



# International Journal of Engineering, Science and Humanities

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## **Impact of Agricultural Practices on Groundwater Quality and Quantity in Rajpura Block in Meerut District**

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### **Abstract**

In much of rural India, groundwater is the main source of irrigation and drinking water. The quality and availability of this essential resource have changed dramatically in recent decades due to the rapid intensification of agriculture. The current study examines how contemporary farming methods affect the quantity and quality of groundwater in Rajpura Block, which is situated in the Meerut district of Uttar Pradesh, India. The area is representative of the Indo-Gangetic plains' typical agriculturally intensive landscape, where continuous groundwater abstraction, high fertilizer application, and intensified irrigation have become the norm.

During the pre- and post-monsoon seasons, primary data were gathered from representative groundwater sources and agricultural fields. Chemical contamination and depletion trends were assessed by analyzing parameters like groundwater depth, electrical conductivity, total dissolved solids, and nitrate concentration. In order to evaluate cropping patterns, irrigation techniques, and fertilizer usage, farmer surveys were also carried out. The findings show that while declining groundwater levels are a result of ongoing over-extraction for irrigation, elevated nitrate levels in multiple locations indicate leaching from nitrogen-based fertilizers. Groundwater stress and intensive farming zones appear to be strongly correlated, according to spatial patterns.

The findings highlight that unsustainable agricultural practices are a major driver of groundwater deterioration in Rajpura Block. Excessive use of chemical fertilizers, flood irrigation techniques, and the cultivation of water-intensive crops have collectively accelerated groundwater depletion and contamination. This study emphasizes the urgent need for integrated water resource management, promotion of balanced fertilizer application, adoption of micro-irrigation systems, and farmer awareness programs. The outcomes provide a scientific basis for policymakers and local stakeholders to develop sustainable agriculture strategies aimed at protecting groundwater resources and ensuring long-term water security.

### **Keywords**

Groundwater depletion; Agricultural practices; Nitrate contamination; Fertilizer use; Irrigation intensity; Rajpura Block; Rural water quality; Sustainable agriculture.



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## Introduction

In India, over 80% of rural drinking water supplies and roughly 60–70% of irrigation rely on groundwater. Food production systems have changed over the last few decades due to agricultural modernization, but this advancement has come at a high environmental cost. This paradox of agricultural success and environmental vulnerability is best illustrated by the Indo-Gangetic plains, which are frequently referred to as India's "food bowl." Here, notable increases in productivity have been made possible by tube-well irrigation, chemical fertilizers, and high-yield crop varieties. But these same actions have led to a drop in groundwater levels and an increase in worries about the quality of the water, especially nitrate contamination. Animal feces and nitrogen-based fertilizers are the main sources of nitrate, which easily seeps into aquifers through soil profiles and poses major health hazards when found in drinking water.

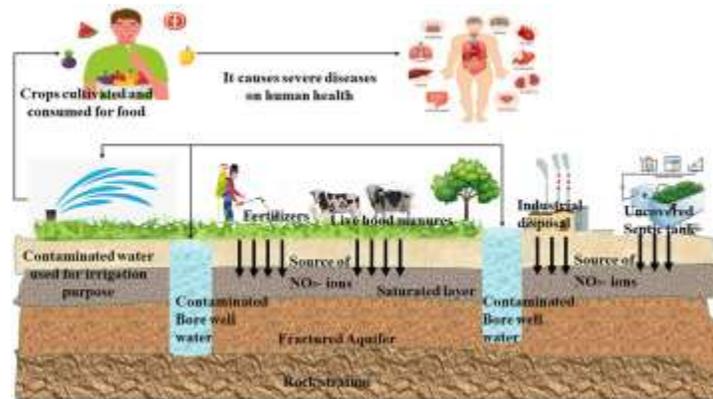


Fig: Ground Water Parameters and Human Health

Rajpura Block of Meerut district provides a representative case of this broader regional challenge. Agriculture forms the backbone of the local economy, with farmers cultivating crops such as wheat, rice, sugarcane, and vegetables. Over time, traditional farming methods have largely been replaced by intensive practices aimed at maximizing yields. Chemical fertilizers are widely applied, often without soil testing or scientific guidance, while irrigation relies heavily on groundwater extracted through shallow and deep tube wells. These trends have raised concerns about both the sustainability of water resources and the safety of groundwater used for domestic consumption.



