Int.J.Curr.Microbiol.App.Sci (2018) Special Issue-7: 3853-3858

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Special Issue-7 pp. 3853-3858**
Journal homepage: http://www.ijcmas.com

Review Article

Impact of Climate Change on Water Resources in India

Sunil Kumar*

Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur-813210, Bihar, India
**Corresponding author*

A B S T R A C T

Climate change is expected to increase the frequency and intensity of current extreme weather events, greater monsoon variability and also the emergence of new disaster i.e. sea level rise and new vulnerabilities with differential spatial and socio-economic impacts on communities. This unprecedented increase is expected to have severe impact on the hydrological cycle, water resource for drinking water, forest and ecosystems, losses of coastal wetlands and mangroves, food security, health and other related areas. The impact would be particularly disastrous for developing countries, including India and further may reduce the resilience of poor, vulnerable communities, which make up between one quarter and one half of the population of most Indian cities. The hydrological cycle is being modified quantitatively and/or qualitatively in most agro-climatic regions and river basins of India by human activities such as land use change, water uses, inter-basin transfers, cropping pattern, irrigation and drainage. Many of the areas are getting transformed from safe area to critical and over exploited area with the fall in water table. In view of this, sustainable management of surface and ground water and the supporting natural environment have gained considerable importance in recent years. An assessment of the availability of water resource in the context of future national requirements taking particular account of the multiplying demands for water and expected impacts of climate change and variability is critical for resource planning and sustainable development as a basis for economic and social development. This study was focused on availability of surface and ground water resources and the potential for water related developments, keeping in view the possible impacts of climate change to meet the foreseeable demand in India. It is required to develop an integrated framework for addressing the issue of water, community adaptability and disaster risk reduction.

Keywords

Impact Climate Change, Water resources

Introduction

Water is one of the most essential natural resource which plays a vital role in maintaining biodiversity, our health, social welfare and our economic development (Donald, 1968). Increasing numbers of warm days and decreasing numbers of cold days have been observed, with the warming trend continuing into the new millennium. Over India, the increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall (IPCC 2014). Ground water has been the mainstay for meeting the domestic water needs of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. The impact of

rainfall variation on the region's ground water resources is not well understood, even though groundwater forms about half of the region's water supply. This is largely due to the complex interactions among land use, aquifer properties, antecedent water table levels and the actual timing and intensity of individual rainfall events. In cases where the aquifer systems are saturated, reductions in rainfall may not have an immediate effect on water tables, but a reduction in rainfall in other conditions below a critical level could eliminate all infiltration beyond the vegetation root zone. As a gross approximation, recharge to the water table aquifer (from which most of our groundwater is derived) might be expected to respond in a similar way as runoff to decreasing rainfall, but this remains a largely unproven assertion. To examine the relative importance of climate on groundwater level variation, Chen *et al.,* (2004) used cross-correlation analysis between historical climate records and groundwater levels. Their results showed that the annual precipitation explained the variations in groundwater levels significantly. The climate affects the demand for water as well as the supply and quality. Particularly, in arid and semi-arid regions of India any shortfall in water supply multiplied with climate change will enhance competition for water use for a wide range of economic, social and environmental applications. Assessing the potential socioeconomic impacts of climate change involves comparing two future scenarios, one with and one without climate change. Uncertainties involved in such an assessment include: (1) the timing, magnitude and nature of climate change; (2) the ability of ecosystems to adopt either naturally or through managed intervention to the change; (3) future increase in population and economic activities and their impacts on natural resources systems; and (4) how society adapts through the normal responses of individuals and businessman and through policy changes that offer the opportunities and incentives to respond.

India's rainfall, population, food and freshwater needs

Long period average annual rainfall in India is about 117 cm; however, this rainfall is highly variable both in time and in space. Almost 75% (88 cm ± 10 SD) of the long average annual rainfall comes down in the four months of June to September (SW monsoon).The heaviest rains of the order of 200-400 cm or even more occur over northeast India and along the Western Ghats of the peninsular India. Largely, the annual average rainfall over the northern Indo-Gangetic plains running parallel to the foothills of the Himalayas varies from about 150 cm in the east to 50 cm in the west.

Surface water resources

India has a large and intricate network of river systems of which the most prominent are the Himalayan river systems draining the major plains of the country. Apart from this, numerous water bodies present in the subcontinent make it one of the wettest places in the world after South America.

The annual precipitation including snowfall, which is the main source of the water in the country, is estimated to be of the order of 4000 billion cubic metres (BCM).

Scenario of ground water resources

Groundwater is a replenishable, finite resource. Rainfall is the principle sources of its recharge, though in some areas canal seepage and return flow from irrigation also contribute significantly to the groundwater recharge.

Table.1 Impact of climate change on water resources

Location	Impact	References
Indian subcontinent	Increase in monsoonal and annual runoff in the central plains • No substantial change in winter runoff. • Increase in evaporation and soil wetness during the monsoon and on an annual basis.	Lal and Chander, 1993
Orissa and West Bengal	One-meter sea levels rise would inundate 1700 km2 of prime agricultural land	IPCC, 1992
Indian coastline	One-meter sea level rise on the Indian coastline is likely to affect a total area of 5763 km2, and put 7.1 million people at risk	JNU, 1993
All India	Increases in potential evaporation across India	Chattopadhyay and Hulme, 1997
Central India	Basin located in a comparatively drier region is more sensitive to climatic changes	Mehrotra, 1999
Kosi Basin	Decrease in runoff by 2-8%	Sharma *et al.*, 2000, a,b
Southern and Central India	Soil moisture increase marginally by 15-20% in monsoon months	Lal and Singh, 2001
Damodar basin	Decreased river flow	Roy *et al.*, 2003
Rajasthan	An increase in ET	Goyal, 2004
River basins of India	General reduction in the quantity of the available runoff, increase in Mahanadi and Brahmini basin	Gossai and Rao, 2006
River basins in northwest & central India	Increase in heaviest rainfall and reduction in number of rainy days	Singh et el., 2008

