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A REVIEW OF THE WORLD'S WATER SCARCITY AS A RESULT OF CLIMATE CHANGE AND ITS PRESERVATION MEASUREMENTS, INCLUDING INDIA

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ABSTRACT - Strategic fresh water supplies for global water and food security will deteriorate because climate change results in stronger floods and droughts, violent cyclones, extreme heat and cold events and altered water systems which lead to declining water reserves and unpredictable rainfall patterns combined with aquifer saltwater penetration and growing agricultural irrigation needs and diminished soil moisture levels and quick surface water evaporation. With a focus on Indian water resources, this analysis sheds light on how climate change affects water volume and quality globally, as well as conservation measures to lessen water scarcity. An estimated 20% of the rise in water scarcity worldwide is thought to be caused by climate change brought on by global warming. Over the past century, the world's water consumption has increased sixfold, and it is predicted to continue growing quickly in the upcoming decades. Two-third of the world's population may live under water stress conditions by 2025, and 1.8 billion people will reside in nations or areas with complete water scarcity. The continent of Africa is most severely impacted by water scarcity. India's gross per capita water availability is expected to drop from approximately 1820 m^3 annually in 2001 to as low as approximately 1140 m^3 in 2050. By 2050, the nation will require 1180 billion cubic meters (BCM) of water each year. Therefore, water resources must be used sustainably, climate adaptation plans be developed, the public and government be made aware of the depletion of water supplies, and immediate steps be taken to conserve and harvest water locally, nationally, and internationally.

KEYWORDS – Climate change, depletion, conservation, water scarcity, and Intergovernmental Panel on Climate Change (IPCC).

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1. Introduction

Two-third of humankind or 4 billion individuals experience lack of water resources. The areas of Sub-Saharan Africa face the highest level of water scarcity while China and India contain approximately 50% of the planet's population. Southern Asia and Northern China as

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well as Australia, the United States, Mexico and north eastern Brazil together with the Mediterranean Region, the Middle East, Near East and Northern Africa and the USA and West Coast of South America are water-stressed basins with annual water availability under 1,000 m^3 per year (Grafton and Hussy, 2011). According to Vörösmarty et al. (2000) and Alcamo et al**.,** (2003) coupled with Arnell (2004) these highly stressed water basins will experience population growth of 1.4 billion to 2.1 billion people. Estimates about high-water-stress population numbers differ significantly throughout various regions of the world (Panwar and Chakrapani 2013 and Rodell et al**.,** 2009 and Shah 2009 and Kundzewich 2007). Indian water availability will not match projected water requirements in 2030 which will negatively impact millions of people with severe water scarcity. A 6% reduction in GDP forms the predicted effect of this situation according to Rana and Guleria (2018).

According to the United Nations (2020) global climate changes will make existing water-stressed regions more dire and introduce new regions where water shortages become problematic. The available clean water supply shows parallel growth patterns with GDP per capita which serves as an economic indicator. Water scarcity together with climate change has significant effects on global human populations based on findings from Khan (2014), Mehta (2012), Jain (2011), Johan (2009), Mall (2006) and Kumar (2005). Experts predict that more than fifty percent of Earth's inhabitants will experience water security problems during the year 2025. Human agriculture consumes more than 70 percent of all fresh water human populations use. Climate change negatively impacts water availability and creates increased pressure to irrigate fields because it reduces crop production levels. A total of 1.2 billion people occupying water-stressed agricultural land make up one-sixth of the global population and an additional 3.2 billion inhabitants live in regions facing various levels of severe water stress in their cultivated areas (FAO, 2020). The use of aquifers has increased because of surface water resource deterioration which leads to sinking groundwater levels.

2. Climate Change Scenario

Global warming will create 20% of worldwide water scarcity, expected to occur in this century. Water consumption across the globe increased sixfold during the past century and has outpaced demographic expansion by over two times while showing rapid projected growth in the next decades. The GMST during 2016–2020 marked the most elevated temperature reading in human history for that time span. Observations show that the planet exceeds 1.1 °C (+/-0.1°C) compared to pre-industrial temperatures from 1850-1900 and contains 0.24 °C (+/-

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0.10°C) more heat than the GMST temperatures from 2011-2015 (WMO 2020). According to expert findings anthropogenic heating produces a 0.2 degree Celsius rise which experts have projected between 0.1 to 0.3 degrees per decade (Intergovernmental Panel on Climate Change SR15 2018).