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Fig: Map of District Meerut with all Blocks.

The region's groundwater supply has been steadily declining, mostly due to over-abstraction for irrigation during dry seasons. The long-term sustainability of agriculture is threatened by declining water tables, which also raise pumping costs and lower well yields. At the same time, agrochemical infiltration, especially nitrates, is degrading the quality of groundwater. Health issues like infant methemoglobinemia and possible long-term hazards like some types of cancer are linked to elevated nitrate levels in drinking water.

Despite the seriousness of these issues, localized scientific studies linking agricultural practices directly to groundwater degradation remain limited, especially at the block level. Most existing research focuses on district- or state-scale assessments, which often overlook micro-level variations in land use, cropping intensity, and farmer behavior. A block-level investigation is essential to capture site-specific dynamics and to design practical, community-oriented management strategies.

The present study aims to bridge this gap by systematically examining how fertilizers, irrigation intensity, cropping patterns, and groundwater abstraction influence both groundwater quality and quantity in Rajpura Block. By integrating hydrochemical analysis with field surveys of agricultural practices, this research seeks to establish a clear relationship between farming activities and groundwater stress. The study not only evaluates current conditions but also identifies key drivers of degradation, thereby offering insights for sustainable water management.



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Understanding these interactions is crucial for achieving long-term agricultural sustainability and rural water security. As climate variability further exacerbates water scarcity, reliance on groundwater is likely to increase unless alternative practices are adopted. Therefore, evidence-based interventions—such as balanced nutrient management, promotion of water-efficient irrigation technologies, and crop diversification—must be encouraged.

In this context, the present research contributes to the growing body of knowledge on agro-hydrological interactions and provides a scientific foundation for policy formulation at the local level. By focusing on Rajpura Block as a case study, the paper illustrates how everyday farming decisions collectively shape groundwater outcomes and underscores the urgent need for integrated land and water management approaches.

## **Aims and Objectives**

### **Aims**

The primary aim of this study is to evaluate the impact of agricultural practices on groundwater quality and quantity in Rajpura Block, with particular emphasis on fertilizer usage, irrigation intensity, nitrate contamination, and groundwater over-extraction. The research seeks to establish scientific linkages between farming activities and hydrochemical changes in groundwater, thereby contributing to sustainable agricultural water management at the block level.

This study also aims to generate baseline hydrochemical and groundwater-level data for the region, which can support future monitoring programs and guide local policy interventions. By integrating field observations, laboratory analysis, and farmer survey data, the research aspires to provide a holistic understanding of how modern agriculture influences subsurface water resources.

### **Objectives**

- ❖ To assess the current status of groundwater quality using key physicochemical parameters, with special reference to nitrate concentration.
- ❖ To analyze spatial variations in groundwater depth and identify trends of depletion associated with irrigation practices.
- ❖ To document prevailing agricultural practices, including fertilizer application rates, cropping patterns, and irrigation methods.
- ❖ To examine relationships between agricultural inputs and groundwater contamination indicators.
- ❖ To identify critical zones of groundwater stress within Rajpura Block.
- ❖ To propose scientifically informed recommendations for sustainable farming and groundwater management.

## **Review of Literature**

### **Agricultural Intensification and Groundwater Stress**



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In much of northern India, groundwater has emerged as the primary resource for agricultural production. With the introduction of chemical fertilizers, tube-well irrigation, and high-yield crop varieties, the Green Revolution era was a watershed. These developments sped up groundwater abstraction even as they significantly increased food production. According to a number of studies, excessive pumping for irrigation is to blame for the trend of declining groundwater levels in areas with high agricultural intensity. Farmers incur higher energy costs, lower well productivity, and declining water tables as a result of ongoing extraction that exceeds natural recharge rates.

