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IMPLICATIONS OF CLIMATE CHANGE ON WATER RESOURCES –A COMPREHENSIVE REVIEW

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Abstract
There is a direct as well as indirect impact of change in climate on human beings, agriculture, food sectors and natural resources. Even with a limited water resources and cultivable land (4% and 9% respectively), India has shown remarkable economic development during the past two decades, with a population of over 1.2 billion people. The rainfall distribution is also highly uneven with highest global rainfall in northeastern region of India and desert likes Thar. Between 2000 and 2015, India saw a substantial shift in precipitation and temperature when compared to the preceding century. In India, this may be an indication of climate change. We discovered that in order to reach an absolute inference and proper reasoning of the trends, an exhaustive and clear knowledge of the impact of climate change on water resources of the country is highly desirable. The purpose of this article is to examine the different factors that contribute to global climate change and to forecast the effect of global climate change on India's water resources situation using the regression technique.

KEYWORDS: - Global Climate, Global Temperature, Water Resources, Rain Fall, Watershed.

INTRODUCTION

Climate change has a major effect on water-either directly or indirectly- resulting in severe social and economic pressure on highly vulnerable nations like India. Millions of impoverished people are battling against limited adaptive ability, rapidly depleting natural resources including unsustainable water management and widespread wetland damage. Economic growth is inextricably linked to global warming. The planet's temperature is rising as a result of uncontrolled natural resource extraction and environmental devastation. Global warming aggravates temporal and geographical fluctuations in precipitation, snowmelt, and available water resources.

According to an American Meteorological Society research report, 2016's worldwide heat record, including severe heat in Asia, occurred solely as a result of global warming caused by human activities such as fossil fuel use. NASA rated 2017 as the second hottest year on record, behind only 2016. Since 2001, seventeen of the earth's eighteen very warm years have occurred. Temperatures have risen by more than one degree Celsius on average since the late nineteenth century, owing to the production of CO_2 and other greenhouse gases (GHG). To prevent the worst effects of climate change, experts agree that the global temperature should not rise by more than two degrees Celsius.

Scientists say that even if humans restrict global warming to two degrees Celsius, more than a quarter of the Earth's surface would become substantially drier. However, if we restrict average warming to 1.5 degrees Celsius, this will be reduced to about one-tenth, saving two-thirds of the area predicted to dry out below two degrees Celsius. Achieving 1.5 degrees would be a significant step toward decreasing the probability of aridification and its associated consequences, according to research published in the journal "Nature Climate Change." By the way, the Paris Agreement, which was approved by 195 nations in 2015, seeks to keep global warming to 1.5 degrees Celsius over pre-industrial levels. Aridification is a significant concern, hastening soil degradation and desertification, as well as the loss of plants and trees critical for absorbing CO_2 that contributes to global warming. Additionally, it exacerbates droughts and wildfires and degrades the quality of agricultural and drinking water. According to NOAA and NASA, climate change may adversely influence the frequency and severity of natural disasters caused by storms, hurricanes, natural fires and floods.

Water resources are diminishing and degrading at an alarming rate. Reduced availability of surface water as a result of shifting rainfall patterns increases reliance on groundwater. In several areas of India, groundwater levels have been declining at an alarming pace as a consequence of over-extraction and changing seasonality and intensity of rainfall.

This results in salt intrusion into aquifers in coastal zones. Scarcity of water results in disputes over distribution and conflict amongst individuals. Climate change effects will have a direct influence on water security, which will have a ripple effect on food security. A recent study by the International Food Policy Research Institute, predicted that by 2050, about 50% of scarcity in global grain production affecting more than half of the world’s population.

The rural economy suffers when agriculture fails as a consequence of hydrological extremes. For a large part of rural India, agriculture remains the major source of income. Natural disasters, such as floods and prolonged droughts, may lead to worry and mental health issues. Over the last several decades, tens of thousands of farmers have committed suicide in India.

