I J C R M

International Journal of Contemporary Research In Multidisciplinary

Research Article

A Study on Environmental Repercussions of Groundwater Overuse in India's Agricultural Practices: A Regional Analysis

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Abstract

Groundwater is a critical resource for agriculture in India, supporting nearly 60% of the country's irrigation needs. However, the relentless exploitation of groundwater for farming has led to alarming environmental and socio-economic consequences. This paper explores the extent of groundwater exploitation in Indian agriculture and its cascading effects on ecosystems, rural livelihoods, and sustainable development. Over-extraction has resulted in declining water tables, reduced aquifer recharge rates, and increased energy consumption for water pumping, contributing to climate change. Additionally, groundwater depletion exacerbates soil salinity, impacts crop productivity, and threatens biodiversity in groundwater-dependent ecosystems. The study analyzes regional disparities in groundwater use, highlighting the severe crisis in states like Punjab, Haryana, and Rajasthan, where water-intensive crops dominate agricultural practices. It evaluates the role of government policies, subsidies for electricity and irrigation, and farmers' reliance on high-yield practices as key drivers of unsustainable groundwater use. Furthermore, the paper discusses alternative strategies such as the promotion of water-efficient technologies (e.g., micro-irrigation), crop diversification to less water-intensive crops, and community-based water management systems. This presentation represents a multi-stakeholder approach to tackling groundwater exploitation, balancing agricultural productivity with environmental sustainability. The findings advocate for policy reforms, education for farmers, and collaborative efforts to conserve groundwater resources, ensuring long-term agricultural resilience and ecological balance in India.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 09-01-2025
- **Accepted:** 12-02-2025
- **Published:** 16-02-2025
- **IJCRM:**4(1); 2025: 233-237

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Manuscript

Swetha P, Karunamoorthi G. A study on environmental repercussions of groundwater overuse in India's agricultural practices: A regional analysis. Int J Contemp Res Multidiscip. 2025;4(1):233-237.

KEYWORDS: Groundwater Exploitation, Over-Extraction, Micro-Irrigation, Crop Diversification, Multi-Stake Approach.

1. INTRODUCTION

Groundwater is the backbone of Indian agriculture, supplying nearly 60% of the country's irrigation needs. With around 251 billion cubic meters (bcm) of groundwater extracted annually, India is the largest consumer of groundwater in the world, surpassing China and the United States combined. The Green Revolution significantly increased food production but also led to the overextraction of groundwater, especially in states like Punjab, Haryana, and Rajasthan, where water-intensive crops like rice and wheat dominate. According to the Central Groundwater Board (CGWB) 2022 report, nearly 36% of India's assessment units are either over-exploited or critical, meaning groundwater withdrawal exceeds natural recharge rates. The stage of groundwater extraction (ratio of annual groundwater

extraction to net annual availability) in Punjab has reached 163.76%, in Rajasthan 148.77%, and in Haryana 135.74%, indicating severe depletion.

The over-extraction of groundwater has resulted in falling water tables, soil salinity, increased energy consumption for water pumping, and loss of biodiversity. Additionally, groundwater depletion is exacerbating climate change effects by increasing the carbon footprint of agriculture through higher energy demands for deep-bore water pumping.

Addressing this crisis requires policy reforms, efficient irrigation techniques (e.g., micro-irrigation), crop diversification, and community-based water management systems to ensure long-term agricultural sustainability and water security in India.

2. OBJECTIVES OF THE STUDY

a. To analyze the extent of groundwater exploitation in Indian agriculture and its environmental consequences.
b. To examine regional disparities in groundwater use, focusing on states like Punjab, Haryana, and Rajasthan.
c. To assess the impact of over-extraction on soil quality, crop productivity, and rural livelihoods.
d. To explore sustainable alternatives such as micro-irrigation, crop diversification, and community-based water management.

