IJETIR
ISSN (Online) 2583-0554
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Impact Factor: 5.731
Volume 4, Issue 2, February 2024

An In-Depth Review of Climate Change Impact on Indian River Basin Hydrology

Abhishek Gurjar[1] and Dr. Mahendra Singh[2]
Research Scholar, Department of Geography[1]
Research Guide, Department of Geography[2]
Sunrise University, Alwar, Rajasthan, India

Abstract: *The globe is facing a water problem due to unexpected hydrologic cycle shifts, the main source of catastrophic disasters. Rapid urbanization and population increase make water resource management problematic. Climate change harms ecosystems, wildlife, agriculture, and other areas, affecting many people's socioeconomic conditions. Most Indians depend on agriculture. Regional climate differences drastically reduce agriculture productivity. Human activity is the main cause of 21st-century climate change concerns. Global climate change affects localities. Due to rising industrialization and urbanization, India's groundwater and surface water resources are diminishing due to hydrological variables like climate change, causing a severe water crisis. Many studies have examined how climate change affects water supplies, but interdisciplinary research on India's river basins is sparse. Thus, to limit climate change's effects on river basins, present research should be evaluated and future research topics suggested.*

Keywords: Climate Change, Hydrological Cycle, Indian River Basins

I. INTRODUCTION

A region's climate is its typical weather. It is statistically the average and variability of weather throughout time. It might be months or millions of years (IPCC, 2014). Human-caused weather changes like temperature shifts are called "climate change". Variations in climate affect a river basin's sediment discharge, soil erosion, and surface runoff. Examining how climate change affects watershed hydrology usually involves building a hydrological model that accounts for climatic input variations. Weather is controlled by rainfall and temperature (Singh et al., 2013). The earth's annual temperature is anticipated to rise from 0.3 to 0.6 degrees Celsius (IPCC, 2014), affecting precipitation and atmospheric CO2 concentration. Temperature and precipitation affect crop productivity and yield most. Shah and Srivastava (2017) found that every degree Celsius increase in temperature reduces agricultural output by 3-5%. Auffhammer et al. (2012) found that drought reduces crop productivity if temperatures rise. Temperature lowers soil moisture and increases irrigation water needs (Venkateswar and Singh, 2015). Groundwater extraction increases when groundwater level decreases (Zaveri et al., 2016). Greenhouse gas emissions also raise temperatures (Montzka et al., 2011). Climate change is influenced by temperature and precipitation.

Streamflow also changes with rainfall (Milliman et al., 2008), which affects water accessibility. Population increase and improper land use have affected water resources recently. Temperature and precipitation affect water resources as demand rises (Jia et al., 2017). Thus, water resource management is essential to maintaining a healthy supply-demand balance.

To ensure proper water resource management, many hydrological and eco-hydrological models (Arnold et al., 1998; Williams et al., 2008; Arnold, 2012a; Bieger, 2016) were utilized. Due to their importance, many scientists have examined how climate change affects temperature, precipitation, and streamflow in Indian River basins. Figure 1 shows the recent increase in studies.

In a Ganges and Godavari river basin survey, Mishra and Lilhare (2016) found that surface runoff is more responsive to temperature and rainfall changes than evapotranspiration. Rao (1995) observed a little decrease in Mahanadi River basin precipitation, however Panda et al. (2013) recorded an increase in streamflow.

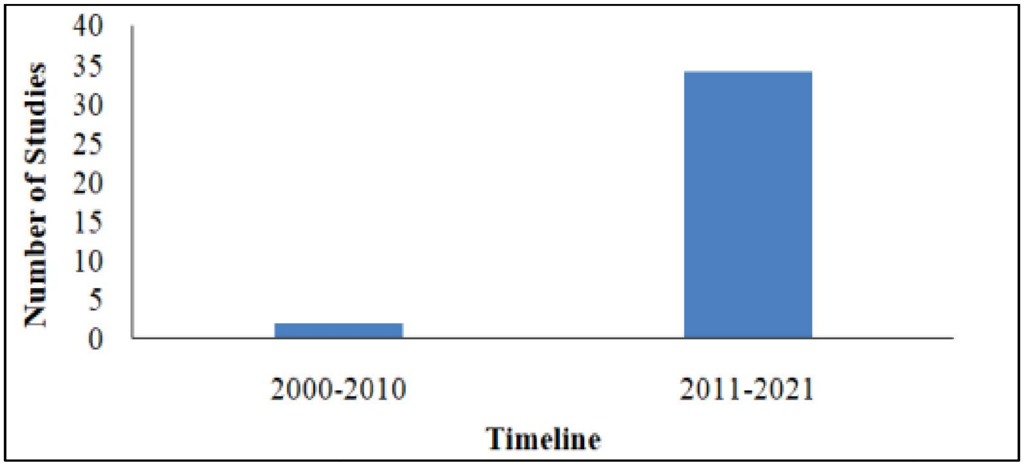

Fig. 1. Number of climate change studies done in India during the twenty-first century.

