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GN Gurjar
School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Sanjay Swami
School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Correspondence
GN Gurjar
School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Climate change and adaptive water management: innovative solution

GN Gurjar and Sanjay Swami

Abstract
Water is the unique source for the survival of life form. Climate change is brings a huge change in the water utilization in different sectors by increasing in the demand and reducing in the availability. The reduction in availability directly related to extreme events of monsoon such as drought, floods etc. Water management is the most important strategy for sustainable use of water resources. India is has 4 percent of total global water resource and its total geographical area is 2.4 percent of the worlds land area. Climate change is the most important issue now a days because it has significantly negative impacts on natural resource and agricultural crop production. Climate change is reducing the productivity and production of many agricultural crops. So, what we need is the sustainable utilization of water resource to complete the food demand by using new water utilization techniques because water is the most limiting and most vulnerable system to climate change.

Keywords: Climate change, crop production, water resources

Introduction
Climate change is one of the most pressing threats to sustainable development across the globe. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) [11] notes that 93% of the impacts associated with climate change will be felt in the water sector. Climate change is already altering precipitation patterns and snowmelt, impacting the frequency and magnitude of floods and droughts, and contributing to more extreme weather events and wildfires globally. Availability of renewable surface and groundwater resources is likely to decrease significantly in most arid and semi-arid subtropical regions, exacerbating competition for water between agriculture, ecosystems, industry and settlements (IPCC, 2014) [11]. Climate change is projected to lower raw and drinking water quality, due to interacting factors including increased sediment and pollutant loads due to heavy rainfall and breakdown of water treatment infrastructure during floods and extreme weather events, with flood hazards projected to increase across half the globe (IPCC, 2014) [11]. The populations of developing countries, primarily in the global South, are particularly vulnerable to the impacts of climate change on water availability due to high levels of exposure to water-related risks, limited coping capacity, and limited ability to recover from loss, often arising from non-climatic factors. The impacts of climate change are exacerbated by rapid population growth, rapid urbanization and chaotic economic development, particularly where water demands already exceed limited supplies. Climate change impacts destabilize development by aff ecting food security, health, infrastructure development and sustainable economic growth in developing countries. Simply put, climate change is not only a critical environmental concern but arguably the most urgent development challenge for the global South. Moreover, the voices of developing-country scientists – best placed to conduct research and present feasible local adaptation plans – are often silent in international public debate. The International Development Research Centre is a Canadian crown corporation, established by an act of parliament in 1970 with a mandate 'to initiate, encourage, support, and conduct research into the problems of the developing regions of the world and into the means for applying and adapting scientific, technical, and other knowledge to the economic and social advancement of those regions' (IDRC, 1970) [9]. This special issue of water international represents a sample of IDRC-supported projects on water and climate change adaptation, implemented by researchers based in developing countries, and initiated as early as 2008.

Measuring adaptive capacity under changing water availability
As the Fifth Assessment Report of the IPCC explains, the impacts of climate change on water

availability and quality vary across the world regions. Research needs to address these impacts at scales that inform and enable appropriate adaptive policies, across all sectors, and in particular, in planning and decision-making on water use and allocation. Similarly, improved methods of measuring the vulnerability and adaptive capacity of affected households and communities are needed to support targeted policies and judicious allocation of limited financial, human and natural resources. Discussions of vulnerability have typically underestimated the importance of underlying drivers associated with gender, poverty and socio-political exclusion (Adger, 2006; Hewitt, 1983) [1, 9]. Traditional assessments of exposure and vulnerability to water-related disasters (e.g. flooding, drought and landslides) also fail to take into account future scenarios informed by climate science. Understanding how existing forms of vulnerability may be compounded by climate change under different scenarios is critical to assess what forms of adaptation are most suitable to reduce risks and improve local adaptive capacity. A number of articles in this special issue combine vulnerability analysis and climate modelling to develop targeted policy recommendations. Five consider how decision-making on water management and allocation by various formal and informal institutions influence the vulnerability and adaptive capacity of households and communities to climate-related water insecurity in the short and long run. In many regions, climate change is causing sea-level rise in coastal zones, leading to saline water intrusion in many coastal aquifers, while at the same time changing precipitation patterns are causing water shortages and increased groundwater abstraction, aggravating the intrusion. The difficulty of downscaling climate change impacts and modelling coastal aquifer hydrodynamics as well as future water demand under various development scenarios makes it particularly difficult for coastal aquifer managers to predict and quantify saline water intrusion rates in a context-specific manner.

