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Economic Analysis of Interactions of Climate Change, Water Resources and Agricultural Production

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Abstract. Climate change refers to changes beyond the average atmospheric condition that are caused both by natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and by artificial factors such as the increase in concentration of greenhouse gases and aerosol. Climate change effects will impose significant additional stress on ecological and socioeconomic systems, but currently these systems are burdened by pollution, natural resource scarcities and other unsustainable practices. Technologically advanced countries are prepared well for responding to climate change, particularly by developing and establishing suitable, institutional and social policies capable for dealing with the consequences. But, the poor and developing countries are affected most by climate change, because they are not having enough and sound technologies or scientific development to deal with this impact. In developing countries like India, climate change is an additional burden because ecological and socioeconomic systems are already facing pressures from rapid population, industrialization and economic development. The average annual per capita availability of water in the country, taking into consideration the population of the country as per the 2001 census, was 1,816 cubic meters reduced to 1545 cubic meters as per the 2011 census. India is facing water stress due to limited availability of water growing demand of water due to increasing population, urbanization and industrialization. In addition, due to contamination of water sources and poor water treatment facility it is often difficult to get safe drinking water [Press Information Bureau, Government of India].

Keywords: adaptation, agriculture, climate change, policy, response options, globalization.

1. Introduction

Negotiators from many of the world's industrialized and developing countries meet each year in an ongoing evolution of one of the most contentious and critical international environmental agreements, the UN Framework Convention on Climate Change. This convention encapsulates the major dilemmas of development, equity, marginalization and globalization within its remit and is likely to have far-reaching consequences across the world in matters as wide-ranging as energy use and settlement patterns. Climate change is arguably the most persistent threat to global stability in the coming century. The Convention itself has learned the lessons from existing international environmental agreements in building legitimacy through a large-scale significant international scientific effort funded by governments through the UN, known as the Intergovernmental Panel on Climate Change (IPCC) [1]. In Marrakech in Morocco in November 2001, at the Seventh Conference of the Parties, delegates focused their minds on both adaptation to climate change and mitigation measures and, for the first time, formally recognized the dilemmas of adaptation for the developing nations. This recognition took the form of funding mechanisms to assist countries to adapt. The Delhi Declaration from the Eighth Conference of the Parties in November 2002 reinforced the importance of adaptation. The Delhi Declaration, in effect, has linked the participation of the developing world in mitigation of emissions to action and funding on adaptation to the impacts of climate change.

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India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat emanates from accumulated greenhouse gas emissions in the atmosphere, anthropogenically generated through long term and intensive industrial growth and high consumption lifestyles in developed countries. While engaged with the international community to collectively and cooperatively deal with this threat, India needs a national strategy to firstly, adapt to climate change and secondly, to further enhance the ecological sustainability of India's development path. Climate change may alter the distribution and quality of India's natural resources and adversely affect the livelihood of its people. With an economy closely tied to its natural resource base and climate-sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected changes in climate.

Climate change refers to changes beyond the average atmospheric condition that are caused both by natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and by artificial factors such as the increase in the concentration of greenhouse gases and aerosol. Climate change effects will impose significant additional stress on ecological and socioeconomic systems, but currently these systems are burdened by pollution, natural resource scarcities and other unsustainable practices. Technologically advanced countries are prepared well for responding to climate change, particularly by developing and establishing suitable, institutional and social policies capable for dealing with the consequences. But, the poor and developing countries are affected most by climate change, because they are not having enough and sound technologies or scientific development to deal with this impact. In developing countries like India, climate change is an additional burden because ecological and socioeconomic systems are already facing pressures from rapid population, industrialization and economic development.

Climate change, an all encompassing global phenomenon is expected to have impacts on natural resources situation, agriculture and global food security, livelihoods of people around the world. It has also aggregated the existing gender inequalities. Thus, there is an urgent need to understand the basis of climate change, its global spread and impacts to develop appropriate coping and mitigation measures. Climate change is impacting the natural ecosystems and is expected to have substantial adverse effects in India, mainly on agriculture on which more than 50 per cent of the population still depends for livelihood. Climate change will also cause increased frequency of extreme events such as floods and droughts. These in turn will impact on water security, agricultural production, and food security. . Overall impact of climate change in India in long term will be observed as, a rise in the average surface temperature by 2 - 4℃, changes in rainfall pattern in distribution, frequency and intensity [during both monsoon and non monsoon periods]; a decline in the number of rainy days, an increase in the occurrence and strength of cyclonic storms reduction in snow cover and glacial recession [2].

2. Influence of Climate Change on Water Resources

Climate change can severely threaten India's water security. India's hydro-climatic regime is expected to alter significantly. The impacts of climate change on glacial recession, decreasing rainfall pattern in some parts of India, greater but variable rainfall pattern in other parts of the country can lead to drought and flood like situations. Increased evapo-transpiration and reduced soil moisture may increase land degradation. Climate change affects surface water resources directly through changes in the major long-term climate variables such as air temperature, precipitation, and evapo-transpiration. The relationship between the changing climate variables and groundwater is more complicated and poorly understood. The greater variability in rainfall could mean more frequent and prolonged periods of high or low groundwater levels, and saline intrusion in coastal aquifers due to sea level rise and resource reduction. The direct effect of climate change on groundwater resources depends upon the change in the volume and distribution of groundwater recharge [3].