This paper illustrates the impact of climate change on the hydrologic process of a watershed.This study predominantly concentrated on the hydrological responses of a watershed and the effects of global climate change through the use of climate and hydrological models in multiple watersheds. Additionally, various regional scales were employed to conduct trend analysis of temperature, rainfall, and other climate variables in order to predict future climatic metrics (Ganguly et al., 2015). The evaluations were gathered for a variety of watersheds in India's river basins.

Overview of Climate Change

Climate change has plagued the planet in the 21st century. However, it affects our nation. IPCC (2001a and 2001b) reports a one-degree temperature rise in India. By predicting future climate conditions, many scientists have devised climate change adaptation and mitigation strategies. Climate change affects hydrology and water resources (Arnell, 2003; Barnett, 2008).

Different scholars have used different methods to study climatic effects in dynamic situations. Despite its complexity (Schaller et al., 2011) and cost (Alotaibi et al., 2018), the GCM model is the most widely used model for forecasting future occurrences. Recent studies (Hao et al., 2018; Grusson et al., 2018; Makhtoumi et al., 2020) used GCM-powered hydrological models to understand how climate change affects hydrological processes. Bae et al. (2015); VIC; Ficklin (2010). GCM projections are used in hydrological models to predict long-term hydroclimate changes. GCMs were used to determine hydrologic parameters with other models. Chen et al. (2012) coupled GCMs and atmosphere-ocean general circulation models (AOGCMs) and found no wind speed decrease.

The hybrid-delta technique uses numerous GCM forecasts to determine the Gomti river basin scenario (Abeysingha et al., 2018). They found higher streamflow and annual rainfall.High flows were projected to increase in frequency and significance. Vandana et al. (2019) found yearly temperature and precipitation increases over the Brahmani River basin using the hybrid-delta technique. Choose the highest-ranked GCM when using them. GCMs often misjudge temperature and precipitation. Schaller et al. (2011) used multiple methods to analyze the CMIP3 climate models to select the most accurate and essential to avert it. In another study, Cai et al. (2009) found no GCM that accurately predicted global temperatures or precipitation. GCMs may work better in some places. These skill score maps can be superimposed on global climatic zone, land cover, and elevation maps to better comprehend GCM data (Cai et al., 2009).

Future Trend of Rainfall and Temperature

Sen's non-parametric estimator for trend analysis estimates the trend's magnitude, and the Mann-Kendall test evaluates it. The analysis predicted climate change impacts on numerous Indian River basins. Three important river basins were studied for trend analysis: Ganges, Brahmaputra, and Meghna (GBM) (Mirza et al., 1998). The Ganga basin had similar precipitation across all river basins, however the Brahmaputra basin, which has two subdivisions, showed divergent trends. Finally, two of the three Meghna basin subdivisions grew and one decreased. Jain et al. (2012) and Laskar et al. (2014) examined northeastern India temperature and precipitation trends. They found higher mean, maximum, and minimum temperatures. Jain et al. (2012) found no evident pattern in climatic change between 1901 and 2001. Jain and Kumar (2012) found a century-long rise in temperature but no trend in rainfall in the Indian River basin. Panda and Sahu studied Odisha's Kalahandi, Bolangir, and Koraput in 2019. They saw growing rainfall despite basically stable temperatures. The experimental conditions showed no significant impact of temperature change on agricultural productivity.