3. Limitations of the Study

a. **Data Constraints:** Limited availability of real-time and region-specific groundwater data.
b. **Regional Focus:** The study primarily focuses on select states, which may not fully represent national variations.
c. **Policy Implementation Gaps:** Challenges in assessing the actual impact of government policies on groundwater conservation.
d. **Farmer Adoption Barriers:** Difficulty in measuring farmers' willingness to adopt sustainable *practices.*

4. Significance of the Study

This study highlights the critical issue of groundwater over-exploitation in Indian agriculture and its environmental, economic, and social impacts. It examines regional disparities, focusing on states like Punjab, Haryana, and Rajasthan, and explores the consequences on soil health, crop productivity, and rural livelihoods. By analyzing sustainable solutions such as micro-irrigation, crop diversification, and community-based water management, the study provides valuable insights for policymakers and farmers. It advocates for policy reforms and awareness initiatives to ensure long-term groundwater sustainability and agricultural resilience in India.

5. METHODOLOGY

This study uses a qualitative research design based on secondary data and a review of 20 relevant literature sources. Data was collected from government reports, academic journals, and reliable publications focusing on Groundwater exploitation in Indian Agriculture.

6. Groundwater Depletion in India: Causes and Consequences

Groundwater is a vital resource for Indian agriculture, supporting approximately 60% of the country's irrigation needs. However, its extensive exploitation has led to significant environmental and socio-economic challenges.

Extent of Groundwater Exploitation:

Over-Extraction: In several regions, groundwater extraction rates have surpassed natural recharge capacities. For instance, in northwest India, the decoupling of groundwater storage from precipitation patterns after 2012 indicates that groundwater pumping for agriculture has a more substantial impact than climate factors.

Declining Water Tables: Continuous over-extraction has resulted in persistently declining groundwater levels, leading to groundwater droughts in various parts of the country.

7. Causes of Groundwater Exploitation

Groundwater exploitation in Indian agriculture is driven by factors such as high dependence on groundwater for irrigation (nearly 60% due to unreliable monsoons and declining surface water), the cultivation of water-intensive crops like paddy and sugarcane, and subsidized electricity for pumping, which encourages over-extraction. Inefficient irrigation practices, such as traditional flood irrigation, waste water, declining rainwater harvesting, and recharge systems, further limit replenishment. Climate change increases the demand for groundwater, and poor enforcement of groundwater regulations, along with unregulated borewell drilling, leads to unchecked depletion of this crucial resource.

8. Consequences of Groundwater Exploitation

Groundwater exploitation in India has several severe consequences. In states like Punjab and Rajasthan, where extraction rates exceed 150%, groundwater tables are rapidly declining. Overextraction also leads to soil salinization, reducing fertility and crop productivity. Increased use of deeper borewells and high-powered pumps raises energy costs for farmers. Additionally, depleting groundwater harms ecosystems, threatening biodiversity in wetlands and rivers. Water shortages reduce agricultural productivity, jeopardizing food security and farmers' livelihoods. Furthermore, excessive withdrawal leads to groundwater contamination, increasing health risks from arsenic, fluoride, and heavy metals. This crisis contributes to socio-economic distress in rural areas, with crop failures, debt, and migration becoming prevalent.

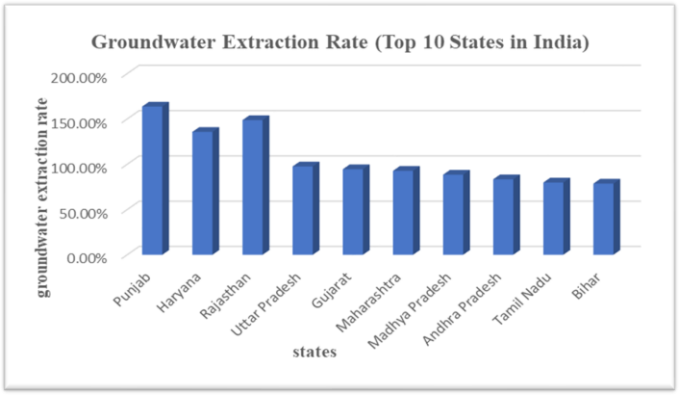
9. Environmental impacts

Over-extraction of groundwater leads to severe environmental consequences. It causes soil degradation through salinization, reducing fertility and lowering crop yields. Additionally, groundwater depletion disrupts ecosystems that rely on it, threatening biodiversity and overall environmental sustainability. Excessive withdrawal also reduces river flows, impacting wetlands, limiting water availability, and endangering

aquatic life. These effects highlight the urgent need for sustainable water management practices.
Addressing these challenges requires implementing sustainable water management practices, promoting water-efficient irrigation techniques, and encouraging crop diversification to reduce reliance on water-intensive crops.

