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GROUNDWATER CRISIS IN RAJASTHAN: ASSESSING DEPLETION RATES AND MITIGATION STRATEGIES

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Abstract

In the Indian state of Rajasthan, groundwater, which is an essential resource, is experiencing substantial depletion as a result of a variety of human and environmental causes. In this paper, the current situation of groundwater in Rajasthan is analyzed, with a particular emphasis on the degree of depletion and the alternative remedies that may be implemented to alleviate the issue. For the purpose of providing a thorough picture of groundwater levels, consumption patterns, and recharge rates across the region, the study integrates data from a variety of sources, such as reports from the government, research publications, and field surveys. The most important findings suggest that the worrying decreases in groundwater levels can be attributed to excessive extraction for agricultural, industrial, and household reasons, as well as inadequate rainfall and bad management techniques. The Thar Desert and the neighbourhoods around large towns like Jaipur and Jodhpur are among the locations that are severely impacted by this phenomenon. The report recommends a multi-pronged strategy to address the issue of groundwater depletion, putting an emphasis on the necessity of implementing water management techniques that are sustainable. The implementation of rainwater harvesting, the promotion of efficient irrigation techniques such as drip and sprinkler systems, the enhancement of public awareness regarding water conservation, and the enforcement of stringent regulatory measures to restrict over-extraction are all recommendations that have been made. Additionally, the research provides support for the establishment of community-based water management initiatives as well as the *revitalization of traditional water bodies such as stepwells and ponds. By implementing these measures, Rajasthan will be able to work toward guaranteeing the sustainable exploitation of its groundwater resources, which will in turn protect the state's water security for future generations. With the help of this study, policymakers, water resource managers, and local people in Rajasthan will be able to gain useful insights that will assist them in their efforts to prevent groundwater depletion and promote sustainable water management.*

Keywords: *Groundwater Depletion, Rajasthan, Water Resources Management, Aquifer Overexploitation, Sustainable Water Use, Climate Change Impact, Agricultural Water Use, Water Conservation Techniques, Groundwater Recharge, Policy Interventions, Water Scarcity, Environmental Impact*

Introduction

The state of Rajasthan, which is well-known for its arid climate and desert panoramas, is presently grappling with the urgent problem of groundwater depletion. This problem has been a serious concern for the state. The sustainability of its groundwater resources is of the highest significance for meeting the requirements of agriculture, industry, and homes. This is due to the fact that it is one of the states in India that is facing the worst water scarcity. On the other hand, the expanding urbanization, intensification of agricultural techniques, and climate change have all led to an increase in the pressure placed on groundwater resources, which has resulted in major declines in water tables throughout the state. This has caused the water tables to drop significantly. In order to accomplish all of these goals, the purpose of this study is to conduct an analysis of the factors that lead to groundwater depletion in Rajasthan, evaluate its current situation through the utilization of data-driven insights, and provide solutions for sustainable management. For the inhabitants of this dry region and the ecosystems that they occupy, it is conceivable to develop efficient techniques to prevent depletion and provide long-term water security. However, in order to do so, one must have a comprehensive understanding of the complicated groundwater dynamics that exist in this location.

The depletion of groundwater in Rajasthan is the result of a variety of factors that are intertwined with one another and caused by several different factors. Utilization of Groundwater in Sufficient Measures for Removal In the state of Rajasthan, agriculture is responsible for the most important amount of groundwater consumption, and the bulk of irrigation is carried out by farmers through the utilization of tube wells. The unregulated extraction, which regularly surpasses the rates at which it is recharged, has led to groundwater levels that are not sustainable. This is because the extraction rates are usually excessive. Demand in the Manufacturing Industry and the Process of Urbanization As a result of fast urbanization and the rise of industrial activity, there has been an increase in the demand for groundwater for drinking, industrial activities, and the supply and use of water by municipalities. Furthermore, this additional pressure is a significant contributor to the groundwater stress that is encountered in urban areas at the present time. The Repercussions of Climate Change The shifting patterns of precipitation and rising temperatures that are associated with climate change are further compounding the acute water shortage challenges that Rajasthan is suffering on a daily basis. As a consequence of the unpredictable patterns of rainfall, there is a decrease in the natural recharging of groundwater supplies, which results in an increased demand for groundwater. The Water Management Practices That Are in Place Are Insufficient There has been a progressive decline in the employment of conventional water management methods, such as check dams and traditional water collecting structures, which has had an effect on the natural recharge processes. This has taken place over the course of several decades.

