International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **2(1),** 79-87, January **(2013)** *Int. Res. J. Environment Sci.*

Climate Change, Water Resources and Food Production: Some Highlights from India's Standpoint

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Available online at: www.isca.in
Received 11th December 2012, revised 20th December 2012, accepted 5th January 2012

Abstract

India accounts for about 17.5 % of the world's population and roughly 4% of the total available fresh water resources. Ground water resources provide for more than 60% of the irrigated land which has already depleted to large extent in many pockets of the country. Except a few perennial rivers most of the rivers are seasonal and rainfed. With increasing population and growing demand from industrial and agricultural sectors the water consumption is set to jump up tremendously in the near future. India is expected to become water stressed country by the years 2020-2025 with per capita water availability falling to 1341 m^3/person/year by 2025. Climate change can severely threat India's water security. India's hydro-climatic regime is expected to alter significantly over the course of the 21st century. Impacts of climate change on water resources are sure to have consequences on the food security of India, as food security cannot be expected without a foolproof water security. Studies conducted by individual authors and other national and international organizations forecast a change in the climate of India and alteration in the hydrological regime. Some changes in climate have already started to appear affecting the water resources of the country. A parallel association also exists between change in water regime and food security. Observing these outcomes in the present context, in this paper (i) the water resources of India (ii) the possible impacts of climate change on its water resources and (iii) likely influence of change in water regime on the food security; have been highlighted. Furthermore, some of the initiatives taken under the National Action Plan on Climate Change by the Government of India to counter the climate change impacts on water resources and food production have also been dealt with.

Keywords: Food security, sustainable development, water security, water stress.

Introduction

Water is the basic need of life for the human beings and any alteration in its availability is directly going to impact them through various means. The adequacy of water availability can be described in terms of 'water stress index'. Water stress index is based on the minimum per capita quantity of water required to maintain an adequate quality of life in a moderately developed arid zone country[1]. Regions having renewable fresh water resources falling below 1667 m^3/person/year are classified as "water stress" regions. Furthermore, regions whose water availability falls below 1000 m^3/person/year can be categorized as chronic 'water scarcity' experiencing regions[1].

India accounts for about 17.5 % of the world's population[2] and roughly 4% of the total available fresh water resources[3]. Most of the rivers are rain-fed and seasonal and only few are perennial. Ground water resources provide for more than 60% of the irrigated land. Groundwater depletion to large extent is forcing the populace to dig deep into the earth. This is adversely disturbing the quality and quantity of the drinking water[4]. Per capita water availability in India in 2001 was 1820 m^3/person/year which is projected to go down to 1341 and 1140 m^3/person/year by the years 2025 and 2050 respectively[5]. These estimates show that India is going to become water stressed country by the year 2020 with per capita water availability severely falling below the 1667 m^3/person/year benchmark. The country faces a sharp water stressed state due to escalating population and tremendous mounting pressure from diverse sectors ranging from agriculture to industry[1]. Water availability does not mean only the quantity of water; it includes its quality as well. Increasing levels of pollution are severely affecting the renewable fresh water resources. Pollution not only makes fresh water undrinkable but also unsuitable for industrial and agricultural purposes.

Another major player emerging as potent factor for water security in India is the global climate change. Climate change can severely threat India's water security. India's hydro-climatic regime is expected to alter significantly over the course of the 21st century. Himalayan glacial recession can prove havoc for the perennial Indus-Ganga surface water resources[6]. 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 and desertification[7]. Above mentioned arguments coupled to the scenario that the water utilization rate in India is 59%, much ahead of the 40% standard[8], clearly point to an urgent need to better adopt water management practices in the country to increase the water security for proper transition into a green economy. In the context of climate change, water resources and food production, this paper highlights (i) the water resources of India (ii) the possible impacts of climate change on its water resources and (iii) likely influence of change in water regime on the food security. Some of the initiatives taken under the National Action Plan on Climate Change by the Government of India to counter the climate change impacts on water resources and food production have also been dealt with in the text.

Water resources scenario

According to estimates total surface and ground water availability in India is around 1869 billion cubic metres (BCM). Out of the total available water about 60% (690 BCM from surface water and 432 BCM from ground sources) is usable and the remaining 40% is not accessible for use due to various geological and topographical considerations. Precipitation in the form of rain and snow account for approximately 4000 BCM of available fresh waters, but most of it is lost to the seas via rivers[9, 10]. 91% of groundwater extracted is consumed by the agricultural sector and rest 9% by the industrial and domestic sectors[11]. Similarly, 89% of surface water is consumed by the agricultural sector and 2% and 9% are used by the industrial and domestic sectors respectively[10].