By the late twenty-first century, climate change is expected to increase the frequency and severity of drought, resulting in hunger in a significant portion of the world. Food shortage or poor food quality may also have a negative effect on mental health. Along with agriculture, a potential crisis in the inland fishing industry may jeopardise food security. Aquatic species are typically more sensitive to water temperatures, and climate change may alter the stratification of water bodies, impairing fish development and survival.

For India, that has a vast coastline, the implications are enormous.

In 2016, the nation recorded the greatest number of fatalities due to severe weather (2119) and property damage totaling more than $ 21 billion. This is almost 1% of India's GDP. The IMF data demonstrates a growing connection between global warming and severe El Nino occurrences that impact India's monsoon. According to Munich Re's National Catastrophe Service's Risk Index study, the frequency of such catastrophes would double in the future owing to climate change.

In India, a decrease in monsoon rainfall has been recorded since the 1950s. Additionally, the frequency of severe weather occurrences has risen. A sudden shift in the monsoon may cause a catastrophic catastrophe, resulting in more frequent droughts and more floods over vast swaths of India. The economic survey 2018/19 found that when rainfall levels fall 100mm below normal, farmer earnings decrease by 7% during the rabi crop and 15% during the kharif seasons. According to the study, climate change may decrease yearly agricultural earnings by 15% to 18% on average and by up to 20% to 25% in unirrigated regions. It emphasizes the fact

that climate change will exacerbate farmer uncertainty and calls for adequate crop insurance and the use of technology to help farmers become more resilient.
According to the study, reducing vulnerability to climate change would require significantly expanding irrigation via effective drip and sprinkler systems. At the moment, about 45 percent of cropland is irrigated. The Indo-Gangetic plain, as well as portions of Gujarat and Madhya Pradesh, are extensively irrigated. However, portions of Maharashtra, Karnataka, Chhattisgarh, Madhya Pradesh, Rajasthan, and Jharkhand are particularly susceptible to climate change due to poor irrigation.
Winter 2017 was the hottest on record, with virtually little precipitation. Recent hailstorms in winter in areas of Maharashtra, MP, and Rajasthan have wreaked havoc on standing crops, while a lack of rainfall has left several major rivers water-stressed. The IMD's prediction for a hotter summer in 2018 will exacerbate the country's water crisis.

Water disappears from river basins

India has about twenty river basins. Most river basins are water stressed as a result of rising demand for residential, industrial, and agricultural usage. This is exacerbated further by the country's unequal distribution of water demand. Increased demand from an expanding population, along with economic activity, places further strain on already-stressed water supplies. With the nation currently suffering water scarcity, it is necessary to increase both water supply and demand management in water-rich areas without infrastructure.
Groundwater is critical to India's economy. It meets about 85% of rural demand, 50% of urban demand, and more than 60% of our irrigation demands. Unregulated groundwater extraction has resulted in widespread overuse in many areas of the nation, lowering the groundwater table and drying up springs and aquifers. According to the 2011 CWG Report, the annual groundwater draw is 245 BCM, or about 62% of the net available water. 91 percent of this was utilized for irrigation. However, the impacts on groundwater have not been consistent throughout the nation. In areas where groundwater extraction surpasses replenishment, the situation is worrisome. States such as Haryana, Punjab, and Rajasthan are currently using more water than is supplied yearly. Several locations in Rajasthan and Haryana have excessive salt concentrations in their groundwater, rendering it unfit for human consumption.
Agriculture uses the majority of India's water (more than 85 percent). Water usage will continue to rise as a result of industrialization and urbanization. Droughts, heavy rains, unseasonal showers, hail storms, and flooding are all on the increase as a result of climate change and have had a detrimental effect on the Indian economy.
Water demand is constantly increasing. With increasing challenges from climate change, migration, and population expansion, it will need innovative and creative governance to manage this priceless resource. By the way, our nation is blessed with enormous saltwater resources that span the length and breadth of over a dozen states and union territories. Assuring the delivery of purified saltwater to a dedicated network would benefit people enormously. A few enterprises have been established in states like as Tamil Nadu, Puducherry, Andhra Pradesh, and Gujarat. However,the country urgently needs to establish a coastal development strategy that makes advantage of saltwater. Alternative fuel sources such as solar and wind energy, which are plentiful in the region, should be utilized for this purpose, and lower pricing

would reduce production costs considerably. The federal government, state governments, local governments, and private operators may all pay to the expense of constructing purification plants in the region.