Safi *et al* (2018) [19] apply simulated sea-level rise under various near-future (2012–2032) climate and water abstraction scenarios, with a multi-objective 3D variable-density flow and soluble transport model. They consider various climatic and non-climatic causes of saline intrusion in the urban coastal aquifer that supplies water to Beirut, Lebanon, to inform adaptation strategies for sustainable aquifer management. A key contribution of the article is its discussion of alternative scenarios that may arise if the following adaptation strategies are adopted to guard against saltwater intrusion in Beirut's aquifer:

1. Water conservation practices to prevent network losses;
2. The injection of treated wastewater for aquifer recharge;
3. The importing of water from inland areas or the use of desalinized seawater, requiring construction of large infrastructure projects; and
4. Water demand and consumption management using smart metering and/or tariff restructuring.

The analysis indicates that sea-level rise due to climate change will likely have a lower impact on the salinity of the aquifer than anthropogenic abstraction, and hence, the authors advocate adaptation strategies that focus on reducing groundwater dependence. They note that even in the ideal case where all groundwater abstraction ceases, aquifer recharge with freshwater will take several decades to reduce the salinity. This study points to the importance of considering the interactions between various drivers of saline intrusion so that context-appropriate adaptation strategies may be implemented. These strategies also need to include a groundwater monitoring programme to assess their effectiveness. In addition to downscaling and quantifying the impacts of climate change in specific contexts, it is essential to understand the vulnerability of households and communities to these impacts and their adaptive capacity to cope with them. Households vary in their exposure to (and therefore risk from) climate–water hazards. Sujakhu, Ranjitkar, Niraula, Salim, Nizami, & Schmidt-Vogt (2018) [20] apply a composite livelihood vulnerability index developed by Hahn, Riederer, and Foster (2009) [8] and Islam, Sallu, Hubacek, & Paavola (2014) [12] to investigate the determinants of vulnerability among farming households in the Asian highlands, which form part of the Hindu Kush Himalayas in Pakistan and Nepal. Farming communities in the Asian highlands face water hazards such as changing rain and snowfall, flash floods, soil erosion, mudflows and landslides. The authors argue that to implement policies that build households' adaptive capacity at the local level, policy-makers need to understand how access to various forms of capital, sensitivity and adaptive capacity shape households' vulnerability. They find that education of the household head, the household's diversification of income sources away from agriculture, dependence on irrigation and technology for cultivation, and degree of influence on decision-making at the local level all affect its vulnerability to water hazards. Thus, this study not only reveals the various forms of capital essential at the household level in the Asian highlands, but also discusses how interlinkages between these forms of capital might produce vulnerability on the ground. For example, in order for a household to build adaptive capacity by diversifying its income sources beyond agriculture and adopting new forms of technology for farming, it needs skills and education (human capital), as well as land and livestock (natural capital).

Nguimalet (2018) [18] presents a community-level perspective of adaptation to changing precipitation patterns in two watersheds impacted by climate change in the Central African Republic and Kenya. Using a mixed-methods approach combining analysis of historical and contemporary precipitation data with surveys of affected communities' autonomous adaptation strategies, this study discusses how autonomous adaptation strategies have evolved over time in response to increasing spatiotemporal variability of precipitation and river flows, and the availability of resources in these under-studied contexts. Kenya and the Central African Republic have suffered prolonged and recurrent droughts in the past. He finds that the study communities' adaptation strategies are largely reactionary, in part due to the absence of investments in forecasting and prediction tools or in capacity-building for disaster preparedness by the governments or the international donor community. In a context of weak institutional capacity, communities are left to cope on their own. This article recommends concerted efforts by national governments and international actors to build institutional capacity for decentralized decision-making and disaster risk reduction in both Kenya and the Central African Republic. The vulnerability of many urban communities to climate impacts is also exacerbated by poor water quality and quantity, and weak or absent institutions that fail to provide and regulate adequate water supply and sanitation. Rapid urban population growth in Asia, the Middle East, and North

