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CLIMATE CHANGE AND CHALLENGES OF WATER AND FOOD SECURITY

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ABSTRACT

Climate change is one of the most complex problems being faced by mankind today. Water and food security are the key challenges under climate change as both of these are highly vulnerable to continuously changing climatic patterns. Various studies have indicated that the average global temperature may increase by 1.4–5.8°C and there would be substantial reduction in fresh water resources and agricultural yield by the end of the 21st century. Though climate change poses a variety of challenges, the present paper focuses only on agriculture and food security and water stress and water insecurity which have immense relevance from the perspective of developing countries in general and India in particular.

INTRODUCTION

Climate change has already caused significant impacts on water resources, food security, hydropower, human health to the whole world (Magadza, 2000). Studies on climate impacts and adaptation strategies are increasingly becoming major areas of scientific concern, e.g. impacts on the production of crops such as maize, wheat and rice (Howden and Leary, 1997; Aggarwal et. Al, 2006) and water resources in the river basin catchments (Wilby, 2005, Wilby et. al., 2006). Climate change has resulted in increases in globally-averaged mean annual air temperature and variations in regional precipitation and these changes are expected to continue and intensify further in the future (Solomon et al., 2007).

IPCC report (2008) predicts that the climate change over the next century will affect rainfall pattern, river flows and sea levels all over the world. Studies show that agriculture yield will likely be severely affected over the next hundred years due to unprecedented rates of changes in the climate system (Jarvis et al., 2010; Thornton et al., 2011). In arid and semi-arid areas the expected precipitation decreases over the next century would be 20% or more. The accelerated increase in the greenhouse gases (GHG) concentration in the atmosphere is a major cause for climate change. The global mean temperature has increased by 0.74°C during the last 100 years. Further more studies conducted by Indian Space Research Organization (ISRO) after the study of 2190 Himalayan glaciers revealed that approximately 75% of the Himalayan glaciers are on the retreat, with the average shrinkage of 3.75 km during the last 15 years (Misra, 2013). These findings raise serious concerns over the accelerated retreat of glaciers in the Himalayan Mountains because it will increase the variability of water flows to downstream regions and threaten the sustainable water use planning in the world's most populous Ganga Basin.

To minimize the impact of climate change on water resources it is necessary to understand and evaluate the vulnerability of water resources to global warming impacts. It is known that water resources play a vital role in human prosperity and crop productivity. The world's agriculture, hydroelectric power and water supplies depend on different components of the hydrological cycle, including the natural replenishment of surface and groundwater resources (ACE, 2002). Water availability issues include how much water can be diverted, when the water can be available and how much water can be stored in surface and ground-water reservoirs. Assessment of seasonal and long-term water availability is not only important for sustaining human life, biodiversity and the environment, but also helpful for water authorities and farmers to determine agricultural water management and water allocation. Climate change is one of the greatest pressures on the hydrological cycle along with population growth, pollution, land use changes and other factors (Aerts and Droogers, 2004).

This paper reviews current knowledge about the relationships between climate change, water and food security. The manuscript also suggests a road map for long-term and near-term strategy for minimizing the impact of climate change on water resources and agriculture.

CLIMATEPROJECTIONS OVER INDIA

Chaturvedi et al. (2012) studied the future climate scenarios over India and the key findings of this study were: (1) under the business-as- usual (between RCP6 and RCP8.5) scenario, mean warming in India is likely to be in the range 1.7–2°C by 2030s and 3.3–4.8°C by 2080s relative to pre-industrial times; (2) all-India precipitation under the business-as-usual scenario is projected to increase from 4 to 5% by 2030s and from 6 to 14% towards the end of the century (2080s) compared to the 1961–1990 baseline; (3) while precipitation projections are generally less reliable than temperature projections, model agreement in precipitation projections increases from RCP2.6 to RCP8.5, and from short-to long-term projections, indicating that long-term precipitation projections are generally more robust than their short-term counterparts, and (4) there is a consistent positive trend in frequency of extreme precipitation days (e.g. >40 mm/day) for decades 2060s and beyond.

Sharmila et al (2015) made the assessment of Future climate scenarios of Indian Summer Monsoon rainfall. Substantial changes are projected in the daily-to-inter annual variability of Indian summer monsoon under RCP8.5 scenario. Heavy rainfall events might increase, while number of wet days might decrease in future. Active/break spells will be more intense and regionally extended in future climate. Severity and frequency of both the strong (SM) and weak (WM) monsoons might increase in future climate.SM (WM) could be more wet (dry) in future due to the lengthening of active (break) spells.