Groundwater resources comprises of two parts namely dynamic, in the zone of water table fluctuation and static resource, blow this zone, which usually remains perennially saturated. The annual replenishable groundwater resource of the country is 433 billion Cubic metres (bcm) and the net groundwater availability is 399 bcm after allocating 34 bcm for natural discharges during non-monsoon season. Growing demands of water in agriculture, industrial and domestic sectors and ground water development has brought problems of over-exploitation of the resource, continuously declining water levels, seawater ingressin coastal areas & ground water pollution in different parts of the country. The falling ground water levels in various parts of the country have threatened the sustainability of ground water resource, as water levels have gone deep beyond the economic lifts of pumping.

Observed climate change and its impacts during the past century

Goswami *et al.*, (2006) found that the frequency of occurrence as well as intensity of heavy and very-heavy rainfall events have highly significant increasing trends; low and moderate events have significant decreasing trend over Central India. Singh and

Sontakke (2002) found that the summer monsoon rainfall over western Indo-Gangetic Plain Region (IGPR)showed increasing trend (170 mm/100 yrs, significant at 1% level) from 1900, while over central IGPR it showed decreasing trend (5 mm/100 yrs, not significant) from 1939, and over eastern IGPR, decreasing trend (50 mm/100 yrs, not significant) during 1900-1984, and insignificant increasing trend (480 mm/100yrs, not significant) was observed during 1984-1999. Broadly, it is inferred that there has been a west ward shift in rainfall activities over the IGPR.

Projected climatic trend

Rupa Kumar *et al.,* (2006) projected that warming is monotonously widespread over the country, but there are substantial spatial differences in the projected rainfall changes. West central India shows maximum expected increase in rainfall. Extremes in maximum and minimum temperatures are also expected to increase in future, but the night temperatures are increasing faster than the day temperatures.

Extreme precipitation shows substantial increases over a large area, particularly over the west coast of India and west central India. Lal *et al.,* (2001) estimated that CO^2 level will increase to 605–755 by 2070. They projected between 1 to 1.4^{o}C&2.23 to 2.87^{0}C area-averaged annual mean warming by 2020 & 2050, respectively. There is an overall decrease in number of rainy days over a major part of the country. This decrease is more in western and central part (by more than 15 days) while near the foothills of Himalayas (Uttarakhand) and in northeast India the number of rainy days may increase by 5–10 days. However, increase in GHG may lead to overall increase in the rainy days intensity by 1–4 mm/day except for small areas in the northwest India where the rainfall intensities decrease by 1 mm/day.

Impacts of projected climate change on water resources

Table 1 shows the selective reports on impact of climate change on water resources during next century over India. The enhanced surface warming over the Indian subcontinent by the end of the next century would result in an increase in pre-monsoonal and monsoonal rainfall and no substantial change in winter rainfall over the central plains. This would result in an increase in the monsoonal and annual runoff in the central plains with no substantial change in winter runoff. They also indicated an increase in evaporation and soil wetness during the monsoon and on an annual basis.

Ground water and climate change

Problems in ground water management in India have potentially huge implications for global warming. The most optimistic assumption suggests that an average drop in ground water level by one meter would increase India's total carbon emissions by over 1%. More realistic assumption reflecting the area projected to be irrigated by groundwater in 2003, suggests that the increase in Carbon emission could be 4.8% for each meter drop in groundwater levels. Chadha (2003) recommended studying the aquifer geometry and establishing the saline fresh interfaces within 20 Km of the coastal area, the effect of glaciers melting on the recharge potential of the aquifer in the Ganga basin together with its effect on the trans-boundary aquifer system particularly of the arid and semi-arid regions. Panda *et al.,* (2007) studied the influence of repeated droughts and increased anthropogenic pressure on the groundwater levels of Orissa

during the period 1994–2003. Preliminary study showed that the groundwater levels of the network observation wells are very sensitive to the monsoon rainfall, and any irregularity in rainfall directly influences the groundwater levels. Due to drought in 2002, the groundwater level dropped significantly in the consolidated formation that covers 80% of the geographical area of Orissa.

It is clear that the global warming threat is real and the consequences of the climate change phenomena are many, and alarming. The impact of future climatic change may be felt more severely in developing countries such as India whose economy is largely dependent on agriculture and is already under stress due to current population increase and associated demands for energy, fresh water and food. In spite of the uncertainties about the precise magnitude of climate change and its possible impacts particularly on regional scales, measures must be taken to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. In addition, the uncertainty involved in predicting extreme flood and drought events by the models are large. It can be concluded that Indian region is highly sensitive to climate change and demand for water from groundwater may increase if precipitation decreases and surface water inflows decrease, this leads to a decrease in discharge elsewhere. The elements / sectors currently at risk are likely to be highly vulnerable to climate change and variability and here exist uncertainties in dealing with vulnerabilities associated to climate change and variability. Climate change may have both direct and indirect effects on both recharge and discharge to an aquifer. Increased temperature may lead to higher potential evapo-transpiration and increased water use demand. Therefore, an effective management of ground water resources requires an integrated approach in both planning and implementation of schemes. Different agencies related to water resources, climate, agriculture and other sectors should coordinate and bring out policies on scientific considerations for effective management of ground water resources in changing climate. A future increase in demand water is likely to have a much greater impact on groundwater than reduced recharge due to climate change. With increased scarcity of groundwater, the time has come when government and community should work together for an integrated management targeted towards providing water to all on a sustainable basis.

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