River basins in India have been divided into three categories viz. major, medium and minor based on their catchment area. There are thirteen major river basins which occupy 82.4% of the total drainage basins area. These basins contribute 85% of the total surface flow and house 80% of the country's population. Apart from these rivers, there are some desert rivers also[12]. A summary of classification of river basins in India is presented in table 1. Some characteristics of the major river basins are also displayed in table 2. In spite of the fact that the country is rich in river basins and blessed by the south-west monsoon accounting for the 75% of the annual rainfall, water availability is emerging as a big concern for its economic and sustainable development[12].

Table-1
Classification of river basins in India based on catchment area

River Basins	Catchment Area in Km^2 and %	No. of Basins
Major	> 20,000 (82.4)	13
Medium	2000 – 20,000 (8)	48
Minor	< 2000 (9.6)	52

(Source[12])

Groundwater is the major source of water in India with 85% of the rural population dependent on it[10]. Moreover, 50% of the urban requirements of the fresh water are met through the ground water extraction[11]. Ground water has two components static and dynamic. The static fresh groundwater reserve i.e. aquifer zones below the zone of groundwater table fluctuation has been estimated at 10,812 BCM. National Water Policy allows only development of dynamic ground water resources and forbids static ground water resources mining[14]. Some basic facts about the dynamic ground water resources in India are given in table 3 and table 4.

Table-2
Description of major river basins in India

Direction of Rivers	River Basin	Catchment Area (Km^2)	Mean Annual Runoff (BCM)
West flowing rivers	Indus (to the border of Pakistan)	321,000	73.30
	Mahi	35,000	11.00
	Narmada	99,000	45.60
	Sabarmati	22,000	3.80
	Tapi	65,000	14.90
East flowing rivers	Brahmani and Baitarani	52,000	28.50
	Cauvery	81,000	21.40
	Ganga	861,000	525.00
	Godavari	313,000	110.00
	Krishna	259,000	78.10
	Mahanadi	142,000	66.90
	Pennar	55,000	6.30
Eastern India	Brahmaputra	194,000	585.00

(Source[13])

Table-3
Basic facts about ground water resources in India

Annual replenishable ground water resource	431 BCM
Major source of ground water recharge	Monsoon rainfall
Contribution of monsoon rainfall recharge	246 BCM (57%)
Overall contribution of rainfall to annual replenishable ground water resource	68%
Share of other sources like canal seepage, return flow from irrigation, recharge from tanks, ponds, and water conservations structures taken together	32%
Natural discharge	35 BCM
Net annual ground water availability	396 BCM
Annual ground water recharge takes place during the Kharif period of cultivation	73%
Annual ground water draft (for 2008-2009)	243 BCM
Largest use (Agricultural sector)	Irrigation sector (221 BCM or 91%)
Domestic and industrial sector use	22 BCM or 9%

(Source[11])

Table-4
Annual replenishable ground water resources

Regions	Annual replenishable ground water resources	Remarks
Indus–Ganga–Brahmaputra alluvial belt in the North; East and North East India (states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal); valley areas of North eastern states	0.25 to more than 0.5 m	Significantly high
Coastal alluvial belt particularly Eastern Coast	0.25 to more than 0.5 m.	Relatively high
Western India, particularly Rajasthan and parts of northern Gujarat	Up to 0.025 m	Scanty
Major parts of the southern peninsular India	only up to 0.10 m	Less
Remaining parts of central India	0.10–0.25 m.	Moderate

(Source[11]); m = meter (per unit area; volume/area)

Table-5
Stage of ground water development

Regions	Stage of ground water development
Delhi, Haryana, Punjab and Rajasthan	> 100%
Gujarat, Tamil Nadu and Uttar Pradesh, Daman and Diu, Lakshadweep and Puducherry	70% and above
Rest of the states / union territories	< 70%

(Source[11])

Table-6
Classification of Assessment units

Total assessment units	5842
Over-exploited units	802 (13.73% ≈ 14%)
Critical units	169 (2.89% ≈ 3%)
Semi-critical	523 (8.95% ≈ 9%)
Safe	4277 (73.21% ≈ 73%)
Totally saline ground water	71 (1.22% ≈ 1%)