Bal et al (2016) down scaled the future scenarios for the whole India. The projections of maximum temperature from all the six models showed an increase within the range 2.5°C to 4.4°C by end of the century with respect to the present day climate simulations. The annual rainfall projections from all the six models indicated a general increase in rainfall being within the range 15-24%.

WATER RESOURCES CONCERNS

Water availability is under threat from changing climate because of possible precipitation decrease in some regions of the world. In the light of the uncertainties of climate variability, water demand and socio-economic environmental effects, it is urgent to take some measures to use the limited water efficiently and develop some new water resources (ACE, 2002). If the water resources are replenished by snow accumulation and the snowmelt process, the water system will be more vulnerable to climate changes (Dracup and Vicuna, 2006).

The water requirement in India by 2050 will be in the order of 1450 km3, which is significantly higher than the estimated water resources of 1122 km^3per year. Therefore to meet the shortfall requirement, it is necessary to harness additional 950 km3 per year over the present availability of 500 km^3 per year (Gupta and Deshpande, 2004). A decrease in water storage coupled with increased evaporation would further widen the gap between water supply and water demand. In addition to increased agricultural demand for water, water availability is further exacerbated due to escalating urban, industrial, and environmental demands for water coupled with poor water management.

Irrigated agriculture is placing increasing pressure on finite freshwater resources, especially in developing countries, where water extraction is often unregulated, un-priced and even subsidized. Globally, about 40% of irrigation water is supplied from groundwater, and India is the world's largest user (Aeschbach-Hertig and Gleeson 2012). The common-pool nature of groundwater and the difficulty of observing it directly make this resource difficult to monitor and regulate, especially in developing countries, (Mukherjee and Shah 2005). Perhaps as a result, groundwater resources in many parts of the world are being depleted because of unsustainable extraction levels that exceed natural recharge rates (Wada *et al*2010, Aeschbach-Hertig and Gleeson 2012). In India, groundwater irrigation covers more than half of the total irrigated area, is responsible for 70% of production and supports some 50% of the population (World Bank 1998, Shah 2010). However, it is now becoming clear that over-extraction of groundwater is depleting aquifers across the country, and water table declines are pervasive (Tiwari *et al*2009, Shah 2009). Despite growing scarcity, groundwater irrigation in India remains highly inefficient from a technical point of view. For example, India's third Minor Irrigation Census has shown that in 2001, only 3% of India's some 8.5 million tube-well owners used drip or sprinkler irrigation and 88% delivered water to their crops by flooding through open channels.

FOOD SECURITY CONCERNS

Food security is defined as a 'situation when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 2002). Global food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment (Lal, 2005). According to the Food and Agriculture Organization (2016); both biophysical and social vulnerabilities determine the net impact of climate change on food security.

Climate Change is projected to have significant impacts on conditions affecting agriculture, including temperature, precipitation and glacial run off. It affects agriculture in more ways than one. It can affect crop yield as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. The key characteristics of Indian agriculture that could influence/increase its vulnerability to climate change are **(i)** the high level of subsistence agriculture with small land holdings **(ii)** majority of agriculture is rain-fed **(iii)** frequent occurrence of extreme weather events such as droughts and cyclones, and **(iv)** the wide variation in agricultural productivity across the country.

Smart agriculture also addresses the interlinked challenges of food security and climate change and benefit smallholder farmers by increasing efficiency of inputs such as labor, seeds and fertilizers, increasing food security. By protecting ecosystems and landscapes, smart agriculture practice helps protect natural resources for future generations. What makes climate-smart agriculture all the more important are occurrences of climatic variability, making farming more vulnerable to the vagaries of nature. Climate-smart agriculture assumes even greater significance given its link to food security. According to a World Bank-commissioned study in 2013, total crop production in India is expected to rise 60% by the 2050s without climate change, but in the event of a temperature increase of 2° Celsius since the industrial revolution, the increase will only be 12%. Moreover, it will have to import twice the amount of food grains than in a scenario without climate change.