Numerous studies examined Gomti river basin streamflow and precipitation. Das et al. (2021) found a rise in temperature and a decrease in streamflow and precipitation, unlike Abeysingha et al. (2014), who found an increase in annual rainfall in upper basin areas and a drop in lower parts. Pal and Mishra (2017) discovered less catchment runoff and higher temperature and precipitation. Khan et al. (2020) and Rajbhandari (2014) studied the Indus basin. They later observed a temperature spike. Ougahi et al. (2022) found comparable results, along with variations in precipitation and glacier and snow melting, which impacts river flows. As temperature rose, discharge frequency and intensity increased. Upper Indus basin flooding was found (Lutz et al., 2016; Rajbhandari, 2014). The Narmada river basin increased temperature by 0.2 per decade while the Cauvery river basin decreased rainfall and streamflow (Tiwari et al., 2021). (Sreelash et al., 2020).

Climate Change on Streamflow and Water Balance Components

Several academics have used representative concentration paths to quantify other climatic models. These models briefly show temperature, precipitation, runoff, streamflow, etc. changes. Sharannya et al. (2018) found a rise in temperature and a drop in streamflow in India's Western Ghats. Rao et al. (2020) and Jana (2012) reported similar findings. Researchers found that RCP 4.5 and 8.5 decreased streamflow and rainfall in the Subarnarekha River watershed.However, Dadhwal et al. (2010) suggest that Mahanadi river streamflow increases. Bisht et al. (2020) expect the Mahanadi river basin's low flow frequency to decrease under the predicted climate. The Mahanadi river basin's results were similar to those of the Brahmaputra, Brahmani, upper Indus, Krishna, Satluj, and Godavari river basins.However, temperature increases diminish streamflow in the Gomti river basin (Das et al., 2021; Abeysingha, 2021). Climate affects temperature, precipitation, and streamflow, altering agricultural methods, according to reviews. An ensemble of two CMIP5 models indicated that rising temperatures and greater rainfall had impacted Baitarini River basin farming methods (Padhiary et al., 2019). After applying the same model to the Raidak basin in India and the Wangchu river basin in Bhutan, Janapriya et al. (2016) observed that streamflow and groundwater increased under RCP 4.5 and dropped under RCP 8.5 Zam et al. (2021) found a 1.5 °C and 3.6 °C temperature increase over the Bhutan-India transboundary river under RCP 4.5 and 8.5, respectively.

These models predict climate change's runoff effects. Thomas et al. (2017) and Uniyal et al. (2015) found contradictory results for the Bundelkhand region and Baitarini River basin, respectively, but surface runoff increases in the Krishna, Mahanadi, and Godavari River basins. Table 1 shows river basin locations and streamflow trends. In addition to hydrological aspects, greenhouse gas emissions affect climate (Montzka et al., 2011).

Table 1: Streamflow trend of Indian River basin.

River basin	Watershed/Catchment	Location	Increase in streamflow	Decrease in streamflow
Baitarani	Anandapur	Odisha	√	
Raidak	Raidak	West Bengal		□√
Gomti	Gomti	Uttar Pradesh		□√
Brahmaputra	Lower Catchment	Assam		□√
Mahanadi		Odisha,Chhattisgarh		
Satluj		Himachal Pradesh, Punjab	□√	
Subarnarekha		Odisha, Jharkhand, West Bengal	□√	

Indus		Himachal Pradesh, Punjab, Haryana, Rajasthan, J&K.	□√	
Cauvery				□√

Limate Resilient Practices

According to IPCC AR5, global warming raises air temperature. It negatively impacts precipitation incidence and distribution, impacting water balance. Climate change harms food and water security worldwide. The UNFCCC proposed two climate change solutions. Reduce GHG emissions to mitigate climate change and adapt to its effects. Anthropogenic activities and GHG emissions cause unpredictable earth's surface temperature and precipitation. To reduce atmospheric GHGs, appropriate actions must be done. Adaptation and coping may also mitigate climate change's negative consequences.

II. CONCLUSION

Climate change is rapidly affecting crop output and water supplies.Most river basins have rising rainfall, temperature, and runoff. Floods are intensifying due to increased precipitation and surface runoff. Groundwater behaves differently under RCP 4.5 and 8.5, rising in some cases and decreasing in others. Some basins abuse groundwater.Many regions' diminishing surface water resources will make groundwater use uneconomical.Climate change affects agricultural irrigation more.Water-saving irrigation is one way to address climate change-related water shortages and food security issues. Changes in planting patterns, breeding, and novel agricultural technology that utilize less water are also advised. Sustainable risk management, which must be linked into climate change improvement, requires decision-making.

Given multiple climate models and emission scenarios, the current overview may help decision-makers understand Indian river basin rainfall and temperature trends. A review of previous studies helps researchers discover climate change research questions.

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