10. Regional Disparities in Groundwater Use Across India: Top 10 States

Groundwater is crucial for irrigation in India, but over-reliance has led to severe depletion, especially in states like Punjab, Haryana, and Rajasthan. These regions face high extraction rates due to water-intensive crops, inefficient irrigation, and subsidies. This data highlights the need for water-saving technologies, crop diversification, and regulation to ensure groundwater sustainability.



Source: Central Ground Water Board (CGWB) reports

Tamil Nadu: Groundwater extraction is critical, with a rate of 79.89%, reflecting semi-critical depletion. The state's agriculture heavily relies on crops like rice and sugarcane, contributing to the overuse of groundwater.
Punjab, Haryana, and Rajasthan exhibit critical groundwater depletion, with extraction rates exceeding 135%, primarily due to water-intensive crops like paddy and sugarcane. Uttar Pradesh, Gujarat, and Maharashtra face semi-critical depletion with extraction rates between 80% and 97%, driven by similar agricultural practices. Madhya Pradesh, Andhra Pradesh, and Bihar experience semi-critical groundwater use as well, with high extraction rates due to rice, cotton, and maize cultivation, further stressing groundwater resources.

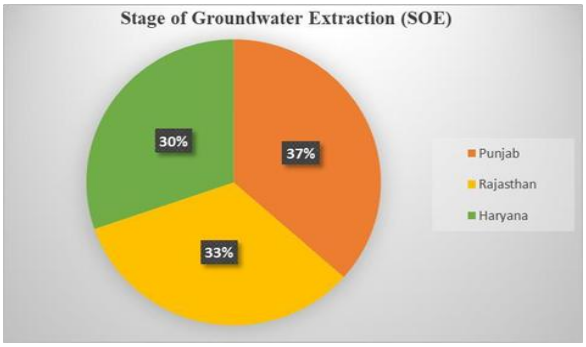
The top three states in India exhibiting critical groundwater exploitation:

PUNJAB **RAJASTHAN**

PUNJAB

STATE	Stage of Round after Extraction (SOE) %	Key Crops (Water Intensive)
Punjab	163.76	Rice, Wheat
Rajasthan	148.77%	Paddy, Sugarcane
Haryana	135.74%	Wheat, Barley, Mustard, roundnut

Source: Central Ground Water Board (CGWB) reports



Punjab, Haryana, and Rajasthan face severe groundwater exploitation due to the heavy reliance on water-intensive crops like paddy and sugarcane, inefficient irrigation practices, and subsidized electricity for pumping. These factors, combined with low natural recharge rates, have led to excessive groundwater extraction, causing rapid depletion.

Groundwater Overuse: Effects On Soil, Crops, And

12.1. **Soil Quality:** Excessive groundwater uses leads to soil salinization, as irrigation water contains salts that accumulate in the soil, reducing fertility and making it less suitable for crops.

12. Groundwater Overuse: Effects on Soil, Crops, And Livelihoods
20% of India's irrigated land is affected by salinity due to excessive groundwater use (India Water Portal).

12.2. **Crop Productivity:** As water tables decline, farmers must dig deeper wells or use more energy-intensive pumping systems. This results in reduced irrigation efficiency, lower crop yields, and a greater reliance on costly inputs.

Crop yields in regions with severe groundwater depletion (Punjab, Haryana, Rajasthan) decreased by 15-30%. Punjab's paddy cultivation consumes 4,000–5,000 liters of water per kg of rice, highlighting inefficiencies 25% of

rural populations in Punjab, Haryana, and Rajasthan have migrated for work due to crop failures.