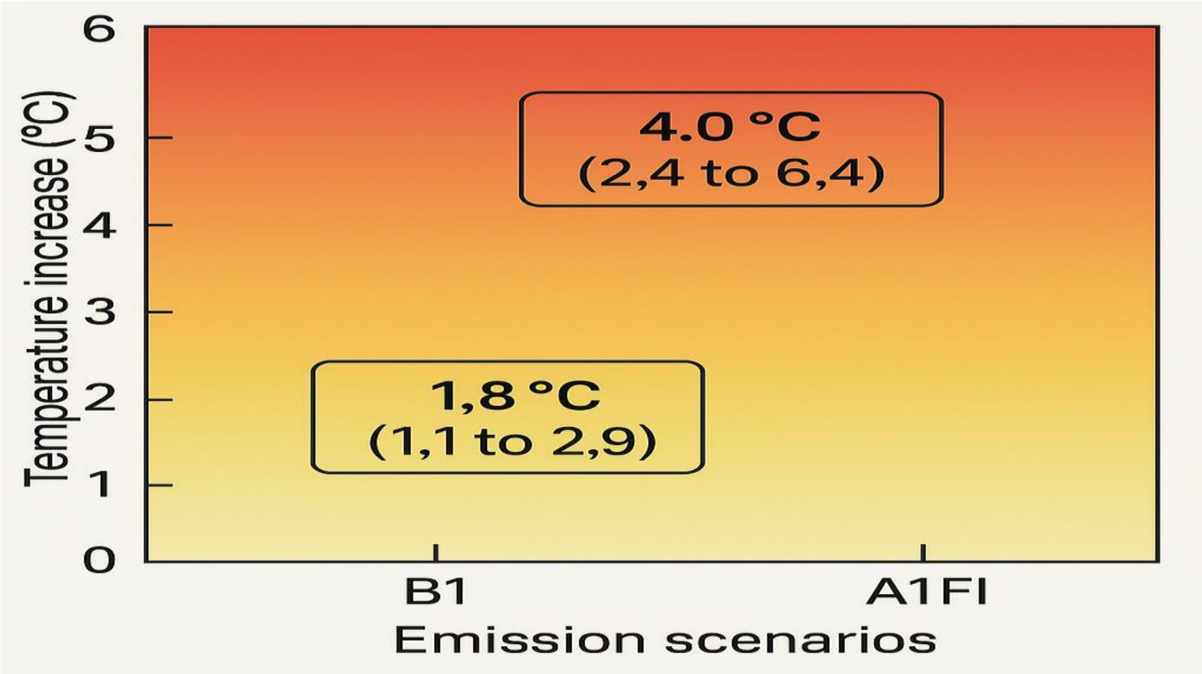

Fig. 1: Temperature of the earth's surface under various emission scenarios. According to scenario B1 the estimated temperature increase is 1.8 °C with expected values between 1.1 °C and 2.9 °C and scenario A1FI projects a temperature rise of 4.0 °C while the possible outcomes vary from 2.4 °C to 6.4 °C.

The followings are the possible outcomes of increased atmospheric concentrations of greenhouse gases:

a) An increase in average temperatures impacts all four climatic factors including lowest winter temperature and summertime average temperature, summertime average precipitation and growth season intensity.

b) Modifications to the rainfall's temporal and spatial distribution.

c) A higher chance of droughts and periods of intense rains.

d) As the temperature of the atmosphere rises, so does its capacity to store water. Thus, the rate of transpiration and evaporation rises. Temperature variations are also associated with cloudiness, humidity, and windiness.