(Source[11])

Central Ground Water Board (India) in its recent report has assessed the stages of ground water development in different parts of the country. Overall stage of ground water development has been computed as 61% (2009) as compared to 58% in 2004. Table 5 depicts the stage of ground water development recorded in different parts of India. According to the report, in Delhi, Punjab, Haryana and Rajasthan the stage of ground water development is > 100%, which means in these states the annual consumption of ground water is more as compared to the annual recharge of ground water. The utilization pattern is however uneven varying from over-exploitation to sub-optimal use. Over-exploitation of ground water resources is causing water stressed conditions in many pockets of the country. Assessments carried out by the Central Ground Water Board (India) of 5842 units (blocks/mandals/taluks) in the year 2009 found 14% units (802 units) to be over-exploited and 3% (169 units) critical (Table 6). Moreover, 71 blocks are completely under the influence of saline ground water. In the states of Punjab, Haryana, Delhi and western Uttar Pradesh unregulated extraction beyond the ground water recharge limits has become a matter of great concern. In Punjab and Haryana indiscriminate extraction of ground water is predominantly for agriculture related activities. Over-exploitation is also widespread in the western part of the country chiefly Rajasthan and Gujarat owing to their arid climate resulting in scanty and irregular rainfall. Similar exploitation pattern is also seen in peninsular India particularly in the states of Karnataka and Tamil Nadu. This is mainly attributed to the lesser availability of ground water resources because of poor aquifer properties of the hard rock terrains prevalent in the region[11].

Climate change and water resources

Three observable phenomena viz. increase in the global average temperature, change in regional precipitation patterns and rise in the sea levels clearly indicate that the global climate is changing[15]. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as, “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. The adverse effects of climate change according to the convention means “changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare”[16]. Enhanced glacial recession and alteration in monsoonal patterns are the most important consequences of climate change that India is going to face. Increasing temperature will not only threat the Himalayan snow cover but also alter the circulation patterns that govern precipitation events. Overall impact of climate change in India in long term will be observed as, a rise in the average surface temperature by 2-4°C; changes in rainfall pattern in distribution, frequency and intensity (during both monsoon and non-monsoon periods); a decline in the number of rainy days (According to estimates by more than 15 days); an augmentation in the rain intensity by 1-4 mm/day; an increase in the occurrence and strength of cyclonic storms[17]; reduction in snow cover and glacial recession.

Indian Network for Climate Change Assessment (INCCA) in its recent report has assessed the likely changes in India in 2030s (which is based on simulation models) in relation to climate change. According to INCCA India in 2030s will have increased greenhouse gas concentrations and an enhanced all-round warming. The rise in annual mean surface air temperature has been projected to be ranging from 1.7°C to 2.0°C with more variability of seasonal mean temperature in winter months. The report further projects intensification in daily maximum and daily minimum surface air temperatures by 2030s. The likely change in warming in the spatial pattern of lowest daily minimum and highest maximum could be from 1°C to 4°C. South peninsula, central and northern India is likely to face a rise in night temperatures. An increase in daytime warming could also be experienced over central and northern India[14].

The Indus, the Ganga and the Brahmaputra are the most prominent snow-fed and perennial Himalayan fresh water river systems of India. An increase in temperature is likely to increase the rate of glacial melting, initially increasing the flow of water in these river basins. Available records suggest that the Gangotri glacier is retreating at about 28 metres per year. However, as the melting of glaciers intensifies their shrinkage will also become more rapid. This rapid glacial recession will reduce the summer and autumn water flow in the river systems in long term[18]. For example, water flow in the river Ganga could drop by two-thirds affecting more than 400 million people who depend on it[7]. A serious environmental problem has also been witnessed in the Indus-Gangetic plain region where some of the river systems have changed their courses many times. For example river Kosi caused heavy flood in Bihar and Nepal when it changed its course[18.] How the reduced snow cover will affect the water security can simply be deduced from the fact that the Himalayan glaciers provide 30-40% of the water supply of the river Ganga and 70-80% of the Indus water supply[7].

