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Climate change effects on water availability

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ABSTRACT : Climate is an important factor of agricultural productivity. In large parts of Asia, agricultural production is mainly dependent on monsoon rains. Climate change is characterized by alteration in temperature, precipitation and sea level rise. India will suffer severely from potential changes in temperature and precipitation. Adaptation options available to climate changes are: changing varieties/ crop, altering fertilizer rates to maintain rain or fruit quality and be more suited to the prevailing climate, water harvesting, conserve soil moisture and improving irrigation efficiency and use water more effectively.

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Agriculture sector is the largest consumer of water in India. About 83 per cent of available water is used for agriculture alone. The quantity of water required for agriculture has increased progressively through the years as more and more areas were brought under irrigation. Climate change is one of the most important global environmental challenges faced by humanity with implications for food production, natural ecosystem, freshwater supply and health etc. Global mean temperature may increase between 1.4 and 5.8°C (IPCC, 2001). Climate change possesses significant threats to food security and peace due to changes in water supply and demand, impacts on crop productivity, impacts on food supply and high costs of adaptation to climate change. Changes in climate may affect agriculture and food security by altering the spatial and temporal distribution of rainfall and the availability of water, land, capital, biodiversity and terrestrial resources.

Water resources in India :

Main water resources in India consist of precipitation on the Indian territory – estimated to be around 4000 cubic kilometers per year (km^3/year) – and transboundary flows, which it receives in its rivers and aquifers from the upper riparian countries. Precipitation over a large part of India is concentrated during the monsoon season from June to September/ October. Due to various constraints of topography, there is uneven distribution of precipitation over space and time. Precipitation varies from 100 millimeters (mm) in the western parts of Rajasthan to over 11,000 mm at Cherrapunji in Meghalaya. Out of the total precipitation, including snowfall, the availability from surface water and replenishable groundwater is estimated to be at 1,869 km^3. It has been estimated that only about 1,123 km^3, including 690 km^3 from surface water and 433 km^3 from groundwater resources can be put to beneficial use. Table 1 shows the water resources of the country at a glance (Anonymous, 2010).

Climate change in global scenarios :

Fluctuations in surface temperature, rainfall, evaporation and extreme events have been observed since the beginning of the 20th century. The atmospheric concentration of carbon dioxide has increased from about 280 ppm to about 369 ppm and the global temperature of earth has increased by about 0.6^0C. The global mean sea level has risen by 10 to 20 cm. There has been a 40 per cent decline in arctic sea ice thickness in late summer to early autumn in the past 45–50 years (Report on Climate Change, 2001). The frequency of severe floods in large river basins has increased during the 20th century. Also, synthesis of river monitoring data reveals that the average annual discharge of freshwater from six of the largest Eurasian rivers to arctic ocean has increased by 7 per cent from 1936 to 1999. In India, several studies have shown that there is an increasing trend in surface temperature, no significant trend in rainfall but decreasing/ increasing trends in rainfall at some locations (Mall *et al*., 2006).

Climate change projection in India :

All India mean annual temperature has shown significant warming trend of 0.05^0 C /10 yr during the period 1901-2003, the recent period 1971-2003 has seen a relatively accelerated warming of 0.22^0 C/10 yr, which is largely due to unprecedented warming during the last decade (Kothawale and Rupakumar, 2005). On a regional basis, stations of southern and western India show a rising trend of 1.06 and 0.36^0 C/100 year, respectively, while stations of north Indian plains show a falling trend of -0.38^0 C/100 year. The seasonal mean temperature has increased by 0.94^0 C/ 100 years for the post monsoon season and by 1.1^0 C/100 year for winter season (Ramakrishna, 2007). Some of the instances of observed spatial variability in the temperature phenomena during last few years include extreme cold winter during 2002-03; wide spread prevailing drought situations during July, 2004, 20 day heat wave in Andhra Pradesh during May, 2003. The trend analysis of rainfall data from 1140 meteorological stations carried out at CRIDA showed negative trend among the stations situated in deep southern parts, central India, parts of north Indian region and north east.

Climate change affects agriculture and food security by alteration in the spatial and temporal distribution of rainfall and decreasing the availability of water, land, capital, biodiversity and terrestrial resources. The climate change scenarios for the Indian sub-continent as inferred by Lal (2001) from simulation experiments using atmosphere-ocean GSMs under the four SRES marker scenarios are presented in Table 2. These results suggested an annual mean area averaged surface warming over the Indian subcontinent to range between 3.5 and 5.5 over the region by 2080s. This projection showed warming in winter season over summer monsoon. In case of rainfall, a marginal increase of 7-10 per cent in annual rainfall is projected with subcontinent by the year 2080s. However, part of the country comprising the areas in central parts covering eastern U.P., eastern M.P., west coast and greater parts of northwest India did not show any change. Among the rainfed districts, 40 per cent stations showed negative trend of 48 per cent with positive trend and 12 per cent no changes in rainfall.

Effect of climate change on water availability :

Change in river system :

This is an environmental problem of serious concern

Table 1 : Water resources of India

Water resources of India	km^3
Estimated annual precipitation (including snowfall)	4000
Runoff received from upper riparian countries 500	500
Average annual natural flow in rivers and aquifers	1869
Estimated utilizable water	1123
Surface	690
Ground	433
Water demand utilization (for year 2000)	634
Domestic	42
Irrigation	541
Industry, energy and others	51

Source: National Water Mission under national action plan on climate change, MoWR, GOI, 2010 in the Indo-Gangetic plain region. During different times in past, different rivers changed their course a number of times. During the period 1731–1963, the course of the Kosi river (the sorrow of Bihar) has shifted westward by about 125 km; courses of Ganga, Ghaghara and Sone at their confluence have shifted by 35 to 50 km since the epic period. ~1000 B.C. and that of the Indus and its tributaries by 10–30 km in 1200 years in the same direction. Between 2500 B.C. and A.D. 500 the course of the Yamuna river shifted westward to join the Indus and then east to join the Ganga thrice.