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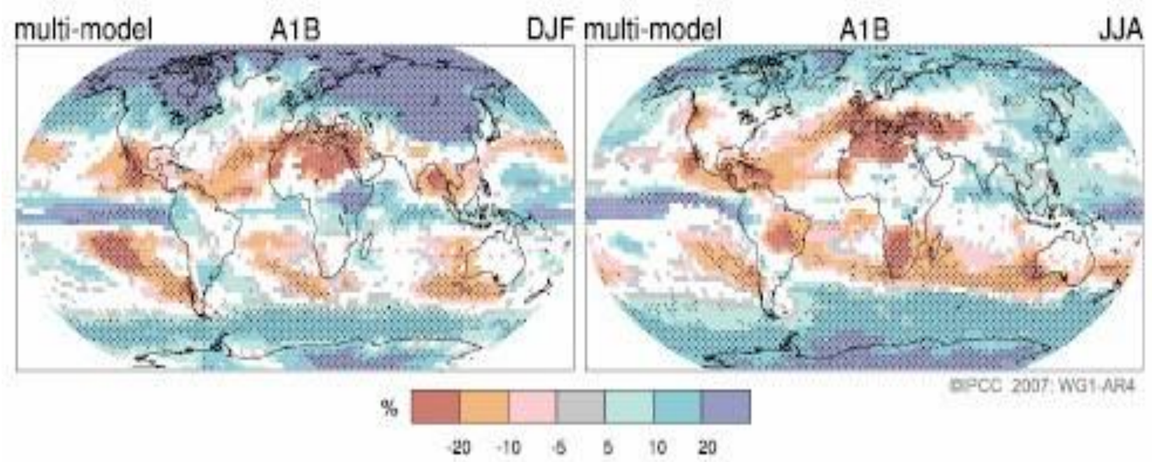
e) Around the world, the amount and location of liquid fresh water are changing due to climate change. The quality of life in those areas is severely impacted when this turns into a chronic problem due to frequent droughts and flood.

According to a UK Meteorological Office report, catastrophic droughts that currently happen once every 50 years could happen every other year by 2100 if action is not taken to slow down climate change.

- **Signs of modifications to the hydrological cycle**

Climate extremes, such as drought, floods, and storms, can happen anywhere in the world due to changes in hydrological systems, which include ocean currents, precipitation patterns, and temperature trends. The alterations made to climatic conditions potentially lead to altered precipitation pattern, magnitudes and frequencies.



(Source: Intergovernmental Panel on Climate Change)
https://www.researchgate.net/profile/Ronald Skeldon/publication/253396071/figure/fig1/AS:298161311633414@1448098604698/Relative-changes-in-precipitation-in-percentages-for-the-period-2090-2099-relative-to.png

Fig. 2: Percentage variations in precipitation between 1980 and 1999 and between 2090 and 2099.

The figures present SRES A1B scenario multimodel mean results during December through February (left panel) alongside June to August (right panel). Over 90 percent of the modeling consensus exists in stippled areas for changes in signs but white areas contain agreement from less than 66 percent of models.

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• Global warming has caused night-time temperatures to climb twice as fast as daytime temperatures since 1950. This has increased cloud cover and humidity, as well as cooling from evaporation during the day.

• The mean concentration of water vapor in the atmosphere has increased. Precipitation into the seas and runoff from the continents must balance out ocean evaporation to preserve the water balance. According to satellite and radiosonde data, the mean concentration of water vapour in the atmosphere has risen, allowing storms to produce more precipitation.

• The middle and high latitudes have seen an increase in precipitation. Over the 20th century, the average annual rainfall in the United States increased by 10%. Since 1950, rainfall has significantly decreased in the tropical regions of the northern Hemisphere, particularly in Africa. The amount of rainfall, evaporation rate, and sea surface temperature have all increased in the tropical Pacific.

• Increased severity of weather extremes: In the Northern Hemisphere, storms linked to atmospheric fronts have been reported to be more intense.

• The United States and Australia had higher rainfall as a result of an above-normal increase in the mean monthly average temperature.

3. Scarcity of water

Conventionally hydrologists employ the population-water equation as their primary tool for shortage evaluation. Water stress develops in an area when its annual water supply per person reaches less than 1,700 m^3 (Gulati and Banerjee, 2016). The population faces water scarcity when yearly water supplies drop below 1,000 cubic meters per person and experiences "absolute scarcity" for supplies that fall below 500 cubic meters per person. By 2025 both China and India remain predicted to endure the effects of water scarcity between any nations.

Effect of Climate Change on Ground and Surface Water Resources:-

• **Water scarcity in India-** The 18% share of the global population lives in India despite its possession of just 4% of global water resources. Severe water scarcity impacts 600 million Indians as three-quarters of households throughout the country do not receive clean drinking

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water services. The irrigation industry consumes almost 78% of the entire national water usage given that it remains the largest water-consuming sector (Gulati and Banerjee 2016).