Trends and Estimatesin Rainfall

In India, the period from June to Septembers observes maximum annual precipitation (nearly 80%) amid southwestern monsoon season [33]. There is no discernible pattern in annual rainfall throughout India over the 135-year period from 1871 to 2005, according to the analysis of data from 306 locations. However, India's yearly rainfall has decreased somewhat, whereas northwestern and peninsular India have seen a small rise [31, 45]. No discernible change in rainfall was seen between 1871 and 2008 in northeastern India, the world's most rain-abundant region. [20] Across India, there has been an increase in heavy rainfall and a decrease in low and moderate rainfall [15]. Central India's mean July and August rainfall decreased significantly (by 10%) between 1951 and 2010 (at the 5% level of significance) [64]. Many important river basins had fewer wet days, but more severe events [21]. As per special report on emission scenarios (SRES), coupled climate model simulation in A1B scenario estimated an increasing in the rainfall in the southern parts of the country[25]. According to the PRECISE (Providing Regional Climates for Impacts Studies) simulation, premonsoon rainfall in the Brahmaputra basin would rise by approximately 100 millimetres between 2071 and 2100, when the base period of 1961–1990 is taken into account [14].

Figure 1 depicts the average annual precipitation from 1901 to 2015 for the United States. Mean precipitation for the years 2000–2015 was lower than for the years 1901–2015 (1,104 mm). It's 1,139 millimetres tall. Drought years have happened recently, as is shown.

Temperature Trends and Projections

2016 was the hottest year reported since official records started in 1901, with a warming trend observed throughout India. (The Inquirer, 2016) The five warmest years have all occurred in the last sixteen years (from 2000 to 2016), with none occurring before. The average annual temperature in the United States rose by 0.22°C between 1971 and 2003[26]. India has had a 0.57°C warming trend per hundred years, according to data spanning the years 1881-1997 [50]. Between 1941 and 1999, the annual mean temperature increased in southern, central, and western India, whereas it decreased in northern and northeastern India [68]. India's average temperature rose during a 107-year period (1901–2007), with the largest rise in the western Himalayan region [45]. With the exception of the monsoon season, the CRU2.1 data indicates an increase in the maximum temperature throughout the year [44]. According to Tyndall Working Paper 55, a complete collection of high-resolution monthly climate grids was created for Europe and the world between 1901 and 2000 and shows substantial increases in India's highest winter temperature and lowest post-monsoon temperature. Sonia and colleagues [67]. From 1901 to 2003, the temperature in northern India increased [20].

An increase in average temperature of 2–4.8°C is predicted throughout India between the 1880s and 2080s, according to 18 CMIP5 models [9]. The PRECIS climate model predicts that warming will pick up speed in India between 2071 and 2100, with nighttime temperatures rising at a higher pace than midday temperatures [29]. For the years 2001–2100, Canadian

Coupled Global Climate Model (CGCM3) simulations of the A2 emission scenario yielded annual maximum and minimum temperatures in the Ganges River Basin of 0.05–0.1°C and 0.42–0.76°C, respectively [13]. Fig. 2 shows that the annual mean temperature in India has increased by around 0.25°C during the last 15 years (2000-2014) when compared to the period 1951-2014 (about 25.06°C). The mean maximum and minimum temperatures have also increased by around 0.28°C and 0.22°C, respectively, during the last 15 years (from 2000 to 2014).