Increased temperature will affect the hydrological regime of the Indian subcontinent. As arrival and withdrawal of the monsoon are temperature related events, increased temperature is sure to alter the pattern and distribution of the Indian monsoon. Rainfall is expected to increase in intensity accompanied by decrease in the number of rainy days. Significant changes in rainfall pattern have already been witnessed in India in recent times. Though glacial sources make Indus-Ganga-Brahmaputra river systems perennial, monsoonal rainfall is primarily responsible for their large annual volume. More intense rainfall concentrated over a few days along with large glacial melt will increase the chances of flash floods in the river basins in short term[8]. Glacial lake outbursts will increase the chances of landslides in the upper regions. INCCA report deals with the projected impact of climate change on the water resources of India in the river basins of four regions namely Himalayan, North-eastern, Western ghat and Coastal regions (on short term basis) in 2030s. In these regions water resources have been evaluated in terms of ‘water yield’ with base years 1970s. Water yield can be defined in terms of total surface runoff, which is actually a function of the precipitation, its distribution, and is influenced by evapo-transpiration and soil characteristics[14]. The projections mentioned in the INCCA report are presented in table 7.

Table-7
Some of the climate change impact on water yield and health of four major regions of India in 2030s

Region	Impact on water resources
Himalayan region	1. Water yield (mainly covered by the river Indus), is expected to increase by 5%–20% in most of the areas. 2. Expected increase in yield up to 50% in some areas of Jammu and Kashmir and Uttarakhand. 3. Rise in rain intensity by 2-12%. 4. Enhanced evapo-transpiration. 5. Increased glacier melt. 6. Flash floods causing large scale landslides, leading to loss of agricultural area affecting food security.
North-Eastern region	1. Precipitation trend exhibits considerable spatial variability in water yield. 2. Northern parts of the region demonstrate a decline in precipitation varying from 3% in the north-western part (of the North-East) to about 12% in the north-eastern part. 3. The central part displays an increase in precipitation which varies from 0% to 25%. 4. The bulk of the North-Eastern region (except some parts of Mizoram, Tripura, Manipur and Assam) depicts an increase in evapo-transpiration in the 2030s. 5. Reduction in water yield for the Arunachal Pradesh by up to about 20% and increased evapo-transpiration. 6. Assam and Manipur demonstrate increase in water yield up to about 40%. 7. Overall scenario: decline in winter precipitation, increased summer precipitation intensity leading to increase runoff and landslides. 8. High night temperatures to affect paddy cultivation as evapo-transpiration will increase. 9. Soil erosion to impact tea plantations. 10. Decrease in food production yields in winters.
Western Ghats	1. The region exhibits wide variability in water yield. 2. Northern portion displays a drop in the water yield varying from 10% to 50%. 3. The central portion shows an increase in water yield ranging from 5% to 20%. 4. The southern parts of Karnataka and Kerala demonstrate a reduction in water yield up to 10%. 5. Cash crops to be affected adversely. 6. Large scale flooding and soil erosion
Coastal region	1. Eastern coastal parts of West Bengal, Odisha and the northern coastal parts of Andhra Pradesh display a drop in water yield as less as 40%. 2. Southern parts of Andhra Pradesh and northern parts of Tamil Nadu indicate growth in water yield by 10% to 40%. 3. The western coastal region demonstrates overall reduction in water yield varying from 1% to 50% (except, in the coast along Karnataka, where an increase of 10% to 20% is projected). 4. Southern tip of the coastal region indicates no change in water yield. 5. Rise in sea level to cause incursion of coastal waters leading to increase in salinity affecting fresh water availability for drinking and agriculture. 6. Productivity and distribution of marine as well as fresh water fisheries to be affected.

(Source[14]; pp. 103, 138-140)

Water yield variability can be clearly documented from table 7, which leaves a clear mark about the impacts of climate change on the water resources of India. The initial increase in volume of river waters in the Himalayan region due to enhanced glacial melting and increased precipitation in short term will be followed by decreased water flow in these river basins. This is because as the glaciers disappear, the only source of water for these river systems will be rainfall. Himalayan glaciers provide 30-40% of the water supply of the river Ganga and 70-80% of the Indus water supply. In these scenarios these river systems could also become seasonal which will be a huge catastrophic event. Though the Mahanadi, Brahmani, Ganga, Godavari and Cauvery indicate an increase in precipitation due to climate change (Based on the Hadely Centre Regional Model), corresponding increase in annual runoff is not demonstrated. This could be attributed to enhanced evapo-transpiration because of temperature rise or variations in rainfall distribution pattern. Remaining basins exhibit a decline in precipitation events. For example, Sabarmati and Luni basins display severe drop in precipitation and consequent reduction of two-thirds of the current runoff. Flooding events may increase in Mahanadi and Brahmani river systems whereas, severe drought conditions may be experienced in the Sabarmati and Luni basins[14]. Disappearance of glaciers, variability in distribution pattern of rainfall, flooding, drought all are possible consequences of climate change in India and threat to our water security. Floods and droughts both affect the availability of water resources.