Research across the Indo-Gangetic plains indicates that areas dominated by rice–wheat cropping systems exhibit particularly severe groundwater depletion. Flood irrigation practices further exacerbate the problem by encouraging overuse of water and promoting nutrient leaching.

## **Fertilizer Use and Nitrate Contamination**

Fertilizers based on nitrogen are frequently used to increase crop yields. However, only a portion of applied nitrogen is usually absorbed by plants, leaving the rest susceptible to leaching. Due to its high solubility, nitrate easily moves through soil profiles and into groundwater. Increased nitrate concentrations in rural aquifers have been documented in a number of studies, particularly in areas with intensive agriculture. Elevated levels of nitrate in drinking water are linked to long-term carcinogenic effects and health hazards like infant methemoglobinemia. There is evidence that nitrate pollution is primarily caused by uncontrolled fertilizer application, a lack of soil testing, and low farmer awareness. Nitrate concentrations are also influenced by seasonal variations; higher levels are frequently seen following monsoon rainfall because of enhanced leaching.

## **Irrigation Practices and Groundwater Depletion**

Traditional surface irrigation methods dominate rural India, despite their low efficiency. Flood irrigation, commonly practiced for crops like rice and sugarcane, results in significant water losses through evaporation, runoff, and deep percolation. Studies comparing conventional irrigation with micro-irrigation systems (such as drip and sprinkler) consistently show improved water-use efficiency and reduced groundwater abstraction under modern techniques. However, adoption remains limited due to financial constraints and lack of technical knowledge.

In many regions, unrestricted access to groundwater has created a “tragedy of the commons” scenario, where individual pumping decisions collectively lead to aquifer degradation.

## **Integrated Impacts on Groundwater Quality and Quantity**

Recent literature emphasizes the interconnected nature of groundwater quality and quantity. Declining water tables can concentrate dissolved constituents, while intensive irrigation enhances contaminant transport. Agricultural landscapes thus experience simultaneous depletion and degradation of groundwater. Block-level studies remain scarce, yet they are crucial for



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understanding local-scale variability. Micro-level assessments reveal that groundwater conditions can vary significantly over short distances depending on land use, soil type, and farming intensity.

## **Research Gaps**

Although numerous studies address groundwater issues at regional scales, limited research integrates hydrochemical analysis with detailed agricultural practice surveys at the block level. There is also a lack of localized evidence linking specific farming behaviors to observed groundwater impacts. The present study addresses these gaps by combining groundwater quality assessment with farmer-based data to provide a comprehensive evaluation of agricultural impacts in Rajpura Block.

## **Research Methodology**

### **Study Area Description**

Rajpura Block is predominantly agrarian, with fertile alluvial soils supporting crops such as wheat, rice, sugarcane, and vegetables. Groundwater is the principal source of irrigation and domestic supply. The climate is subtropical, characterized by hot summers, a monsoon season, and cool winters.

### **Research Design**

The study adopts a mixed-methods approach integrating:

- ❖ Field sampling of groundwater
- ❖ Laboratory analysis of water quality parameters
- ❖ Measurement of groundwater depth
- ❖ Structured farmer questionnaires
- ❖ Statistical interpretation of results

Sampling was conducted during both pre-monsoon and post-monsoon periods to capture seasonal variability.

