrigation. According to Bhaduri et al. (2005) expanding the irrigation potential through groundwater irrigation is often a priority based on the assumption that it not only reduces the variation in supply and is more reliable, but also provides the flexibility to cope with unforeseen water shortages. This reduces the risks for farmers in purchasing farm inputs and therefore often leads to higher agricultural productivity.

The dependence on groundwater irrigation will further increase with the impacts of climate change, especially in those areas already affected by low and irregular rainfall. Because withdrawal of groundwater often exceeds recharge, if the groundwater resource is not managed well, depletion of groundwater and degradation will pose a serious threat to farmers and the environment. Options for adaptation to climate change and improving sustainability include improved management and governance of large irrigation systems by focusing on demand management rather than supply management. This includes improving water use efficiency and helping to reduce water losses. In addition, alternatives to groundwater irrigation, such as water harvesting and the use of marginal water must be provided. The easy access to and availability of water for irrigation often leads to higher consumption levels than actually needed by farmers. The inefficiency and lack of water pricing structures that reflect the actual price of water hardly provides any incentive for farmers to conserve their water resources. Improved water use efficiency can be achieved by: technical modernisation of the design and operation of new or rehabilitated irrigation systems; improved on-farm water management, including water-saving technology especially drip irrigation; volumetric water prices as an incentive to save water; cropping patterns, plant breeding and crop-growing practices that are suited to water availability and soil conditions; agricultural research that focuses on water saving, in connection with traditional crops, improved crop-growing practices and increased use of salt-tolerant plants.

The boom in groundwater use in India and its consequences

As per the report by Narayanamoorthy (2006) the use of groundwater for irrigation, as opposed to canals or tanks, has increased from 29 % in 1950/51 to 62 % in 2002/03. As per the report by Bhaduri et al. (2005) the so-called groundwater boom is mainly attributed to the absence of large-scale surface irrigation schemes and the availability of low cost electric and diesel pumps in combination with low or no charges for electricity. The consequences of this boom in groundwater use are dramatic: the very intensive use of groundwater, combined with low and irregular rainfall, has led to groundwater withdrawal exceeding recharge. While water resource depletion and degradation is a serious threat in India and South Asia, leading to major environmental consequences, the economic consequences for farmers will be equally serious.

Water Harvesting

One of the major options for increasing the availability of water lies in the expansion of water storage facilities to balance out the discrepancies between periods of peak supply and peak demand. However, such strategies need to take a new and broader view of water storage. Apart from the 'large dam option' – which, with its high economic, social and environmental costs, will come under more severe scrutiny in the future – the whole gamut of water storage options needs to be explored and better utilised. These options range from improved agricultural practices to enhanced water retention in the soil, small water storage tanks and other means of water harvesting, and reconstruction and rehabilitation of traditional tanks that were in use in India for centuries, through to new ways of management of ensembles of small, multi-purpose reservoirs and the construction and improved operation of large dams and reservoirs.

Use of Marginal Water

In countries suffering from water scarcity, the use of marginal water is common in agriculture, posing great risks to human health for farmers and consumers. However, this approach may offer a viable option for optimising the use of limited water resources, when handled in a proper manner. Marginal-quality water can be broken down into the following categories: urban wastewater domestic wastewater from commercial and industrial effluent and wastewater from commercial establishments; agricultural drainage water surface runoff and deep percolation, often containing salts, agricultural chemicals and nutrients and saline or sodic surface water and groundwater the reactions of water moving through the soil profile.

Because marginal water contains various pollutants, use of wastewater needs to be carefully managed. Both the quality management of water according to the technical, economic and social possibilities and the sustainable use of marginal-quality water need to be documented and experiences shared among water professionals and practitioners. To improve the quality of marginal water can be done by the ways of leaching and drainage to balance salt in the soil profile; blending saline and sodic waters with freshwater and establishing property rights for wastewater and creating economic incentives.

Optimization and Planning for Multi-Purpose Dam Development

During recent decades, there has been a debate over whether large-scale infrastructure projects, such as dams, are inflexible approaches to water management, with the costs direct and indirect in some cases outweighing the benefits. This has certainly been the case in some instances. Under changing climate conditions, the variability of water flow in the future will make maintaining electricity supply a more complex job for hydro planners, institutions and engineers. Adaptation to climate change, especially in monsoon regions of the Indian sub-continent, will also require more effective measures to deal with droughts and floods. Although today far greater attention is being given to other storage options such as natural wetlands, small tanks, groundwater aquifers and enhanced soil moisture, large dams could nevertheless be beneficial if used in a more flexible and multi-purpose way.

Appropriate reservoir management techniques could contribute to an efficient linkage between energy and water supply, food security, poverty alleviation, and climate change adaptation. Adopting standards for evaluating the sustainability of hydropower projects under different climate change scenarios is stipulated as an important criterion for decision-making in hydropower governance.

Multi-purpose planning can also be applied to existing dams. The rehabilitation of existing dams is a crucial first step to sustainable water management in the context of climate change. Inadequate infrastructure can lead to major risks of water waste, thus exacerbating water stress and increasing the risks of major accidents. There are three general improvement options: They are upgrading and rehabilitating facilities associated with the dam; optimising operation of reservoirs, by managing daily and seasonal water levels and release patterns for single or multi-purpose uses and optimising the role of the dam within the larger system it services, by introducing new water uses. apacity building for adaptation in water resources management

Adapting water management to climate change will require building capacity of people and institutions, by training engineers, hydrologists, planners and many other professionals. Strengthening the ability of people to manage their water resources more efficiently and equitably is vital. This can be achieved by integrating climate change adaptation into watershed management planning processes. Making resources available for strengthening both institutional and individual capacities is a critical early step in adapting to climate change.

GTZ (2008) note that viable options for capacity building and they are: identifying priority adaptation measures and institutional responsibilities for implementing them in a participatory process; identifying alternative crops that are better adapted to expected future climate conditions; designing water-saving irrigation schemes; organising exhibitions to raise public awareness of expected changes in climate; introducing climate change into the curriculum for all school levels and integrating knowledge of expected hydrologic impacts of climate change into watershed management.

Conclusion

It could be seen clearly from the above discussion that the climate change has serious impact on water resources. Climate change alters the rainfall pattern, temperature, precipitation level, transpiration, humidity, wind velocity and water flow in the water bodies. Climate change impact on water resource has alarming impact on Indian irrigation system. Adaptation of climate change impact on water resources is very important to sustain the cropping system, drinking water need, and water for other uses. Many climate change adaptation options are available and adoption of such adaptation options depends on government policies and programmes. The government of India has developed a large number of climate change adaptation options in water resources and implementation of such climate change adaptation options depends on participation of people, farm households and other stakeholders of water resources. The government should motivate the farmers towards practicing water resource adaptation options in the context of climate change. The government should give incentives and subsidies to the farm households towards cultivating the crops by the way of following appropriate water resource adaptation practices in the context of climate change. The water resource adaptation practices should be disseminated among the people in general and farm households in particular through conducting awareness campaign and awareness generation programmes.

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