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"CLIMATE CHANGE AND GROUNDWATER DEPLETION IN INDIA: TRENDS, CAUSES, AND POLICY RESPONSES"

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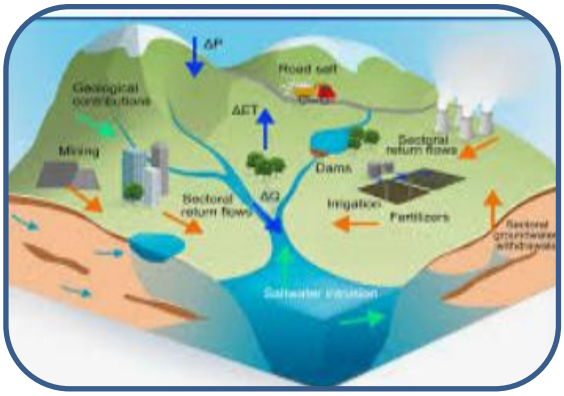
ABSTRACT:



Groundwater is a critical resource for agriculture, drinking water, and industrial use in India, supporting nearly half of the country's irrigation needs and a major share of rural water supply. However, the combined pressures of climate change and unsustainable extraction have led to alarming levels of groundwater depletion across several regions. Variability in rainfall patterns, delayed monsoons, rising temperatures, and increased frequency of droughts particularly linked to changes in the Indian Monsoon have significantly reduced natural recharge rates. As surface water availability declines, dependence on groundwater has intensified, further accelerating depletion. States such as Punjab, Haryana, Rajasthan, and parts of Madhya Pradesh are witnessing critical groundwater stress due to intensive agricultural practices and water-intensive crops. Climate-induced evapotranspiration, declining soil moisture, and irregular precipitation patterns exacerbate the crisis. In response, the Government of India has implemented various policy measures under the Ministry of Jal Shakti, including groundwater regulation frameworks, watershed development programs, and initiatives such as aquifer mapping and rainwater harvesting promotion. Despite these efforts, gaps remain in enforcement, community participation, and climate-resilient water management strategies. This paper examines the trends and causes of groundwater depletion in India within the context of climate change and critically evaluates existing policy responses. It emphasizes the need for integrated water resource management, sustainable agricultural practices, and localized climate adaptation strategies to ensure long-term water security.

KEYWORDS: *Climate Change, Groundwater Depletion, Indian Monsoon and Water Security.*

INTRODUCTION:

Groundwater plays a central and indispensable role in India's socio-economic framework, acting as a lifeline for agriculture, domestic consumption, and industrial development. In a country where a significant portion of the population depends directly on agriculture for livelihood, groundwater serves as the primary source of irrigation, contributing nearly half of the total irrigated area. It also fulfils a substantial share of drinking water needs, especially in rural areas where piped water supply systems are limited. Over the decades, the expansion of irrigation infrastructure, particularly through tube wells and bore wells, has led to a dramatic increase in groundwater extraction. As a result, India has emerged as the largest user of groundwater globally, accounting for nearly one-fourth of total global groundwater withdrawal. While this extensive use has supported agricultural productivity and food

security, it has simultaneously placed immense pressure on aquifer systems, leading to unsustainable extraction patterns and declining water tables across many regions.

The increasing demand for groundwater is driven by multiple interrelated factors, including rapid population growth, urbanization, industrialization, and changing consumption patterns. The Green Revolution, which significantly boosted agricultural output, also intensified groundwater usage due to the widespread cultivation of water-intensive crops such as rice and sugarcane. In many parts of India, groundwater has become a default and often unregulated resource, largely due to its accessibility and reliability compared to surface water sources. However, this overdependence has resulted in the over-exploitation of aquifers, with several regions now categorized as "over-exploited" or "critical." The situation is further aggravated by inadequate regulation, lack of effective monitoring systems, and limited awareness among users regarding sustainable water management practices. Consequently, groundwater depletion has emerged as one of the most pressing environmental and developmental challenges facing the country today.

In recent years, climate change has added a new dimension to the groundwater crisis, intensifying both its scale and complexity. Climate change affects the hydrological cycle in multiple ways, altering precipitation patterns, increasing temperatures, and influencing evapotranspiration rates. In the Indian context, the monsoon system plays a crucial role in replenishing groundwater reserves. However, climate-induced changes in the monsoon-such as delayed onset, uneven spatial distribution, and increased frequency of extreme rainfall events have disrupted the natural recharge processes of aquifers. Instead of steady and moderate rainfall that facilitates percolation into the ground, many regions now experience short bursts of intense rainfall, which leads to surface runoff rather than groundwater recharge. This shift significantly reduces the efficiency of natural replenishment mechanisms.