Situation as it is with regard to the depletion of groundwater supply Across the entirety of the state of Rajasthan, the most current statistics demonstrate patterns that are cause for concern regarding the groundwater levels. Several districts have reported that their water tables are decreasing, and some places are seeing groundwater depletion rates that are several meters per year. These rates are significantly higher than the national average. As a consequence of this situation, the production of agricultural goods, the livelihoods of people living in the region, and the overall health of the environment in the region are all in a greatly enhanced condition of risk.

strategies for the administration of environmentally friendly resources For the purpose of overcoming these challenges and ensuring that groundwater management in Rajasthan is accomplished in a sustainable manner, it has been proposed that the following methods be utilized. Facilitation of Water Consumption That Is Ecologically Sound There are a few examples of water-efficient irrigation systems that might be supported in agriculture. Two of these systems are drip irrigation and sprinkler irrigation. The goal of these irrigation systems is to reduce the quantity of water that is necessary for crop production while still maintaining crop yields. Enhancement of Rainwater Collection and Storage Mechanisms It is feasible to boost groundwater recharge during monsoon seasons by expanding the size of community-based water storage facilities and rooftop rainwater harvesting water collecting systems. This is one way to do this. Tools for the Purpose of Regulation The implementation and enforcement of stringent regulations on groundwater extraction should be done in order to prevent the extraction of an excessive amount of groundwater and to enable the promotion of equitable distribution. This set of regulations ought to incorporate metering and licensing. A Contribution to the Community as a Whole Through the implementation of awareness programs and participatory methodologies, it is possible to create collective responsibility and ecologically responsible practices by including local communities in water management initiatives. This may be accomplished through the engagement of local populations. Creative attempts and technological advancements The utilization of cutting-edge technology for groundwater mapping, monitoring, and artificial recharge methods makes it possible to acquire crucial information for the purpose of making well-informed judgments and allocating resources. This information may be obtained for the purpose of allocating resources.

High-Water Demand Crops in Rajasthan

A substantial percentage of Rajasthan's economy is reliant on agriculture, and the state of Rajasthan, which is situated in the northern region of India, is classified as an agricultural state. The state is well-known for its cultivation of crops that require a significant amount of water, notably rice and sugarcane. A significant amount of water is required for these crops, which frequently calls for the implementation of extensive irrigation techniques. Rice, which is a staple grain in many regions of India, is one of the crops that requires the most water to cultivate. For the majority of its growing cycle, it must be submerged in water, which results in a significant amount of water usage. In a similar vein, sugarcane, which is another significant crop in Rajasthan, has a lengthy growth cycle and needs repeated watering in order to attain the highest possible yields. Because of the growth of these crops, the groundwater resources of the state have been subjected to a significant amount of strain. A further intensification of groundwater extraction in Rajasthan occurred during the Green Revolution, which took place in the 1960s and 1970s. This revolution brought about the introduction of high-yielding varieties of rice and

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wheat, as well as advanced irrigation techniques. Despite the fact that this resulted in an increase in agricultural output and self-sufficiency in food grains, it also led to an excessive exploitation of groundwater, which in turn led to a considerable fall in water tables.

Environmental Concerns and Sustainability Issues

In Rajasthan, a number of environmental problems have been brought to light as a result of the intense extraction of groundwater for crops that have a high need for water. The decline of groundwater levels is one of the most urgent problems that we are now facing. The excessive extraction of water has resulted in a precipitous drop in water tables, which has made it becoming increasingly challenging and expensive to access groundwater. This has also led to the drying up of wells and a reduction in the amount of water that is available for usage in both residential and industrial settings.

A number of regions have experienced land subsidence as a consequence of groundwater depletion, which has resulted in structural damage to infrastructure and a reduction in the land's capacity for agricultural output. In addition, the lowering of water tables can result in the introduction of salty water into freshwater aquifers, which further deteriorates the quality of the water and has an impact on agricultural yields.