Another change in rainfall pattern due to climate change is the reduction in number of rainy days. This will severely affect the ground water recharge as the adequate amounts of rainwater will not be able to percolate down to the ground water tables[8]. With the demand for ground water expected to rise due to increased population and augmented demands from industrial and agricultural sectors, the decrease in water table will force us to go beyond the dynamic ground water resources which does not look well from the point of view of sustainable development. The INCCA report predicts with the exception of the Himalayan region reduction of rainy days in most parts of the country including the Western ghat, the North eastern region and the Coastal regions of India[14].

Food production and security

We cannot expect our food security without water security and any impact on the availability of water resources due to climate change is going to impact the food security of India. Food security is directly dependent on agriculture. Agriculture system in India can be divided into rainfed and irrigated systems. Agriculture is important from two perspectives in the Indian context i. it provides food, ii. it provides livelihood security to the majority of the population[18]. A large tract of arable land in India is rainfed and its productivity depends on pattern and distribution of rainfall. Summer rainfall provides 70-75% of India's total annual rainfall which shows a decreasing trend under the climate change scenario. Any spatio-temporal change in pattern and distribution of rainfall will pose a serious threat to the agriculture system and consequently food security[12,18]. To feed the increasing population and sustain the economy, India will require doubling of current food production, including an increase of food grains' production from 2 to 4 billion tonnes annually[17]. However, there is a probability of 10-40% loss in crop production in India by 2080- 2100 due to global warming and consequent changes in climate related events[14].

United Nations' Food and Agricultural Organization body in its assessment report evaluated that the large contiguous areas of the irrigated land associated with the Indus, Krishna and Godavari river basin deltas are at an increased risk from a combination of factors like reduction in flows and salinity. Reduced outflows to the seas will cause intrusion of salinity in the low lying areas making freshwater aquifers vulnerable. The report further stressed about the risk of annual flood cycles and the sea level rise on the irrigated land present along the Ganges-Brahmaputra river basin deltas. The stress of these factors on some of the major productive land will cause a decline in the agricultural output, biodiversity and the normal capability to recover. The alteration in precipitation and evaporation events will cause a drastic shift in the present pattern of soil moisture deficits, ground water replenishment and runoff. Rainfed agriculture is expected to feel the immediate impacts of climate change in the form of volatility in yield performance because of moisture stress and declining rainfall[19]. Most severe reduction in runoff is expected in the Krishna basin (30-35%), in reaction to 20% decline in rainfall, which is already under severe stress from the developmental pressures. On the other hand Mahanadi river basin is expected to witness increasing floods due to rise in peak runoff[20]. These two southern peninsula rivers display an opposite trend in the climate change regime. However, both the factors viz. reduced runoff and increased floods will impact the agricultural productivity and food security. Flooding will further increase soil erosion hampering the fertility of the agricultural lands. Declining snow cover, unpredictable and erratic rainfall will severely affect the water supply for agriculture of the Indus-Ganga river basin systems. These basins cover a large tract of the highly fertile land providing food to the enormous number of people. Reduction in water flow of the Indus river system will be catastrophic for the food surplus currently generated in the Punjab and Haryana[20].

As mentioned above increased salinity will be one of the possible consequences of climate change on the water resources of India. Increased evapo-transpiration, due to rise in temperature and reduced runoff will be the principal causes of salinity intrusion. In the coastal deltas increased ground water abstraction can result in salinity intrusion rendering water unsuitable for agriculture[20]. Moreover, rise in evapo-transpiration will cause a reduction in soil moisture content putting further stress on the food crops. Increased evapo-transpiration and reduced soil moisture may increase land degradation and desertification[7].

National action plan on climate change (NAPCC)

NAPCC identifies measures which simultaneously promote the developmental objectives of the country while addressing the issue of climate change. It provides strategies of adaptation and mitigation to counter the impacts of climate change and at the same time puts emphasis on the advancement of developmental needs of India. Eight national missions have been established under the NAPCC to deal with the climate change[21]. Five of the eight missions are discussed below which are directly related to water resources and food security under the climate change regime. The materials under this topic have been taken from Prime Minister's council on climate change, Government of India.