The annual water availability for each person in India decreased from 6,042 cubic meters in 1947 to 1,545 cubic meters in 2011 and experts predict it will decrease further to 1,340 cubic meters by 2025 followed by 1,140 cubic meters by 2050, as per the Ministry of Water Resources statistics. Irrational water scarcity problems threatened multiple Indian cities like Delhi and Bengaluru as well as their counterparts Hyderabad and Shimla.

Scientists recognize the western and peninsular regions of India among the most vulnerable areas concerning groundwater during climate change. The experts at Eddy et al., (2011) estimate that the Ganga basin will experience temperature rises between 1 and 4.8°C during the 2000-2050 time period. The main problem when using on-site sanitation systems is how pathogenic bacteria and viruses move directly from these systems into nearby groundwater sources and underground aquifers.

The procedure will affect both groundwater critical levels and emission rates and operation expenses (Green, 2011). Research shows that groundwater pumping with electricity and fuel leads to the production of 16–25 million mt of carbon emissions which correspond to 4–6% of India's total carbon output. Researchers from Ahsan et al., (2020) and Markou et al., (2020) agree that agriculture will become the most vulnerable industry due to climate change effects and unpredictable weather patterns.

Research by WRI (2014) indicates that 54% of Indian territory faces high to extremely severe stress levels in the areas monitored. The northwest section of India shows the most severe stress zone. Both Punjab and Haryana together provide 50% of Indian rice supply while holding 85% of national wheat reserves. This makes the region India's food-producing hub. Plenty of water consumption is necessary to grow these two crops. Regions with red and dark-red colors have been classified as highly or severely stressed and they absorb 40% of annual surface water availability according to Central Ground Water Board study results from 2017. These areas include 1499 of the 6881 units studied. The region classified as dry along with the categories of "critical" and "over-exploited" makes up 22% of the assessed ground water units throughout the nation.

Groundwater levels in India decline swiftly because people increasingly draw water from below the surface. One meter of vertical descent occurred each year at 16 percent of

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analyzed wells from IWT 2.0. The Northwestern region of India faces the highest vulnerability in this situation. The 550 wells across the region show declining groundwater levels in 58% of their examined wells. The research shows that national water supply will fall behind demand by 50% during the year 2030. The water extraction rate exceeds the rate at which water replenishes annually in these particular states. The Indian city of Chennai officially operated exclusively on groundwater supplies for the first time in 2019.

4. Reasons for water scarcity in India

• Growing water demand as a result of urbanization, industry, population growth, and a rise in agricultural activity.

• Ineffective water management and distribution of water among industry, agriculture, and urban users.

• Inefficient agricultural water use, including the cultivation of water-intensive crops like rice in water-scarce locations.

• Chemical and wastewater discharge into ponds, rivers, and streams.

• The discharge of effluent and sewage into bodies of water bodies.

• A decrease in conventional locations for water recharge. The majority of the rainwater that falls on us ends up in rivers and the ocean as surface runoff.

• The development of dams and other infrastructure has made traditional rainwater gathering methods, such as building Johads and Khadins, less common.

• Large water bodies that could increase their capacity to store water during the monsoon season do not have timely de-silting activities.

• Overuse of readily accessible ground and surface water supplies. The water supply is being drastically reduced by the careless use of groundwater caused by borewell excavation and electricity-powered groundwater pumping. There are now almost 20 million borewells in India, compared to hundreds in the past.

• One of the main causes of water scarcity is the changing climate.

5. The effects of climate change on food security and water resources

Agricultural productivity will suffer as a result of the precipitation fluctuations. Future projections indicate that India's winter precipitation will decrease, which would raise the need for water to irrigate rabi crops. Heavy droughts and floods will also affect Kharif crop production. Higher temperatures will encourage weed growth and their migration to higher latitudes. Consequently, crops may experience increased environmental stress, making them

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more susceptible to weeds, insects, and diseases. Weed growth's impact on yield indicates losses of 28–74% for rice and 15–80% for wheat, respectively. These setbacks will negatively affect the GDP and economic growth of the country. In India, the agricultural sector uses over 89% of the water resources that are available. Temperature and precipitation variations will cause the soil to lose moisture, which may lower agricultural productivity. Rain-fed agriculture will be immediately impacted by this depletion, while areas that rely on surface and groundwater will be indirectly affected (Zhuo et al., 2017). Despite the positive benefits of increased CO_2 on crop development, it is predicted that India's crop production could decline by 10–40% by the year 2100 AD. With each degree Celsius increase in the global mean temperature, the yield of wheat, rice, maize, and soybeans would probably decline by roughly 6%, 3.2%, 7.4%, and 3.1%, respectively (Zhao et al., 2017). Water-efficient technologies like drip and sprinkler irrigation should be developed and used by farmers.