River Runoff

With a total fresh water resource of 1.91 km3 per year, India ranks 132 in the world in terms of water availability per person, while being home to 17.2% of the world's population (UNFAO 2013; India-WRIS 2011). There is a wide disparity in the distribution of water resources throughout the globe. Water resource availability varies by region, with the Brahmaputra River basin in northeast India having 17,000 m3 available per person, while in western India, the Sabarmati River basin only has 240 m3 available per person [2]. The daily streamflow data for the Sutlej River in northern India have decreased during a 41-year period (1970–2010) at three gauge locations, showing a downward trend (Kasol, Sunni, and Rampur). As a result of its enormous hydroelectric and agricultural production potential, the basin is important [63]. Winter streamflow of the Chenab River rose statistically substantially owing to variability in snow and glacier melting between 1961 and 1995, while the Beas River had a statistically significant decrease in mean annual streamflow and a declining but negligible trend [7]. Annual streamflow data (1982–2012) collected at four gauge stations along the Gomti River (total area 30,437 km2), a tributary of the Ganges River in northern India, show a decreasing trend (Neemsar, Sultanpur, Jaunpur, and Maighat). This is due to the river's heavy dependence on monsoon rainfall for much of the year [1]. Only one gauging station (T. Narasipur) in southern India's Upper Cauvery basin (catchment area 36,682 km2) saw a significant decline in annual streamflow data during a 30-year period (1981–2010) except for a 0.778 m3=s yearly decrease from 2001–2010. According to the research of Raju and Nandagiri, from 1972 to 2007, the Mahanadi River basin's outflow (Tikerpara) (catchment area 141,589 km2) in peninsular India had a reduction in streamflow of 3,388 million cubic metres per decade. According to the research conducted by Panda et al. The frequency of particular floods at Bahadurabad on the Brahmaputra River rose between 1956 and 2007. (Climate Change Cell 2009). It was found by [12] that between 1972 and 2003, the annual stream flow at the Mundali outflow in the Mahanadi basin increased by 4.53%, which they linked to a 5.71% decrease in forest coverage. GBM long-term mean runoff is expected to increase by 33.1%, 16.2%, and 39.7% by the end of the twenty-first century in the Ganges basin, Brahmaputra and Meghna basins, respectively [37]. In terms of mean annual discharge, the Brahmaputra River System ranks fourth in the world [41]. Under the SRES A1B scenario, upstream flow in the Himalayan River basins, such as the Brahmaputra and the Indus, is expected to drop between 2046 and 2065 [17]. The Brahmaputra riverflow at Chilmari is expected to increase by 5–20 percent in 2100, according to Mahanta et al. (2014). (based on 22 GCMs and the A1B, B1, and A2 scenarios). A 4.5–39% increase in monsoon flow is expected in the lower Meghna Basin's discharge, including seasonal flow shifting (Kamal et al. 2013). A2 and B2 scenarios in HadCM3 predict a 5.4–17.1

percent rise in the Tungabhadra River's average annual streamflow in 2050. According to the research conducted by[39].

According to [5], peak runoff in Mahanadi is expected to rise by 38 percent between 2075 and 2100, suggesting a rising flood, whereas average runoff is expected to fall by 32.5 percent between 2050 and 2075, indicating drought conditions. Major flooding in 1750 caused the Brahmaputra River to split and join the Dihing River, resulting in the creation of Majuli Island, the world's largest river island. Due to river erosion, the island's total area shrank from 751.31 km2 in 1971 to 421.65 km2 in 2001, a loss of 3.43 km2 per year on average.

In the present research paper assessment of pollution level, CO_2 Emissions, fossil fuel consumption, Coal consumption, methane emissions, forest area and global temperature and its impact on Rain Fall, Total Fresh Water Withdrawal and Mean Temperature of Watershed were comprehensively reviewed.

Methodology

For the purpose of analyzing the difficulties in evaluating the effects of climate change on Indian water resources, this research makes use of existing literature as well as a variety of fine-resolution datasets. Uncertainties in water resource assessments are identified by examining the most rain fall status, fresh water withdrawals and water shed temperature level, thereafter a critical evaluation is done to determine the degree of uncertainty around the observed and predicted effects of climate change on India's water resources. Researchers examine the connections in the various observed variables responsible for global climate change and the effects of human actions on water resources.