The average annual per capita availability of water in the country, taking into consideration the population of the country as per the 2001 census, was 1,816 cubic meters which reduced to 1,545 cubic meters as per the 2011 census. India is facing water stress due to limited availability of water due to increasing population, urbanization and industrialization. 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. Impact of climate change on the ground water regime is expected to be severe. Groundwater is the principal source of drinking water in the rural areas. About 85 per cent of the rural water supply in India is dependent on groundwater. India on the whole has a potential of 45.22 Mha-m/year of replenishable groundwater. Unfortunately, due to rampant drawing of the subsurface water, the water table in many regions of the country has dropped significantly in the recent years resulting in threat to groundwater sustainability [3].

3. Impact of Climate Change on Agriculture

Agriculture represents a core part of the Indian economy and provides food and livelihood activities to much of the Indian population. Agriculture production is directly dependent on climate change. While the magnitude of impact varies greatly by region, climate change is expected to impact on agricultural productivity and shifting crop patterns. The possible changes in temperature, precipitation and CO_2 concentration are expected to significantly impact on crop growth. There are two ways in which climate change can affect the food production system. One is direct and another is indirect. Direct effects would be through changes in temperature, water balance and atmospheric composition as well as extreme weather events and indirectly changes through changes in the distribution, frequently and severity of pest and disease outbreaks, incidence of fire and in soil properties. These direct and indirect effects on agricultural system will not only respond to climate change but, through fluctuating yield, have a negative impact on production and distribution. The effects of climate change on agricultural yields vary by region and by crop [4].

The uncertainties associated with climate change do not permit a precise estimation of its impact on agriculture and food production. However, what is happening already in terms of changing seasonal patterns and respective increases in temperature, moisture concentrations and CO2 levels is likely to have adverse impacts on ecosystems and therefore on crops, livestock, pests and pathogens. The physiological response of crops to changing climate is expected to be varied. Although some positive outcomes are expected, the new climatic conditions are more likely to have negative impacts such as a rise in the spread of diseases and pests, which will reduce yields. The nature of changes may be uncertain but what is certain is that changing environmental parameters are highly likely to affect ecosystems and the cultivation of crops. Examining these various parameters in turn provides a better picture of the challenges which global agriculture is facing in an era of climate change.

The predominant crops such as rice, banana and sugarcane in both the Krishna and the Cauvery river basins being water-intensive, will be affected negatively by the increased moisture stress in the short-term future, leading to reduced yields and change in the cropping patterns [5].

Higher temperatures lead to heat stress for plants, increasing sterility and lowering overall productivity. Higher temperatures also increase evaporation from plants and soils, increasing water requirements while lowering water availability. In many places, growing seasons are changing, ecological niches are shifting, and rainfall is becoming more unpredictable and unreliable both in its timing and its volume. This is leading to greater uncertainty and heightened risks for farmers, and potentially eroding the value of traditional agricultural knowledge such as when to plant particular crops. One degree Celsius increase in temperature alone could lead to decrease of 6 million tons of wheat production. This loss is likely to increase to 27.5 million tonnes in case of a 5^{o}C increase in mean temperature. An increase of temperature from 1 to 4^{0} C reduced the grain yield of rice (0 to 49%), potato (5 to 40%), green gram (13 to 30%) and soybean (11 to 36%). The linear decrease per ^{o}C temperature increase was 14%, 9.5%, 8.8%, 7.3%, and 7.2% in rice, potato, soybean, wheat, and green gram, respectively (India Second National Communication to the United Nations Framework Convention on Climate Change 2012)

Changes in temperature and seasons could affect the timing of reproduction and migration. Many stages within an aquatic animal's lifecycle are controlled by temperature and the changing of the seasons [6]. Climate change is a relatively intangible threat and increasing climatic variability is likely to aggravate the problems of future food security by exerting pressure on agriculture. However, there are lot of uncertainties about the assessment of impact, adaptation and mitigation of climate change [7]

Agriculture is inherently sensitive to climate conditions, and is among the most vulnerable sectors to the risks and impacts of global climate change [8], [9]. Adaptation is certainly an important component of any policy response to climate change in this sector [10]. Studies show that without adaptation, climate change is generally problematic for agricultural production and for agricultural economies and communities; but with adaptation, vulnerability can be reduced and there are numerous opportunities to be realized [11]-[17].