Rising temperatures associated with climate change further exacerbate the problem by increasing evaporation and evapotranspiration rates. Higher temperatures not only reduce soil moisture but also increase the water requirements of crops, thereby intensifying irrigation demand and, consequently, groundwater extraction. In addition, the increasing frequency and severity of droughts in various parts of the country have forced communities to rely even more heavily on groundwater as a fallback resource. This cyclical pattern where climate change reduces water availability and simultaneously increases demand creates a vicious cycle that accelerates groundwater depletion. Regions such as Punjab, Haryana, Rajasthan, and parts of central India, including Madhya Pradesh, have witnessed particularly severe declines in groundwater levels due to this combined effect of climatic and anthropogenic pressures.

Another critical aspect of the groundwater crisis is the degradation of water quality, which often accompanies quantitative depletion. As groundwater levels decline, the concentration of dissolved salts and contaminants tends to increase, leading to issues such as salinity, fluoride contamination, and arsenic presence in certain regions. Climate change can further influence these processes by altering groundwater flow patterns and increasing the intrusion of saline water in coastal aquifers due to sea-level rise. Thus, the challenge of groundwater management is not limited to ensuring adequate quantity but also involves maintaining acceptable quality standards for safe and sustainable use.

Recognizing the gravity of the situation, the Government of India has undertaken several initiatives aimed at improving groundwater management and promoting sustainable water use practices. Policies and programs such as aquifer mapping, watershed development, rainwater harvesting, and demand-side management have been introduced to address the issue. Institutions like the Central Ground Water Board (CGWB) and the Ministry of Jal Shakti play a key role in monitoring and regulating groundwater resources. However, despite these efforts, significant gaps remain in terms of implementation, coordination, and community participation. Many policies continue to be supply-driven rather than demand-oriented, and enforcement mechanisms are often weak or inconsistent. Furthermore, the integration of climate change considerations into groundwater management strategies is still at a nascent stage. In this context, it becomes imperative to adopt a holistic and integrated approach to groundwater management that takes into account both climatic and non-climatic factors. Sustainable solutions must involve a combination of technological interventions, policy

reforms, and behavioural changes at the community level. Practices such as efficient irrigation methods, crop diversification, artificial recharge, and decentralized water management systems can play a crucial role in mitigating groundwater depletion. At the same time, there is a need to strengthen institutional frameworks, improve data availability, and enhance public awareness regarding the importance of water conservation.

Therefore, this study seeks to analyse the trends and underlying causes of groundwater depletion in India, with a particular focus on the role of climate change. It also aims to critically evaluate existing policy responses and identify gaps that hinder effective implementation. By examining the interplay between environmental changes and human activities, the study attempts to provide insights into sustainable groundwater management strategies that can ensure long-term water security. The findings of this research are expected to contribute to the ongoing discourse on climate resilience and resource sustainability, highlighting the urgent need for coordinated and adaptive approaches to address one of the most critical challenges of our time.

OBJECTIVES OF THE STUDY:

1. To examine the trends of groundwater depletion in India.
2. To analyse the impact of climate change on groundwater resources.
3. To identify major causes of groundwater depletion.
4. To evaluate government policies and programs.
5. To suggest sustainable solutions for groundwater management.

METHODOLOGY:

The present study is primarily based on secondary data collected from a variety of reliable and authoritative sources. These include government publications such as reports from the Ministry of Jal Shakti and the Central Ground Water Board, which provide comprehensive data on groundwater levels, extraction rates, and policy initiatives. In addition, peer-reviewed research papers, academic journals, and scholarly articles have been consulted to understand the scientific dimensions of climate change and its impact on groundwater systems. Reports from international organizations such as the Intergovernmental Panel on Climate Change and the World Bank have also been utilized to gain a global perspective and comparative insights into water resource management and climate-related challenges. These diverse sources ensure the credibility, validity, and depth of the data used in the study. For the analysis, both descriptive and analytical methods have been employed to interpret the collected data and identify key trends and patterns. The descriptive approach has been used to present an overview of groundwater depletion, climate variability, and policy frameworks in a systematic manner. Meanwhile, analytical techniques have been applied to examine the relationship between climate change factors such as rainfall variability, temperature rise, and drought frequency and groundwater dynamics. The study also critically evaluates existing policies and programs to assess their effectiveness in addressing groundwater depletion. Through this combined methodological approach, the research aims to provide a comprehensive understanding of the issue and to highlight gaps, challenges, and potential areas for improvement in groundwater management strategies.

DISCUSSION:

Groundwater depletion in India has emerged as a serious concern over the past few decades, characterized by a continuous decline in water table levels across many regions. According to the Central Ground Water Board, a large number of assessment units are now categorized as "over-exploited" and "critical," indicating that groundwater extraction exceeds natural recharge (CGWB, 2023). In several states such as Punjab, Haryana, Rajasthan, Uttar Pradesh, and Madhya Pradesh, groundwater levels are declining at rates of 0.5 to 1 meter per year, which is highly unsustainable.