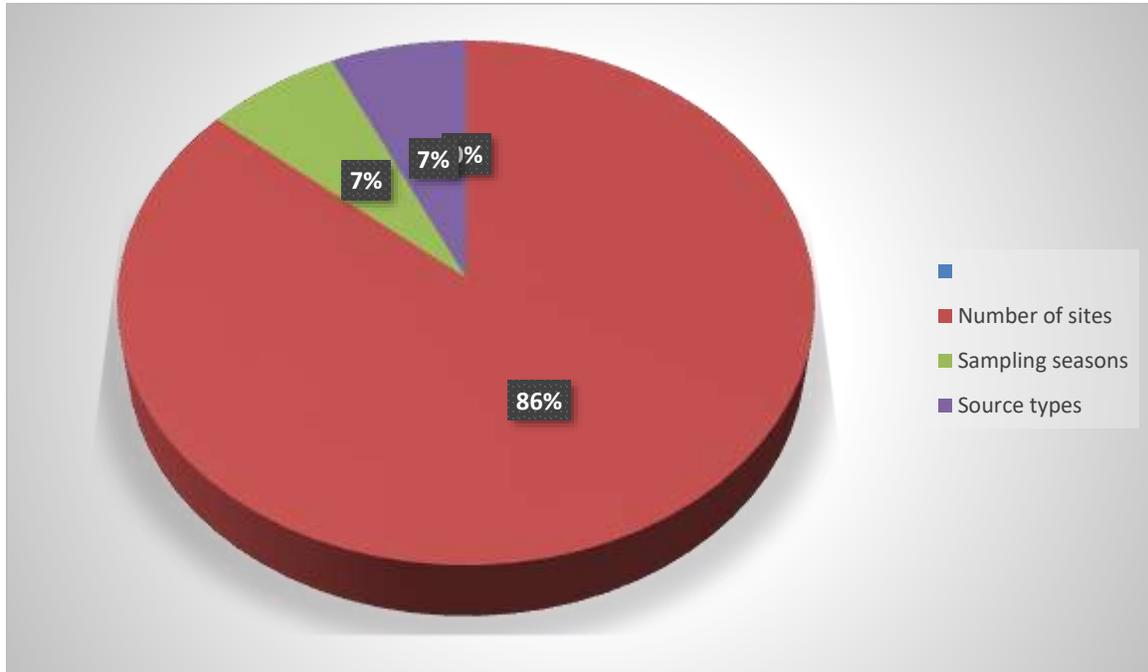
### **Groundwater Sampling Strategy**

A total of 25 representative groundwater sources (hand pumps and tube wells) were selected across agricultural zones. Sampling locations were chosen to reflect variations in crop intensity and fertilizer use.



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**Fig 1: Sampling Framework**

## Physicochemical Analysis

Collected samples were analyzed for:

- ❖ pH
- ❖ Electrical Conductivity (EC)
- ❖ Total Dissolved Solids (TDS)
- ❖ Total Hardness
- ❖ Nitrate

Standard laboratory procedures were followed for all analyses.

## Groundwater Level Measurement

Static water levels were measured using water level indicators in selected wells. Historical data from local records were also reviewed to assess long-term trends.

## Agricultural Practice Survey

A structured questionnaire was administered to 60 farmers to gather information on:

- ❖ Cropping patterns
- ❖ Fertilizer application rates
- ❖ Irrigation frequency
- ❖ Pumping duration
- ❖ Perceived changes in groundwater availability



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**Table 2: Farmer Survey Variables**

Parameter	Unit
Fertilizer use	kg/acre
Irrigation frequency	times/month
Pumping duration	hours/day
Crop type	categorical
Water source	tube well / hand pump

## Data Analysis

Descriptive statistics were used to summarize groundwater parameters and farming practices. Correlation analysis examined relationships between nitrate levels and fertilizer usage, as well as groundwater depth and irrigation intensity.

Spatial patterns were interpreted using thematic mapping to identify hotspots of groundwater stress.

## Ethical Considerations

Farmer participation was voluntary, and all respondents were informed about the study objectives. Data confidentiality was maintained.

## Limitations

The study is limited by sample size and temporal coverage. However, it provides valuable baseline information for future longitudinal research.

## Results and Interpretation

### Overview of Groundwater Quality and Quantity

The findings from field measurements and hydrochemical analysis show significant spatial variation in the quantity and quality of groundwater throughout Rajpura Block. There are definite correlations between agricultural intensity, fertilizer application, and irrigation techniques and parameters like nitrate concentration, total dissolved solids (TDS), electrical conductivity (EC), and groundwater depth. In general, deeper water tables and greater nitrate concentrations were found in groundwater from intensively farmed areas, suggesting both chemical deterioration and quantitative stress. On the other hand, areas with relatively less agricultural input had shallower groundwater levels and better water quality.