IMPACTSON INDIAN AGRICULTURE

Agriculture is the mainstay of Indian economy and provides food and livelihood security to a substantial section of the Indian population. The impact of climate change as witnessed in recent times has immense potential to adversely affect agriculture in this country in a variety of ways. As a large part of the arable land in India is rain-fed, the productivity of agriculture depends on the rainfall and its pattern. Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall but also by shifts in the timing of the rainfall. Any change in rainfall patterns poses a serious threat to agriculture, and therefore to the economy and food security. Summer rainfall accounts for almost 70 per cent of the total annual rainfall over India and is crucial to Indian agriculture. However, studies predict decline in summer rainfall by the 2050s.29 Semi-arid regions of western India are expected to receive higher than normal rainfall as temperatures soar, while central. India will experience a decrease of between 10 and 20 per cent in winter rainfall by the 2050s. 30 Relatively small climate changes can cause large water resources problems particularly in arid and semi-arid regions such as northwest India. Productivity of most crops may decrease due to increase in temperature and decrease in water availability, especially in Indo-Gangetic plains. This apart, there would be a decline in the productivity of rabi as compared to kharif season crops. Rising temperature would increase fertilizer requirement for the same production targets and result in higher GHG emissions, ammonia volatilization and cost of crop production. Increased frequencies of droughts, floods, storms and cyclones are likely to increase agricultural production variability. Therefore, we have to place equal emphasis on saving lives and sustaining livelihoods.

CONCLUSIONS

A number of adaptation options in agriculture face a dilemma. Increasing water availability and increasing the reliability of water in agriculture, i.e. through irrigation, is one of the preferred options to increase productivity and contribute to poverty reduction. However, as a result of the predicted climate change, semi-arid and sub-humid tropical areas that would greatly benefit from increased irrigation may see water availability changing temporally and spatially and rainfall not only declining, but also being more erratic and unfavourably distributed over the growing season, so that irrigation in the long term might not be a viable option.

In addition, the interrelations between adaptation and mitigation need to be carefully considered (Bates et al., 2008). At best, adaptation and mitigation strategies exhibit synergies.

Policy attention is needed in the following areas:

- Developing long-term water policies and related strategies, taking into account country-specific legal, institutional, economic, social, physical and environmental conditions (FAO, 2008c). Policies and strategies will also need to integrate the different sectors depending on water – rainfed and irrigated agriculture, livestock, fisheries, forestry, nature and biodiversity protection, manufacturing and industry, and municipal water use. Water policies need to address such issues as upstream-downstream competition over water resources and equitable allocation of water across regions and generations;
- An early warning system should be put in place to monitor changes in pest and disease profiles and predict new pest and disease outbreaks. The overall pest control strategy should be based on Integrated Pest Management because it takes care of multiple pests in a given climatic scenario.
- The agriculture credit and insurance systems must be made more comprehensive and responsive to the needs of small farmers.
- Increasing water productivity by promoting efficient irrigation and drainage systems;
- Improved watershed and resource management, integrating the different natural resources – water, soil, flora and fauna – through, for example, the promotion of Integrated Water Resources Management (IWRM) processes;
- Enhancing water availability through better use of groundwater storage, enhancing groundwater recharge where feasible, and increasing surface water storage.
- Institutional and governance reforms that balance demand and supply across sectors and that mainstream climate change adaptation;
- Enhancing stakeholder participation in water development and climate change adaptation;
- Improve information and early warning systems to provide land and water users with timely and adequate information and knowledge about availability and suitability of resources to promote sustainable agriculture and prevent further environmental degradation. Information exchange and dialogue between the agriculture, water and climate communities is vital (FAO, 2008), not only at national levels but also at trans-boundary river basin level;
- Human resource, capacity and skills development of policy makers and end-users to help them deal with new challenges;
- Increase investments in agriculture and rural development.

REFERENCES

1. *ACE (Atmosphere, Climate and Environment). (2002). Climate change fact sheet series for key stage 4 and A-level, Buchdahl, p. 1–171.*
2. *Aerts, J., and Droogers, P. (2004). "Climate change in contrasting river basins:adaptation strategies for water, food, and environment." The Netherlands:CABI Publishing, p. 1–264.*
3. *Aeschbach-Hertig, W., and Gleeson, T.(2012)."Regional strategies for the accelerating global problem of groundwater depletion." Nat. GeoSci, 5 853–61.*
4. *Aggarwal, P. K., Kalra, N., and Chander, S. et al. (2006). "InfoCrop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. I. Model description."AgricSyst, 89:1–25.*
5. *Bal, P. K., Ramachandran, A., Palanivelu, K., Thirumurugan, P.,Geetha, R., and Bhaskaran, B. (2016)."Climate change projections over India by a downscaling approach using PRECIS." Asia Pacific Journal of Atmospheric Sciences,August 2016, Volume 52, Issue 4, pp 353–369*
6. *Bates, B.C., Kundzewicz, Z.W., Wu, S., and Palutikof, J.P. (eds) (2008)."Climate Change and Water." Technical Paper of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat.*
7. *Chaturvedi, R.K., Joshi, J., Jayaraman, M., Bala, G., and Ravindranath, N.H. (2012)."Multi-model climate change projections for India under representative concentration pathways."CURRENT SCIENCE, VOL. 103, NO. 7, 10 OCTOBER 2012*
8. *Dracup, J. A., Vicuna, S. (2005). "An overview of hydrology and water resources studies on climate*

change: the California experience." CopyrightASCE,1–12.