Sea-level rise :

Das and Radhakrishnan (1991) reported a rising trend in sea level at Mumbai (Bombay) during 1940–86 and Chennai (Madras) during 1910–33, based on the annual means of tide-gauge observations. Srivastava and Balakrishnan (1993) studied the atmospheric tide-gauge data and confirmed a rise in sea level by 8 cm. A case study in Orissa and West Bengal (IPCC, 1992) estimated that in absence of protection, one metre sea-level rise would inundate 1700 km^2 of predominantly prime agricultural land. In another study in the year 1993, it was found that in absence of protection, a one metre sea-level rise on the Indian coastline is likely to affect a total area of 5763 km^2 and put 7.1 million people at risk. The regional effects of climate change on various components of hydrological cycle, namely surface run-off, soil moisture and evapotranspiration (ET) for three drainage basins of Central India have been analyzed. Results indicated that basin located in a comparatively drier region is more sensitive to climatic changes. The significant effect of climate change on reservoir storage, especially for drier scenarios, necessitates the need for further critical analysis of these effects.

Climate change poses significant threats to food security and peace due to changes in water supply and demand, impacts on crop productivity, food supply and high costs of adaptation to climatic changes.

Mitigation and adaptation :

Climate change challenges to future food security seem immense. There are two potential pathways in dealing with climate change, *i.e.* mitigation and adaptation.

Table 2 : Climate change projection in India

Year	Season	Changes in temperature °C		Changes in rainfall (%)	
		Lowest	Highest	Lowest	Highest
2020s	*Rabi*	1.08	1.54	-1.95	4.36
	Kharif	0.87	1.12	1.81	5.10
2050s	*Rabi*	2.54	3.18	-9.22	3.82
	Kharif	1.81	2.37	7.18	10.52
2080s	*Rabi*	4.14	6.31	-24.83	4.50
	Kharif	2.91	4.62	10.10	15.18

Lal (2001)

Table 3 : Impact on water resources during the next century over India

Indian sub-continent	Increase in monsoonal and annual run off in the central plains. No substantial change in winter run-off
Orissa and west Bengal	One meter sea level rise would inundate 1700 km^2 of prime agricultural land
Indian coastline	One meter sea-level rise on the Indian coastline is likely to affect a total area of 5763 km^2 and put 7.1 million people at risk
All India	Increases in potential evaporation across India
Central India	Basin located in a comparatively drier region is more sensitive to climatic changes central India Basin located in a comparatively drier region is more sensitive to climatic changes
Kosi basin	Decrease in discharge on the Kosi river decrease in run-off by 2–8 %
Southern and Central India	Soil moisture increases marginally by 15–20 % during monsoon months
Chenab river	Increase in discharge in the Chenab river
River basins of India	General reduction in the quantity of the available run off, increase in Mahanadi and Brahmini basins
Damodar basin	Decreased river flow
Rajasthan	Rajasthan Increase in evapotranspiration

Source : Mall *et al.* (2006)

Mitigation is related to lowering the levels of harmful gases in the atmosphere. Adaptation is about using water efficiently. Water sector adaptations can address water scarcity and food security issues but the costs of adaptation are particularly high in the developing world. As there is no additional water available, the needed increase in food production must come from increasing water productivity through two basic pathways (Molden, 2007) :

- Extending the yield frontier in areas where present yields are close to their potential yield.
- Closing the yield gap where considerable yield gains can be achieved with modern technology.

Producing more crops per drop of water and energy can achieve a further increase in food production on already available land, water and energy resources. Water and energy saving measures would allow considerable gains in yield. In many irrigated systems now facing water scarcity, water use efficiency and productivity could easily be doubled (Molden, 2007); rainwater harvesting and light irrigation would enable significant production growth in rainfed systems (Rockstrom *et al.*, 2003). Enhancing water use efficiency holds the key to tackling water scarcity and food security issues in smallholder agricultural systems.

- Water productivity improvements can effectively address food insecurity and poverty alleviation.
- Management practices that increase agricultural yields also improve water productivity.
- The greatest potential to increase yields and water productivity in rainfed, arid and semi-arid regions particularly with development of water harvesting, supplemental and deficit irrigation and field water conservation to reduce non-productive evaporation, improved nutrients and drought resistance varieties. Interventions like agro-forestry, integrated farming system and conservation agriculture also holds key solutions to these problems.
- Major opportunities to improve water productivity are found in water management practices along the continuum from rainfed to partially and fully irrigated farming systems-crop management, soil and water conservation and irrigation practices like drip, sprinkler and improved surface irrigation.
- Water productivity gains are realized also by non-water management interventions. These measures include the choice of crop varieties particularly drought, flood and saline tolerant, fertilizer investment, carbon sequestration and residue management through biochar, pest and weed management, timely operations and post harvest management.
- Improving livestock water productivity should be an integral part of water resource management.
- Water productivity gains in agriculture can secure water resources for other landscape uses and ecosystem services.
- Integrated water and land management at the watershed scale is the key to improving water productivity and enabling sustainable water resource management. The challenge for IWRM is to manage trade-offs when re-allocating green and blue water across scales from field to watershed level and to limit negative side-effects such as reductions in downstream water availability due to upstream land management activities.
- Targeted policy actions can support integrated water and land management for improved water productivity.
- Capacity building and awareness are essential.

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