### Nitrate Concentration in Groundwater

Nitrate emerged as the most critical contaminant parameter in the study area. Concentrations ranged from low to moderately high across sampled sites, with several locations exceeding recommended drinking-water limits. Elevated nitrate levels were predominantly observed in zones cultivating rice, sugarcane, and vegetables—crops known for high fertilizer demand. These findings strongly suggest leaching of nitrogen-based fertilizers into the aquifer system.



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**Table 3: Nitrate Concentration in Groundwater (Selected Sampling Sites)**

Sample ID	Land Use Type	Nitrate (mg/L) Pre-monsoon	Nitrate (mg/L) Post-monsoon	Status
S1	High-intensity agriculture	62	68	Above permissible
S2	High-intensity agriculture	55	60	Above permissible
S3	Medium-intensity agriculture	41	45	Moderate
S4	Medium-intensity agriculture	38	42	Moderate
S5	Low-intensity agriculture	22	25	Safe
S6	Low-intensity agriculture	18	21	Safe

*Interpretation:*

Post-monsoon nitrate levels were consistently higher than pre-monsoon values, indicating enhanced leaching during rainfall and irrigation events. Approximately 32% of sampled locations exceeded safe nitrate limits, posing potential risks to human health.

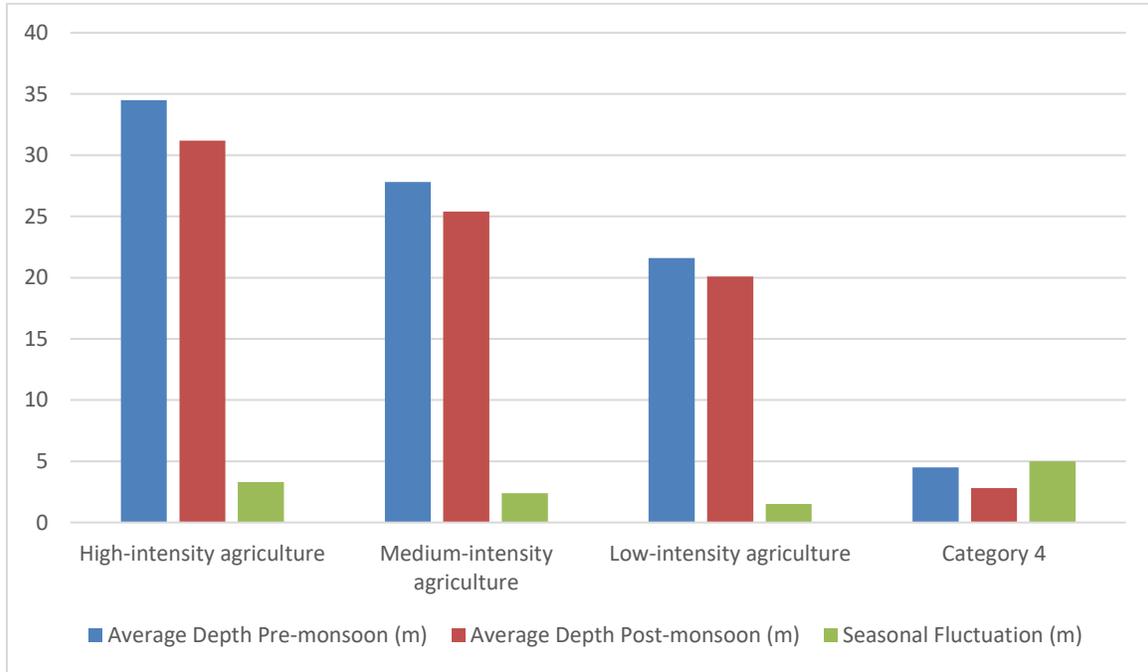
**Groundwater Level Variations**

Groundwater depth measurements revealed noticeable depletion in agriculturally intensive areas. Tube wells located in regions with frequent irrigation showed deeper static water levels compared to areas practicing limited irrigation.