and Sub-Saharan Africa is outpacing the ability of governments to extend the existing piped water infrastructure (where it exists) to all residents. Residents who do not have access to the formal piped network, particularly those living in informal settlements, rely on a variety of alternative sources, such as informal private water suppliers or unlicensed private bore wells, to meet their water needs (Alameddine *et al*., 2018) [2], leading to unsustainable practices at larger scales if not properly regulated or managed. Therefore, working with informal water providers and/or households that rely on private water sources to improve and guarantee water availability for all will be an important adaptation challenge for governments in these developing contexts. Cain's commentary in this issue presents a participatory action research study conducted by Development Workshop with low-income communities and their informal water providers in the peri-urban musseques (slums) of Luanda, Angola, one of Africa's fast-growing megacities.

In contrast to the government's view of the informal water suppliers as exploiters of the poor, Development Workshop's research reveals that the informal water sector fills a large gap in the public utility's supply– it serves nearly a third of Luanda's residents. However, the informal water supply is expensive relative to the public utility and is often untreated, increasing health hazards. Development Workshop argues that the formal utility should work with, and regulate, the informal, community-based providers until the utility can supply all residents. They find that community-based water management committees and associations are an effective transitional solution that can help residents access water, collect payments, maintain standpipes, and ensure that the water providers remain accountable to citizens. In a second study focusing on Beirut, Lebanon, Alameddine *et al*. (2018) [2] examine the costs to and impacts on households of saltwater intrusion, in addition to the costs to utility suppliers. Salinization of groundwater increases economic burden at the household level, including the cost of purchasing freshwater, degradation and damage of household appliances, and in some cases, the installation of desalination units. The authors develop a model to quantify the economic burdens due to seawater intrusion and measure households' willingness to participate, and to pay for a government programme to tackle groundwater salinity. They find that nearly two-thirds of the surveyed households were willing to participate in and pay for a government instituted or building-level plan to manage the salinity of water, if it ensured adequate good water supply. In addition to making a case for building-level and city-wide interventions for desalination, their study also highlights the importance of regulating excessive groundwater extraction through water demand management, to avoid falling into the trap of further salinizing groundwater, a process accelerated by climate change–induced sea-level rise. These studies note the importance of water demand management through formal or informal institutions, regulations, community capacity-building, and other approaches to adapt to the impacts of climate change.

Innovative approaches to adaptive water management

Water supply or demand management under climate change involves decision-making under high levels of uncertainty regarding projected impacts. To avoid risk-averse decisions that might prove inefficient and costly, such as large-scale infrastructural investments, Vicuna *et al* (2018) [22] propose and evaluate 'water option contracts' as a flexible adaptation measure. Option contracts are risk sharing instruments that allow less vulnerable water consumers to trade their water rights with more vulnerable consumers during extreme events. They can help avoid complex, ex ante decisions on expensive infrastructure, or large-scale regulatory reform in the water sector. However, their success depends on their cost-effectiveness, and the availability of a clearly defined water rights regime that allows trading of water rights between different user groups. The authors recommend and test the triggering conditions for two types of option contracts as adaptation measures in the case of the Maipo basin in Santiago de Chile. They conclude that option contracts could reduce transaction costs between various users and improve water management practices in the basin. Lebel, Lebel, Chitmanat, Uppanunchai, and Apirumanekul (2018) [14] address the issue of decision-making under climate, fish and water-demand-related uncertainties in Northern Thailand's aquaculture industry. They argue that fish farmers adopt a range of short-term or long-term adaptation strategies, depending on the type of aquaculture, for decision-making. But the relative costs and benefits of each of these measures remain unknown in the face of climate change, variable fish demand, and growing water demand from other sectors. They use a rule-based assessment model to evaluate the robustness of various adaptation strategies for aquaculture under different climate risk and water-demand scenarios at multiple spatial and temporal scales. Here, a robust strategy is one that performs satisfactorily, if not ideally, and increases net profits for aquaculture under a range of scenarios.