Various statistics of pollution, CO2 emission, fossil fuel consumption, coal consumption, Methane emission and forest area has been taken from official site of world bank and other public sector annual reports from 2009 to 2019.

Table1 Normality Tests

	Statistic	p
Shapiro-Wilk	0.897	0.171
Kolmogorov-Smirnov	0.174	0.839
Anderson-Darling	0.446	0.227

Note. Additional results provided by *moretests*

The Kolmogorov-Smirnov Test and the Shapiro-Wilk Test, two well-known normality tests, are shown in the above table. As a result, we'll utilise the Shapiro-Wilk Test as our numerical method of evaluating normality since it's better suited for small sample sizes (50 samples). Given that the Shapiro-Wilk Test's Sig. value is higher than 0.05, the data are considered normally distributed here.

Table2 descriptive statistics of pollution, CO2 Emissions, fossil fuel consumption, Coal, methane emissions, forest area (% of total land)

Descriptive

	year	pollution (micrograms per cubic meter)	CO2 Emissions (metric tons per capita)	fossil fuel consumption	Coal (TWh; direct energy)	methane emissions (kt of co2 equivalent)	forest area (% of total land)
Sum	2009	50.6	1.29	80.6	40149	7591370	30.9
	2010	50.3	1.35	80.8	41997	7704390	30.9
	2011	50.8	1.41	81.2	44018	7807040	30.8
	2012	47.5	1.51	81.2	44185	7869970	30.8
	2013	47.9	1.54	80.9	4499	7880460	30.8
	2014	45.9	1.65	80.9	4495	7957650	30.8
	2015	47.2	1.64	79.7	4384	8021410	30.7
	2016	45.2	1.65	79.1	4319	8068580	30.7
	2017	45.5	1.72	78.9	4336	8137390	30.7
	2018	45.6	1.88	78.4	4410	8174420	30.0
	2019	44.5	1.92	78.0	4384	8215821	29.9

Source: https://data.worldbank.org/indicator

Table 2 of descriptive statistics shows the different level of pollution, CO_2 emission, fossil fuel consumption, coal consumption, Methane emission and forest area from 2009 to 2019, almost for 10 years here, it is clearly indicated that the pollution (micrograms per cubic meter) is reducing with every successive year, it was 50.6 in 2009 however in 2019 it is 44.5. As CO_2 emission is concerned, we can see that it is being increased with every year, and that is an alarming situation to for the world climate. as regards to fossil fuel consumption is concerned,

some reduction is Noteworthy and it is going down with every succeeding year, however the coal consumption is gearing up with every next year.
Methane emission is one of the major reasons of increasing Global temperature and same is to be indicated in Figure 2, where A Remarkable growth has been considered in the Methane emission since 2019 to 2019 in 10 years and a serious concern for all the environmentalist and the economies as it is the main contributor of the global warming that causes the imbalance rainfall and other things. on the other side forest area is something which protect the environment from the adverse effect of the global warming although unfortunately in last 10 years approximate one percent reduction of total forest area has been noticed that should be taken care of and must be kept 33% at least. all the economies and the environment list advocating the increasing forest area which eventually protect the environment from the direct adverse effect of the ozone depletion and the other adverse effect of environment.

Table 3 Global Temperature

	Year	Global Temperature
Sum	2009	25.5
	2010	25.4
	2011	24.8
	2012	24.8
	2013	24.6
	2014	24.8
	2015	24.9
	2016	25.3
	2017	25.1
	2018	25.0
	2019	24.9

Global temperature has been unpredictable since 2009, it was recorded 25.5 in 2009 and 24.9 in 2019, so here it seems, that it has reduced, but if the whole table is to be observed, this can be stated that the Global temperature has been unpredictable and uncertain in last 10 years. United Nations and all developed countries are much concerned about the increasing Global temperature and therefore the corrective measures are to be taken by the different economy to reduce the level of it, and particularly after 2017 the measures to reduce the carbon emission and global temperature, has been on the top priority of all developed economies and the United Nations as well.