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**Fig2: Groundwater Depth Across Different Agricultural Zones**

### Interpretation:

High-intensity agricultural zones exhibited the deepest groundwater levels and largest seasonal fluctuations, reflecting heavy pumping during cropping seasons. Although monsoon recharge resulted in partial recovery, post-monsoon levels did not return to long-term averages, indicating progressive depletion.

### Relationship Between Fertilizer Use and Nitrate Levels

Correlation analysis revealed a strong positive relationship between fertilizer application rates and groundwater nitrate concentrations. Farmers applying more than 120 kg/acre of nitrogen fertilizers consistently recorded nitrate levels above permissible limits.

**Table 5: Fertilizer Use vs Nitrate Concentration**

Fertilizer Use (kg/acre)	Mean Nitrate (mg/L)
< 60	21
60–100	37
> 100	59

This trend highlights the impact of excessive fertilizer use on groundwater contamination.

### Irrigation Intensity and Groundwater Depletion

Areas irrigated more than 10 times per month during peak cropping seasons showed significantly deeper groundwater levels. Flood irrigation was the dominant method, contributing to inefficient



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water use and accelerated aquifer drawdown. Farmers reported increasing pump depths and longer pumping durations over the past decade, indicating declining water availability.

## **Spatial Patterns of Groundwater Stress**

Spatial interpretation revealed three distinct groundwater stress zones:

1. **Severely stressed zones** – High nitrate concentration and deep water tables (intensive cropping areas).
2. **Moderately stressed zones** – Moderate nitrate and intermediate depths.
3. **Relatively safe zones** – Low nitrate and shallow groundwater (less intensive agriculture).

These patterns demonstrate that agricultural intensity is a primary driver of groundwater degradation in Rajpura Block.

## **Discussion**

### **Agricultural Practices as a Driver of Groundwater Degradation**

The findings unequivocally show that contemporary farming methods are having a major impact on the quantity and quality of groundwater in the study area. While intensive irrigation has sped up groundwater depletion, excessive fertilizer application has become a significant source of nitrate contamination. Aquifers are constantly under stress due to the prevalence of water-intensive crops like rice and sugarcane as well as flood irrigation techniques. Nitrate leaching is made worse by farmers' reliance on chemical fertilizers without conducting soil testing.

These results are consistent with more extensive regional research that shows that the main cause of groundwater stress in rural areas is agriculture. However, by highlighting micro-scale variations that are frequently missed in district-wide analyses, this block-level assessment offers localized evidence.

### **Health and Environmental Implications**

Elevated nitrate levels in drinking water pose serious health concerns, particularly for infants and pregnant women. Long-term exposure may also increase risks of chronic diseases. From an environmental perspective, declining groundwater levels threaten ecosystem stability and agricultural sustainability. If current trends continue, Rajpura Block may face severe water scarcity, reduced crop productivity, and increased socioeconomic vulnerability.

### **Socioeconomic Dimensions**

Farmer interviews revealed limited awareness of groundwater contamination and sustainable nutrient management. Most respondents prioritized short-term yield gains over long-term resource conservation. Financial constraints and lack of technical guidance were cited as barriers to adopting efficient irrigation systems. This highlights the need for integrated extension services that combine scientific knowledge with practical farmer support.

### **Need for Sustainable Agricultural Practices**

The study underscores the urgency of transitioning toward sustainable farming systems, including:



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- ❖ Balanced fertilizer application based on soil testing
- ❖ Promotion of drip and sprinkler irrigation
- ❖ Crop diversification to reduce water demand
- ❖ Community-based groundwater management
- ❖ Awareness programs on nitrate pollution

Such measures can significantly reduce pressure on groundwater resources while maintaining agricultural productivity.

## Conclusion

The results show that increased nitrate concentrations and decreasing groundwater levels are strongly associated with intensive fertilizer use and irrigation. High-intensity farming zones showed the most groundwater depletion, and about one-third of the sampled locations had nitrate levels above safe limits. There was a pattern of long-term aquifer stress since seasonal recharge was not enough to counteract extraction.