National water mission (NWM): i. It promotes integrated water resource management in order to conserve water and reduce wastage ii. It strives to increase water use efficiency by 20% iii. It puts emphasis on recycling of waste water to meet a considerable share of the water requirements of the urban areas iv. It promotes adoption of modern technologies like desalination techniques to make ocean water usable v. It revisits the National Water Policy (NWP) for better management of the river basins under the climate change scenario of variability in rainfall and river flows vi. It seeks to optimize the competence of existing irrigation systems and rehabilitation of the old ones vii. It puts emphasis on water neutral and water positive technologies viii. The mission seeks to advance i. storage (both above and below ground), ii. rainwater harvesting, iii. recharging of ground water resources, iv. sprinklers, drip and ridge and furrow irrigations.

National mission for sustaining the Himalayan ecosystem (NMSHE): i. The basic objective of this mission is to develop management instruments that sustain and safeguard the precious Himalayan glaciers and mountain ecosystems, ii. It seeks to address the problem of glacial recession through research, consultations with experts and international collaboration, iii. To assess fresh water resources and health of the ecosystem the mission seeks to establish an observational and monitoring network for the Himalayan environment, iv. To safeguard the hill agriculture on account of climate change the mission emphasizes community based management of these fragile ecosystems, v. Enhancement of forested lands is also encouraged through incentives with the basic aim to maintain two-thirds of the area of the mountainous regions under forest to check erosion and land degradation.

National mission for a green India (NMGI): i. The mission has been launched to increase the forest cover (carbon sinks) of the country. The current area under forests is 23% which is much below the national target of 33%, ii. It seeks to afforest 10 million hectares of land, iii. The mission will be taken up mostly on the degraded forest land, iv. Community based participatory approaches like joint forest management is emphasized.

National mission for sustainable agriculture (NMSA): i. To make Indian agriculture better adapted to climate change this mission seeks to device various strategies including monitoring and evaluation of impact of climate change on agriculture systems of the country ii. The mission promotes research on new varieties of crops (especially heat resistant crops) and alternative cropping patterns which are capable of withstanding outcomes of climate change like extreme weather, flooding, drought, moisture deficiency and variability iii. To promote sustainable agriculture it seeks to converge and integrate traditional knowledge, biotechnology, information technology, geospatial technology etc. iv. It proposes new credit and insurance mechanisms for the farmers v. Enhancing the productivity of rainfed agriculture is the main focus.

National mission on strategic knowledge for climate change (NMSKCC): i. It promotes enlistment of the global community and multisectoral collaboration in research and technology development to counter the climate change impacts ii. It also promotes establishment of research units on climate change in Universities and other academic institutions and their networking iii. The research will also focus on socio-economic impacts of climate change on the population including coastal communities iv. It seeks creation of a Climate Science Research Fund to support research works and Strategic Knowledge Mission for identification of climate change challenges and suitable responses v. It seeks to encourage development of innovative technologies for climate change adaptation and mitigation with involvement of private sector.

A Critical Appraisal

The population of India according to 2011 census has increased from 1.03 billion in 2001 to 1.21 billion in 2011. Moreover, the level of urbanization has also risen from 27.82% in 2001 to 31.16% in 2011[22]. With the present population projected to grow to 1.6 billion by 2050[2] the country will face serious water stressed situations and a gigantic task to feed such an enormous population. 85% of the rural population depend on ground water for daily needs and 50% of the urban requirements are met through the ground water extraction. Agricultural sector accounts for about 90% of the total water resources consumption. With burgeoning population the demand for water resources will rise along with the growing demands from Industrial and agricultural sectors. Water that is available to us is severely threatened by the climate change scenario, which is also jeopardising the food basket of the country. The hazards of the climate change can be easily documented from some of the recent events in the south-east Asian country Philippines. Severe tropical storms, Typhoon Washi in 2011 and Typhoon Bopha in 2012 have caused havoc in the form of flash floods and landslides. Moreover, these recent cyclonic events have occurred in the regions that rarely experience severe tropical storms. The coastal regions of India have also experienced erratic rainfall in recent years.