The high dependency on groundwater for irrigation, accounting for nearly 60–70% of total irrigation, is one of the major reasons for this decline (NITI Aayog, 2018). Additionally, erratic rainfall patterns and reduced recharge rates due to climate variability have worsened the situation. Urbanization and land-use changes have further limited infiltration, thereby disturbing the balance

between extraction and recharge. These trends highlight the growing threat to India's water security and the urgent need for sustainable groundwater management.

Groundwater depletion in India is driven by a combination of climatic, agricultural, demographic, and institutional factors. Climate change has significantly altered rainfall patterns, delayed monsoons, and increased temperatures, resulting in higher evapotranspiration and reduced groundwater recharge (IPCC, 2021). Frequent droughts and extreme weather events have further intensified dependence on groundwater resources.

Agricultural practices also play a crucial role, particularly the cultivation of water-intensive crops such as paddy and sugarcane. The widespread use of tube wells and bore wells, often without regulation, has led to excessive groundwater extraction (World Bank, 2020). Rapid population growth and urbanization have increased demand for domestic and industrial water, further straining groundwater resources. In addition, poor water governance, lack of strict regulations, weak policy enforcement, and limited public awareness have contributed significantly to the ongoing depletion.

Climate change has both direct and indirect impacts on groundwater resources. One of the most significant effects is the reduction in recharge due to irregular and intense rainfall patterns. Instead of gradual infiltration, heavy rainfall leads to runoff, reducing groundwater replenishment (IPCC, 2021). Rising temperatures also increase evaporation and evapotranspiration, leading to reduced soil moisture and increased irrigation demand. Another major impact is the deterioration of groundwater quality. In coastal areas, rising sea levels contribute to salinity intrusion into aquifers, making water unsuitable for use. Reduced surface water availability further increases dependence on groundwater, accelerating its depletion (World Bank, 2020). These impacts collectively threaten water security and highlight the need for climate-resilient groundwater management strategies.

The Government of India has introduced several policies and programs to address groundwater depletion. The Ministry of Jal Shakti has taken a central role in implementing water conservation strategies, while the Central Ground Water Authority regulates groundwater extraction. These institutions have developed frameworks to promote sustainable groundwater use (Ministry of Jal Shakti, 2022). Key initiatives include the Atal Bhujal Yojana, which emphasizes community participation, and the Jal Jeevan Mission, which aims to provide safe drinking water to rural households. The National Aquifer Mapping Programme (NAQUIM) helps in scientific management of groundwater resources. Additionally, watershed development programs, rainwater harvesting, and micro-irrigation techniques have been promoted to improve water conservation (CGWB, 2023). These initiatives aim to enhance groundwater recharge and ensure sustainable use.

Despite various initiatives, groundwater management in India faces significant implementation challenges. Weak enforcement of groundwater laws allows continued over-extraction, particularly in rural and agricultural areas (NITI Aayog, 2018). The lack of coordination among different agencies also affects the efficiency of policy execution. Another major issue is limited community participation, which is crucial for sustainable water management. Additionally, insufficient data and monitoring systems make it difficult to assess groundwater conditions accurately. Climate change adaptation is also not adequately integrated into existing policies, limiting their effectiveness (IPCC, 2021). These challenges highlight the need for stronger governance and improved institutional mechanisms.

SUGGESTIONS AND RECOMMENDATIONS:

To address groundwater depletion, a holistic and integrated approach is required. The adoption of Integrated Water Resource Management (IWRM) can help in the efficient use of both surface and groundwater resources. Agricultural reforms, such as shifting to less water-intensive crops and promoting efficient irrigation systems, can significantly reduce water demand (FAO, 2018). Climate adaptation strategies, including rainwater harvesting, watershed management, and artificial recharge structures, should be implemented at the local level. Strengthening policies through strict regulation of groundwater extraction and improved monitoring systems is essential. Community-based water management and awareness programs can further enhance sustainability. These measures can collectively ensure long-term groundwater security in India.

CONCLUSION:

Groundwater depletion in India is a critical issue exacerbated by climate change and unsustainable extraction practices. The declining trends pose a serious threat to agriculture, drinking water supply, and overall water security. Although several government initiatives have been introduced, their effectiveness is limited due to gaps in implementation and lack of public participation. Addressing this issue requires a multi-dimensional approach that integrates climate resilience, sustainable agriculture, and efficient water management practices. Strengthening institutional frameworks, enhancing community involvement, and promoting awareness are essential for ensuring long-term groundwater sustainability. With coordinated efforts, it is possible to mitigate groundwater depletion and secure water resources for future generations.

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