4. Climate Stimuli for Adaptation

The applicability of adaptation options depends on the nature of the stimuli and associated vulnerability [17]-[19]. Conventional climate impact scenarios usually focus on the changes in average (mean) temperature and moisture. Some have also considered other climate characteristics such as the growing season length and the timing of frosts, and climate-related factors such as pests and diseases, invariably for an average year sometime in the future [19]-[21]. While most impact studies have considered changed average (mean) climate conditions, usually in a comparative static manner, analyses of agricultural vulnerability indicate that the key attributes of climate change are those related to climatic variability, including the frequency of non-normal conditions [20]-[23]. For example, the most common problematic climatic conditions identified by a sample of farm operators in Southern Ontario were moisture extremes [drought and excess rain], which accounted for 80 % of responses [24]. Conditions associated with growing season length, heat or solar radiation, the more commonly analyzed variables in climate-scenario-based crop yield studies, were rarely mentioned. Recent debates focussing on the relationship between climate change stimuli and adaptation in agriculture recognize that climate change includes not only long term changes in mean conditions, but also a change in the year-to-year variation in growing season conditions, and the frequency and magnitude of extreme weather events [25], [26]. Understanding that climate change includes climatic variability and extreme events is important in analyses of adaptation. This is particularly so for agriculture, which is generally well adapted to mean or average conditions, but is susceptible to irregular or extreme conditions such as more frequent droughts and deviations from ‘normal’ growing season conditions [9], [24].

5. Analytical Approaches to Adaptation in Agriculture

Insights into agricultural adaptation to climatic change come from a variety of research approaches, which consider various scales [plant, plot, field, farm, region, sector, nation and international] and employ several different perspectives [27]-[28]. These approaches include research on climate change impacts; natural hazards; agrarian political economy; innovation adoption; agricultural systems and farm decision-making; risk management; and agricultural vulnerability and adaptation.

6. Conventional Climatic Change Impact Assessment

Early climate change impact assessments did not consider adaptation. Yet, with the potential to modify adverse impacts of climate change, adaptation is important to the estimation of climate change impacts [9]. Although agriculture is one of the most widely studied sectors with respect to the impacts of climate change [26], [29], adaptation in agriculture has still received little explicit consideration in the impact assessment literature [22]. This is partly because many studies do not go beyond estimating crop yield responses, essentially ignoring human decision-making in the agri food sector. Conventional, scenario-based studies providing predictions of potential impacts in agriculture have addressed adaptation mostly by making assumptions about human responses [12], [13]. Early (first-generation) impact assessment models provided estimates of the overall agricultural impacts or damages of climate change based on the assumption that no adaptations would occur [30], [31]. Later (second-generation) impact assessment models arbitrarily assigned adaptations to climate change, assuming adaptive responses on the part of agricultural producers or the system as a whole with respect to changes in average temperature and moisture conditions. More recently, impact assessments have recognized the importance of farm-level decision-making in the adaptation process, particularly when climatic extremes are considered, and studies have begun to focus on the role of human agency by researching farmer perceptions and risk management choices. However, there is still little analysis

in the impact assessment literature of actual farm level decision-making in agriculture or of how such decisions relate to public policies.

7. Conclusion and Policy

Climate Change is a serious global environmental concern, which is impacting global natural ecosystems and is expected to have substantial adverse effects in India. Studies reveal that climate change, through its multi dimensional implications and especially by affecting water resources would impact mainly agricultural sector. This, in turn would lead to loss of livelihood for a majority of farmers including women. Impact of climate change in India in long term will be observed as, a rise in the average surface temperature by 2-4 ℃, changes in rainfall pattern in distribution, frequency and intensity during both monsoon and non monsoon periods], a decline in the number of rainy days, an increase in the occurrence and strength of cyclonic storms reduction in snow cover and glacial recession. These far reaching changes will have serious repercussions for water resource scenario. It could be in terms of extremes like floods and droughts leading to loss in farm production, returns and livelihoods.

Effect of climate change on agriculture can be reduced through more efficient irrigation and watershed management, improved crop varieties, improved land cultivation, farm and livestock management and the development of crop varieties and breeds that are adapted to changing climatic conditions. Even though farmers realize change in rainfall amount and pattern, and rise in temperatures over a period of time, it is essential to provide awareness regarding climate change impacts and also the possible adaptation strategies to reduce the adverse impacts of climate change or maximize the potential benefits due to climate change. Need of the hour is to develop suitable strategies to mitigate the effect of climate change on natural resources, especially on water resources. In this regard, space and geo-spatial technologies are the valuable tools for synoptic and time series monitoring of the resource base and help in identifying the key measures towards sustainable management and conservation of natural resources [32]. Additional strategies for increasing adaptive capacity include bridging yield gaps to augment production, development of adverse climate tolerant genotypes and land use systems, assisting farmers in coping with current climatic risks through providing weather linked value-added advisory services to farmers [33]. Community-based adaptation strategies can help rural communities strengthen their capacity to cope with disasters, improve their land-management skills, and diversify their livelihoods. While national adaptation policies and strategies are important, implementation of these strategies at the local level will be the ultimate test of the effectiveness of adaptation [34].

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