World Summit on Sustainable Development calls for integrated water resources management and increase water use efficiency plans[23]. Integrated management of river basins, ground water, watersheds and wetlands is the need of the hour. However, management means proactive and participatory approach and not only centralised planning. There is need to fully understand the hydrological cycle being impacted by the climate change and merging it with the integrated management systems. Researches clearly point to a climate change scenario and which looks inevitable. This calls for immediate adaptation and mitigation plans. NAPCC launched by the Government of India is a welcome step in this direction. However, a recent critical evaluation of NAPCC by Sujatha and Sudhir (Indian Institute of Technology, IIT, Madras, India) has shown that the action plan on climate change needs immediate revision for effective climate change mitigation and adaptation plans[24]. Some of the evaluations can be described in following terms:

NMGI should not just be a plantation programme and grasslands and wetlands need equal attention. Local people and communities should be actively involved in the forest regeneration programmes. Moreover, the problems of forest diversion and deforestation and measures for checking them need to be fully addressed. The participatory approach by involvement of local communities in decision making and implementation, provision of learning sites, landscape level institutions and starting REDD+ cell are some positive developments of this mission.

NMSHE needs two urgent priorities. First, we must know whether our policies on the Himalayan ecosystems are matching the policies of the nations that share the Himalayan ranges. And second, the focus must be on the diverse array of unique ecosystems and microclimates that Himalayas characterise as they are not homogenous. Micro-level issues such as shifting cultivation in the north-eastern India need to be addressed. Research in areas covering precipitation, meteorology and hydrology need further and specific focus.

Coordination between different institutional structures like Central Water Commission (CWC), Central Ground Water Board (CGWB), National Rainfed Areas Authority (NRAA) etc. is needed. Demand management of water on priority basis, and proper integration of water sector with climate change, ecology and development concerns should be done. Issues such as glacial recession, alteration in precipitation patterns and hydrological cycle need priority focus. Water resource development, conservation and management practices should be decentralised, local, small scale and community based. Moreover, the relationship between water use in the mission and agriculture need to be defined and water saving technologies in agricultural sectors should be promoted.

Models should be developed for successful farming practices in different agro-climatic zones of the country. As each agro-climatic zone differs with another in basic characters models should be zone specific as well as crop specific. These models should be replicated when proved successful. High dependence on chemical fertilizers needs to be reduced and adaptation for agriculture should be in response to floods and droughts. Water saving practices, water harvesting, soil characteristics, innovative technologies and methods and strategies need great deal of research and study. National Initiative on Climate Resilience Agriculture (NICRA) undertaken by Indian Council of Agricultural Research (ICAR) is welcome step in the direction of adaptation and mitigation for sustainable agriculture and food security.

Conclusion

The research works done on climate change forecast its implications on water and food security of India. Some of the affects of climate change on water resources and food production have already started to appear. We cannot expect our food security without a foolproof water security as agriculture cannot sustain without adequate water available for its consumption. With increasing population and demands from various sectors including industry and agriculture the consumption of water is going to jump up in the coming decades. Climate change poses a threat to the water security of India. Enhanced glacial recession and their ultimate disappearance will prove disastrous for the Himalayan rivers. Erratic and unpredictable rainfall will compound the impact of climate change on these river basins. There is possibility of turning these river basins into seasonal rivers. In South India the climate change impact will also be seen on river basins like Krishna, Mahanadi, Godavari etc. While some of the river basins will experience flood like situations, others will suffer from drought like situations. Reduction in number of rainy days, decrease in soil moisture due to increased evapo-transpiration, decline in ground water recharge will put tremendous pressure on the available water resources. Change in water regime is bound to impact the food production and its security. Apart from above mentioned reasons intrusion of salinity will also threat the food security of India. Thus, under these changing scenarios proper adaptation and mitigation techniques are the needs of the hour. Government of India has formulated a National Action Plan on Climate Change with different missions to counter the impacts of climate change in India. These measures cannot be termed adequate until and unless they are implemented with a determined capacity and in proper direction. Since impacts of climate change are multidimensional, an interdisciplinary, integrated and over the board approach cutting across all the ministries involved in the missions is required. An independent ‘Climate Change Challenge Council’ designated as “4C” breaking all ministerial confines should be set up. The council should be tasked with overseeing the works related to the climate change and the developments of new institutions and mechanisms as suggested by the recent study conducted by the IIT Madras. Climate change is an international problem, but the effects will be felt at the local levels and from there the effects will move up to the national and then to international level. Participatory approach involving local communities; coordination between village, block, subdivision, district, state and centre, and international community is must to tackle the climate change and its impacts on water resources and food security.

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