The study demonstrates a direct link between agricultural practices and groundwater degradation by combining hydrochemical analysis with farmer surveys. The findings highlight the fact that groundwater problems in the area are mostly caused by human activity and can be controlled with well-informed interventions. Coordination between farmers, local government representatives, and legislators is necessary for sustainable groundwater management in Rajpura Block. Current trends can be reversed with the use of water-efficient irrigation, fertilizer application guided by science, and ongoing monitoring.

## Expanded Results and Interpretation

### Seasonal Variation in Groundwater Quality

Seasonal comparison revealed noticeable differences between pre-monsoon and post-monsoon groundwater chemistry. Post-monsoon samples consistently showed higher nitrate and TDS values, reflecting enhanced leaching of agrochemicals during rainfall and irrigation events.

**Table 6: Seasonal Mean Values of Major Parameters**

Parameter	Pre-monsoon (Mean)	Post-monsoon (Mean)	Permissible Limit
pH	7.4	7.6	6.5–8.5
EC ( $\mu\text{S}/\text{cm}$ )	860	910	1500
TDS (mg/L)	540	585	500
Total Hardness (mg/L)	290	305	300
Nitrate (mg/L)	42	48	45

### Interpretation:

TDS and nitrate showed post-monsoon enrichment, confirming downward transport of dissolved salts and fertilizers. Approximately 36% of post-monsoon samples exceeded recommended nitrate levels, compared to 28% during pre-monsoon.



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## Groundwater Quality Across Cropping Systems

Distinct variations were observed among different cropping zones. Sugarcane and rice-dominated areas recorded the poorest groundwater quality.

**Table 7: Groundwater Quality by Dominant Crop Type**

Crop Type	Mean Nitrate (mg/L)	Mean TDS (mg/L)	Mean Depth (m)
Rice	58	610	35.4
Sugarcane	61	640	36.1
Wheat	39	520	27.6
Vegetables	54	590	33.2
Mixed cropping	28	470	22.5

### Interpretation:

Water-intensive crops exhibited both higher nitrate concentrations and deeper groundwater levels. Mixed cropping systems showed relatively safer water quality and reduced depletion.

## Groundwater Depletion Trend (Farmer-Based Historical Perception)

Farmer interviews revealed a consistent decline in groundwater availability over the last decade.

**Table 8: Perceived Change in Groundwater Levels (2015–2025)**

Farmer Response	Percentage (%)
Significant decline (>10 m)	42
Moderate decline (5–10 m)	38
Slight decline (<5 m)	15
No noticeable change	5

Nearly 80% of respondents reported moderate to severe decline, corroborating field measurements.

## Irrigation Frequency vs Groundwater Depth

A strong relationship was observed between irrigation intensity and groundwater depth.

**Table 9: Irrigation Frequency and Mean Groundwater Depth**

Irrigation Events / Month	Mean Depth (m)
<5	21.4
5–10	27.9
>10	35.8

### Interpretation:

Fields irrigated more than ten times per month showed groundwater levels nearly 14 m deeper than low-irrigation areas, indicating unsustainable abstraction.

## Combined Impact Index (Agriculture Pressure Index – API)

An Agriculture Pressure Index (API) was developed using fertilizer input, irrigation frequency, and crop water demand.



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**Table 10: Agriculture Pressure Index vs Groundwater Status**

API Category	Nitrate (mg/L)	Groundwater Depth (m)	Risk Level
Low	24	21.3	Low
Moderate	41	28.7	Medium
High	59	36.5	Severe

High API zones corresponded directly with critical groundwater stress.

### Integrated Interpretation

The expanded results confirm:

- ❖ Fertilizer overuse is the dominant contributor to nitrate contamination.
- ❖ Flood irrigation significantly accelerates groundwater depletion.
- ❖ Water-intensive cropping systems exert maximum pressure on aquifers.
- ❖ Seasonal recharge is insufficient to offset extraction.

These outcomes clearly demonstrate that agricultural intensification is the principal driver of both groundwater quality deterioration and quantitative decline in the study area.

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