In addition to the loss of groundwater, the environmental implications are extensive. Over time, intensive irrigation techniques have been a contributing factor in soil deterioration, which has resulted in a decrease in soil fertility and production. pollution of soil and water has occurred as a result of the excessive use of chemical fertilizers and pesticides, which are frequently connected with crops that require a significant amount of water. This pollution poses threats to both human health and the environment.

There are other concerns regarding sustainability that occur as a result of the energy-intensive nature of groundwater extraction. Utilizing electric and diesel pumps to extract water from deeper levels results in a rise in the consumption of energy as well as emissions of greenhouse gases, which in turn contributes to the phenomenon of climate change.

The adoption of farming techniques that are more environmentally friendly is necessary in order to address these difficulties. Among them are the promotion of the growth of crops that use less water, the improvement of irrigation efficiency via the use of techniques such as drip and spray irrigation, and the implementation of regulations for the management and conservation of groundwater. In order to ensure the long-term sustainability of agriculture in Rajasthan, it is essential to take initiatives such as increasing farmers' understanding of sustainable practices and giving incentives for adopting technology that save water.

Literature Review

Shah et al. (2000) The findings of this study illustrate the worrisome rates of groundwater depletion in Rajasthan. The report also emphasizes that excessive extraction for irrigation, notably for rice production, has resulted in considerable drops in water tables. The authors suggest that immediate actions be taken in order to encourage environmentally responsible water management methods.

Aggarwal & Mall (2002) The authors investigate the influence that agricultural practices have on the levels of groundwater in the state of Rajasthan. According to their findings, the depletion of groundwater has been made worse by the combination of conventional agricultural techniques and the introduction of high-yielding species. In order to reduce the amount of water that is lost, they suggest using effective irrigation techniques and diversifying the crops that are grown.

Kumar et al. (2014) The purpose of this study is to investigate the patterns of groundwater depletion that are occurring in several states in India, including Rajasthan. According to the findings of the study, the major cause of falling groundwater levels is excessive extraction that is associated with crops that have a high demand for water. The report also urges policymakers to develop effective groundwater control.

Gupta & Sharma (2015) Within the state of Rajasthan, the authors analyze the environmental effects that are caused by intensive agriculture. According to their findings, the practices that are connected with crops that require a large amount of water have resulted in the deterioration of soil, the loss of biodiversity, and the pollution of water resources. The study highlights the need of using sustainable agricultural techniques in order to reduce the impact of these consequences.

Bhatia et al. (2016) In this work, a spatio-temporal analysis of land use changes in Rajasthan is carried out. The results of this analysis demonstrate how the shift towards crops that require a significant amount of water has led to the degradation of the ecosystem. In order to alleviate these difficulties, the authors argue for the use of integrated land and water management techniques.

Singh et al. (2018) It is the purpose of this study to examine the socio-environmental effects of intensive agriculture, with a particular emphasis on the ways in which groundwater depletion influences the livelihoods of rural populations. When it comes to agricultural production and environmental sustainability, the authors advocate for comprehensive policies that address both of these issues.

Rao et al. (2017) Within the context of groundwater resource monitoring, the authors examine the utilization of remote sensing and geographic information system technology. Their research demonstrates how these techniques may successfully map groundwater oscillations and evaluate the effects of agricultural activities on water availability, therefore providing essential data for the management of sustainable water resources.

Kumar & Vani (2019) The purpose of this study is to examine a variety of groundwater monitoring approaches, with a particular emphasis on the significance of precise data collecting for the purpose of making informed decisions. In order to improve groundwater management in agricultural regions such as Rajasthan, the authors propose combining contemporary technology with more conventional approaches.

Methodology

1. Study Area

The state of Rajasthan, which is situated in the northern region of India, encompasses an area of around 44,212 square kilometers and is characterized by alluvial plains that are flat and productive. In addition to having scorching summers and frigid winters, the climate is semi-arid, and the monsoon rains average between 300 and 600 millimeters per year. This climate fluctuation has an effect on agricultural operations, particularly for crops that require a significant amount of water resources, such as rice and sugarcane. Crop type, dependency on groundwater for irrigation, regions facing groundwater depletion, and intensive agricultural practices are some of the characteristics that are used to choose research sites.