The author find that while short- and medium term adaptation strategies are important, long-term adaptation poses several challenges depending on the timing of investments and the actual onset and duration of the impacts. They find that adaptation in the sector needs to be diverse enough to cater to different aquaculture systems and flexible enough to change with time by incorporating new knowledge and technologies. The study raises important questions regarding changes in policy culture, institutions and knowledge creation that need to occur for those robust adaptation decisions to be made. Lele, Srinivasan, Thomas, and Jamwal (2018) [15] argue that while climate change is an important stressor affecting water availability, other stressors such as rapid urbanization, migration and land-use change also affect water demand, though their impacts are largely ignored in many adaptive water management plans. They also argue that the normative focus of adaptive water management should include not only the goals of adaptation and resilience but also important general developmental goals such as adequacy, sustainability, justice and democratic governance. According to Lele *et al*., acknowledging a multiplicity of goals helps to analyze the synergies and trade-offs between these goals while designing responses, just as the study by Lebel *et al*. (2018) [14] demonstrates in the case of Northern Thailand's aquaculture industry. They note that the literature gives primacy to the city as the spatial unit of analysis and assumes climate change to be the main stressor, even as cities continue to source water from and dispose wastewater in distant areas, outside the city. In this article, they propose and apply a multiple-stressors, multiple-concerns, multi-scalar approach to analyse the impacts of climate change on two rapidly urbanizing sub-basins within the Cauvery River basin in southern India in the context of other dynamic changes underway in the basins. Based on observations of practice at the household, city and

watershed levels, the authors argue for a relational, linked sectors and scales approach to policies and infrastructural interventions for water allocation, distribution and management under a changing climate so that adaptations at one scale, or in one sector, do not result in maladaptation's in another domain.

Although the mechanisms that enable us to acknowledge and act on this complex, interlinked approach to climate impacts and adaptation are beyond the scope of this article, the approach nevertheless calls for a radical reorganization of institutions and their interrelationships through organizational learning and capacity-building, funding for research and development, improved research, and its dissemination for public education. The final study, by Vatta *et al*. (2018) [21], presents a simple, low-cost technological solution that can be easily implemented at the individual farm level to improve water management in a context where regulations impacting agricultural water use are slow and costly to change, as in the case of Indian Punjab. To prevent farmers from over extracting dangerously low levels of groundwater, the authors test the impacts of using a low-cost soil-moisture-sensing tensiometer on groundwater and electricity consumption for irrigation, and subsequent crop yields. They find that the tensiometer saves over a tenth of the water and electricity used for irrigation, with no reduction in crop yield. Scaled up, the tensiometer could reduce the overexploitation of groundwater and the concomitant energy used to pump groundwater in Indian Punjab. However, for widespread adoption of tensiometers, the authors find that farmers need to be aware of the pitfalls of the over-extraction of groundwater and the possible benefits of water saving technologies. Thus, this article shows that technological solutions need to be complemented with institutional and regulatory changes that raise awareness and change the incentive structures for farmers to encourage water-saving behaviour.

Conclusion

Water is the most important natural resource occupied all over the land of 97 percent of the total land area. The sustainable use of water can stabilize the crop production under climate change which is most important for countries "Food Security". The future research should be based on the sustainable utilization of water resource by developing water efficient research techniques and such techniques must be suitable under climate change. Human population must be feed which is possible by producing enough food for them and it is possible by water only. Because of unsustainable use of natural resource and over exploitation of water resource causes destruction for human being. Around the global level 16 M peoples are not even getting food one time.

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