12.3. **Rural Livelihoods**: Depleting groundwater threatens farmers' incomes, leading to crop failures and increased financial strain. It often results in rural distress, with some farmers forced to migrate for work due to the unsustainable agricultural practices.

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13. **Effective Practices for Groundwater Sustainability in Agriculture**

Sustainable groundwater management in Indian agriculture requires a multi-pronged approach. Micro-irrigation techniques like drip and sprinkler systems can reduce water use by 40-60% while increasing crop yields by 30-50%. Crop diversification, such as shifting to millets and pulses, helps lower water consumption by 30-40% and boosts farmer incomes. Community-based water management, including rainwater harvesting and check dams, enhances groundwater recharge, with projects like WADI improving recharge by 30%. The conjunctive use of surface and groundwater, especially during monsoons, has reduced groundwater extraction by 15-20% in Gujarat. Additionally, policy reforms, including PMKSY subsidies for micro-irrigation and water pricing in Maharashtra, have contributed to a 15% reduction in groundwater overuse. Implementing these strategies is essential for long-term water sustainability in Indian agriculture.

14. CONCLUSION

The over-extraction of groundwater in Indian agriculture has led to alarming environmental, economic, and social consequences, threatening the long-term sustainability of both farming and water resources. The Green Revolution significantly boosted agricultural productivity but also intensified groundwater dependence, particularly in states like Punjab, Haryana, and Rajasthan, where water-intensive crops such as rice and wheat dominate. As a result, the depletion of groundwater has outpaced natural recharge rates, leading to declining water tables, soil degradation, increased energy consumption, and ecosystem disruptions. The consequences extend beyond the environment, affecting rural livelihoods, food security, and the overall economic well-being of farming communities. The growing reliance on deep borewells and high-powered pumps has escalated energy costs, while soil salinization and declining water quality have negatively impacted agricultural productivity. Furthermore, groundwater depletion has contributed to climate change by increasing the carbon footprint of agriculture due to excessive energy use for irrigation. The study highlights the urgent need for policy interventions, technological advancements, and behavioral shifts in agricultural practices to mitigate the crisis. Addressing this issue requires a holistic approach that balances agricultural productivity with environmental sustainability, ensuring the long-term resilience of India's farming sector while conserving vital groundwater resources.

15. Suggestion

To address the severe issue of groundwater over-extraction in Indian agriculture, a multipronged approach combining technological, policy-driven, and community-based solutions is essential. First and foremost, promoting micro-irrigation technologies such as drip and sprinkler systems can significantly reduce water wastage while enhancing crop productivity. Simultaneously, crop diversification should be encouraged by shifting away from water-intensive crops like paddy and sugarcane to drought-resistant alternatives such as millets, pulses, and oilseeds. This shift not only conserves groundwater but also improves soil health and ensures long-term agricultural resilience. Moreover, community-based water management initiatives, including rainwater harvesting, check dams, and watershed development, should be expanded to improve groundwater recharge. The government should also invest in real-time groundwater monitoring systems using satellite technology and sensors to track depletion levels and regulate groundwater use effectively.

In addition to technological interventions, policy reforms play a crucial role in sustainable groundwater management. The government should gradually phase out subsidies for free electricity and excessive groundwater extraction, which currently encourage unsustainable practices. Instead, financial incentives should be redirected toward water-saving techniques and sustainable farming practices. Introducing water pricing mechanisms can further encourage judicious use of groundwater, ensuring it is treated as a valuable resource rather than an unlimited commodity. Furthermore, extensive awareness campaigns and farmer education programs should be implemented to promote water conservation techniques and highlight the risks associated with unchecked groundwater depletion. Collaborative efforts between policymakers, agricultural scientists, and local farmers will be key to ensuring a balanced approach that supports both agricultural productivity and environmental sustainability. By integrating these solutions, India can safeguard its groundwater resources while ensuring food security and rural livelihoods for future generations.

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