Table 4 Rain Fall in India, Total Fresh Water Withdrawal and Mean Temperature of Watershed

	year	Rain Fall in India (In Millimeters)	Per Cubic Water Total Fresh Water Withdrawal	Mean Temperature of Watershed
Sum	2009	1106	2.00	9.84
	2010	1110	2.11	8.69
	2011	1125	2.55	9.20
	2012	1074	2.87	9.66
	2013	1216	3.01	9.27
	2014	1034	3.51	7.16
	2015	1093	3.48	9.09
	2016	1083	3.86	7.17
	2017	1127	4.10	6.98
	2018	1021	4.46	7.58
	2019	1284	4.89	7.13

CONCLUSION

This research paper concludes that different observed variables such as pollution, CO_2 emission, fossil fuel consumption, coal consumption, methane emission and forest area all affect the global climate adversely and if the current situation remain at place for few years, earth will no longer be safe for human beings as it would have become either too much cold or hot where life cannot be imagined. Several parts of the nation will feel the effects of climate change more acutely in the coming years. Planned and unplanned urban development will be impacted by precipitation changes in many ways, including changes in the design of hydrological infrastructure. Climate change would have an especially negative impact on India's agricultural and water resources economy because of the country's reliance on the monsoon. As a result, it's critical to enhance climate change assessments and adjust methods based on projected outcomes.

Water resource management systems now in place have significant data collecting gaps, such as monitoring and processing systems that are unable to keep up with the anticipated difficulties of a fast-changing climate. Climate change effects, mitigation, and adaptation are all addressed in the National Action Plan on Climate Change (NAPCC), which was announced in 2008. India's long-term goals include increasing forest cover from 23% to 33% of the country's land area and improving water usage efficiency by 20%. (Pandve 2009). Water resource security must be ensured, and climate change causes and consequences must be minimized.

FUTURE COURSE OF ACTION AND POLICY FRAMEWORK

Agrarian economy, 7,517 km of coastline, the Himalayan area, and islands characterize India, a developing nation with the world's highest percentage of the world's impoverished (30 percent). As a result of changing rainfall patterns, groundwater recharge, floods, and droughts, the country's water resources are also under serious danger from climate change. This includes pollution of surface water and groundwater resources. The Government of India's National Water Policy was originally announced in 1987. Considering the constantly changing climate, the 2002 National Water Policy focused on ecological and environmental considerations for allocating water resources. According to India's National Water Policy (2012), water should be seen as a shared resource for the purpose of water resource planning and management. Although governments have implemented numerous policies at various levels, water law is still inconsistent and unsatisfactory in the twenty-first century [32] due to many components at local, regional, national, and international levels and enforcement problems. Increases in urban and bare soil areas have been recorded in India, whereas vegetation losses have occurred. Improved weather forecasting and water resource management may be aided by accounting for changes in land use and land cover [70].

China, the world's most populous country with a burgeoning economy, is extremely reliant on water supply. China's water resources are distributed very unevenly in space and time, with dry areas in the northwest and moist areas in the southeast. During the period 1956–2000, precipitation decreases in the spring and fall while rising in the winter [75]. The annual average temperature is expected to rise by 1.5–2.7°C between 2040 and 2069, and by 1.9–3.3°C between 2070 and 2099 under RCP4.5, which uses 35 climate models from CMIP5. In addition, most of China except for the southwest has seen an increase in precipitation of 2–20 percent [71]. Over the period 1961–2012, the standard precipitation index detected 143 drought episodes in China lasting at least three months [73]. It is intended to increase regional water resources in order to improve water infrastructure, such as a diversion project to relieve dry conditions in the north [51].

Increasing access to high-quality data, upgrading data collecting networks, and promoting interdisciplinary research institutes throughout the nation are all urgently needed in order to address future water resources issues. Using this data, policymakers will be able to make more informed choices on water and climate change issues.

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