6. Conservation strategies of India

Indian laws promote water conservation by creating new legislation to control water pollution. Organizations are using the Environment (Protection) Act of 1986 along with the Water (Prevention & Control of Pollution) Act of 1974 whether through public interest litigation based on Articles 32 and 226 of the Indian Constitution. Many global organizations such as businesses and institutions work towards water preservation activities throughout the world. Water scarcity has transformed into a worldwide crisis that United Nations initiatives step by step reveal to the public. Around the globe the problem of water scarcity gained increased prominence when World Water Day 2007 selected “Coping with water scarcity” as its central theme. The 2013 World Day to Combat Desertification explored the relationship between water shortage and drought as they influence land deterioration processes. The International Drinking Water Supply and Sanitation Decade marks a designated timeframe that strengthens the need for providing access to clean drinking water.

Various government initiatives have been taken to both save water resources and stop shortages. Establishing the National Water Development Agency in 1982 along with implementing the Integrated Watershed Management Programme (IWMP) and starting the National Water Mission form part of the government's water conservation efforts. The Indian

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government declared 2013 the "Water Conservation Year" as part of its sustained efforts to promote sustainable water usage.

NITI Aayog introduced the Composite Water Management Index as a practical instrument to evaluate and enhance the effectiveness of water resource management (Rana and Guleria, 2018).

India must take the following actions to conserve water:

• **Mitigation of Drought and Water Banking:** The capability to utilize and access water stands fundamental for implementing the water banking framework. The establishment of water banks becomes possible through groundwater storage and water transfer which aids in addressing drought-caused environmental damage and agricultural difficulties as well as economic consequences. Water banks defend water resources while safeguarding against drought conditions so that farmers can utilize water traditionally for agricultural purposes.

• **The Water Misuse Act:** Protecting our water sources will be aided by the creation of an act for water usage and the strict application of the current water laws.

• **Rainwater harvesting that works:** In addition to replenishing groundwater aquifers, it will lessen surface runoff during the rainy season.

• **Encouragement of afforestation:** Trees help absorb rainfall, replenish groundwater, and stop surface runoff and erosion. Since they are the Earth's CO_2 sinks, afforestation is the most effective strategy to lessen the effects of climate change.

• **Encouraging sustainable, adaptable agriculture:** The agriculture industry utilizes the most Earth's fresh water resources so sustainable farming methods need adoption. The system includes crop weather advisories and environmentally friendly farming methods as well as native and enhanced cultivars and better soil health and biodiversity preservation. Drip irrigation systems and sprinkler technology should receive promotion and training through farmer education programs for water conservation purposes.

• **Encouraging groundwater recharge:** Without sufficient aquifer recharge and more prudent and effective water usage, the nation would not be able to satisfy its future demands. The gathering of rainwater should be prioritized. Groundwater levels will rise when check dams are constructed on riverbeds.

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• **By raising public awareness:** People who are more knowledgeable about water management and conservation will be able to use water more effectively and save it. Adopting water budgeting, water usage efficiency, etc., need incentives for communities.

7. Conclusion

The population of India that suffers from severe water stress stands at approximately 600 million. The upcoming decades are likely to worsen the water shortage crisis. Water management procedures involving Reduce Reuse and Recycle should operate at all consumption levels to deal with diminishing water supply. We still have more work to do to ensure that water is used sustainably, that water resources are protected and conserved, that rainwater is collected, that surface and ground resources are developed, that water banks are established, etc. In order to minimize losses, preserve productivity, and take advantage of the opportunities presented by climate change, people should learn to adapt to and manage climate-induced shocks, such as storms, prolonged dry spells, unseasonable and heavy rainfall, and rising temperatures.

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