9. FAO. (2002)."The State of Food Insecurity in the World 2001. Rome" FAO.

10. FAO. (2008)."Water for Agriculture in Africa: Resources and Challenges in the Context of Climate Change." Ministerial Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change. December. Sirte, Libyan Arab Jamahiriya.

11. FAO. (2016) "Climate change and food security: risks and responses", Food and Agriculture Organisation, 2016.http://www.fao.org/3/a-i5188e.pdf

12. Gupta, S.K., Deshpande, R.D. (2004). "Water for India in 2050: first-order assessment of available options." Rev. Pap. Curr. Sci. 86 (9), 1216–1224.

13. Howden, S. M. O., and Leary, G. J. (1997). "Evaluating options to reduce greenhouse gas emissions from an Australian temperate wheat cropping system." Environ Modell Software, 12:169–76.

14. IPCC. (2008). "Climate change and water, Intergovernmental panel on climate change technical report IV." June 2008.

15. Jarvis, A., Ramirez, J., Anderson, B., Leibing, C., and Aggarwal, P. (2010). "Scenarios of climate change within the context of agriculture." In: Climate Change and Crop Production. CAB International.

16. Lal, R. (2005). "Climate change, soil carbon dynamics, and global food security." In: Lal R, Stewart B, Uphoff N, et al., editors. Climate change and global food security. Boca Raton (FL): CRC Press, p. 113–43.

17. Magadza, C. H. D. (2000). "Climate change impacts and human settlements in Africa: prospects for adaptation." Environ Monit Assess, 61:193–205.

18. Misra, A. K.(2013). "Global climatic variations and its impact on Indian hydrological conditions." Int. J. Eng. Sci. Res. Technol, 2 (2), 148–158.

19. Mukherji, A., and Shah, T.(2005)."Groundwater socio-ecology and governance: a review of institutions and policies in selected countries" Hydrogeology J. 13 328–45

20. Shah, T.(2009)."Climate change and groundwater: India's opportunities for mitigation and adaptation Environ." Res. Lett. 4 035005

21. Shah, T.(2010)."Taming the anarchy: Groundwater Governance in South Asia (London: Routledge)"

22. Sharmila, S., Joseph, S., Sahai, A.K., Abhilash, S., and Chattopadhyay, R. (2015). "Future projection of Indian summer monsoon variability under climate change scenario: An assessment from CMIP5 climate models." Global and Planetary Change. Volume 124. January 2015, Pages 62–78.

23. Solomon,S., Qin, D., Manning, M., Chen, Z., Marquis, M., and Averyt, K., et al., (2007). "Climate Change 2007: The physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Inter-Governmental Panel on Climate Change." Cambridge University Press, Cambridge.

24. Thornton, P.K., Jones, P.G., Ericksen, P.J., and Challinor, A.J. (2011). "Agriculture and food systems in sub-Saharan Africa in a 4°C+ world Philos." Trans. R. Soc. A: Math. Phys. Eng. Sci. 369 (1934), 117–136.

25. Tiwari, V. M., Wahr, J., and Swenson, S.(2009)."Dwindling groundwater resources in Northern India, from satellite gravity observations"Geophys. Res. Lett, 36 L18401.

26. Wada, Y, van Beek, L. P. H., van Kempen, C. M., Reckman, J. W. T. M., Vasak, S., and Bierkens, M. F. P.(2010)."Global depletion of groundwater resources"Geophys. Res. Lett. 37 L20402.

27. Wilby, R. L. (2005). "Uncertainty in water resource model parameters used for climate change impact assessment."Hydrol Process, 19:3201–19.

28. Wilby, R. L., Whitehead, P. G., and Wade, A. J., et al. (2006). "Integrated modelling of climate change impacts on water resources and quality in a lowland catchment" River Kennet, UK. J Hydrol, 330:204–20.

29. World Bank (1998). "India—Water Resources Management Sector Review: Groundwater Regulation and Management Report World Development Sources," WDS 1998-3 (Washington, DC: World Bank)