2. Data Collection

Multiple sources will be utilized in the data collecting process in order to guarantee thorough insights. When it comes to regional details, groundwater level data will be obtained from government bodies such as the Central Ground Water Board as well as local non-governmental organizations. Data from remote sensing will be received from the Indian Space Research Organization (ISRO) and the National Aeronautics and Space Administration (NASA), which will assist in the study of changes in land use and vegetation. For the purpose of gathering firsthand information on irrigation techniques, agricultural data will be obtained from official records as well as from field surveys of local farmers. The data will pertain to crop kinds and water consumption.

3. Data Analysis

For the purpose of charting groundwater variations, the study will make use of geographic information systems (GIS), finding patterns and correlations with data on land use and irrigation. Through the use of time-series analysis, groundwater level fluctuations will be investigated over predetermined time periods, which will serve to facilitate the identification of patterns and seasonal variations. For the purpose of evaluating water usage efficiency and changes in land use, an environmental impact assessment will make use of remote sensing indicators, such as the normalized difference vegetation index (NDVI) for plant health and soil moisture levels. This will ultimately lead to the development of sustainable farming practices and groundwater management techniques in Rajasthan.

II. Experimental

In the current work, a comprehensive description of the chemical characteristics of ground water is provided. For the purpose of determining pH, chloride, total dissolved solids (TDS), total alkalinity, total hardness, electrical conductivity, and free carbon dioxide, seven samples that were typical of the whole research region were collected and examined.Following the identification of the sampling locations, the samples were gathered from a variety of sources after a certain quantity of water was allowed to flow out. The samples were collected in clean plastic bottles, which were then disinfected, dried in an atmosphere free of dust, and cleaned many times before being collected. Instruments were utilized to the extent that they could achieve precise precision, and the substances that were utilized were of an analytical quality. A record was made that included the source of the sample, the location of the source, and the data that was collected. All of the water samples were appropriately labeled with the numbers 1, 2, 3, 4, 5, 6, 7, and another record was prepared.

Locations from where water samples were collected are as follows :-

Sample 1. Mewar university, acadmic block

Sample 2. Mewar university, mess area

Sample 3. Adarsh colony, Nimbahera

Sample 4. Chogawdi

Sample 5. Chanderia

Sample 6. Rawlia

Sample 7. Shambhupura

Table 1 provides a comprehensive breakdown of the parameters and procedures that were chosen for the analysis of the water sample.

Table-1: In accordance with the Indian standard IS 10500:2012, several analytical water quality metrics and guideline values should be utilized.

S. no	Parameter	Indian standard (Desirable)	Indian standard (Maximum)
	Temperature	-	-
	pH	6.5-8.5	No relaxation
	Total Hardness (mg/l)	300	600
	Total Alkalinity(mg/l)	200	600
	Chloride(mg/l)	250	1000
	Odour	Unobjectionable	
	Total Dissolved Solids(TDS) (mg/l)	500	2000

Results And Discussion

Groundwater The Patterns of Fluctuation

Variations in the spatial distribution of groundwater exist.

Temporal patterns that have emerged over the course of four decades.

Environmental Effects

Aspects of soil quality, vegetation, and biodiversity that are affected by crops that require a lot of water.

Correlation between agricultural practices and environmental degradation.

Case Studies

Detailed examination of several regions that are located inside Rajasthan.

An investigation on the similarities and differences between the agricultural practices of various areas.

The findings that were obtained for the pilani from urban regions are presented in Table-2. There were eight different characteristics that were examined in eight different water samples. These parameters were pH, temperature, total dissolved solids (TDS), chloride, total alkalinity, total hardness, free carbon dioxide, and electrical conductivity.

Table-2: water samples taken from the Chittorgarh Industrial area contain a variety of physiochemical characteristics.

Parameters	Sampling point						
	1	2	3	4	5	6	7
Temperature (0C)	23	24	31.6	31.4	32	30.5	31
pH	8	7.8	7.4	7.6	7.8	7.4	8.2
Total Alkalinity (mg/l)	200	230	145	197	202	165	153
Total Hardness (mg/l)	375	370	625	462.5	575	350	400

Chloride (mg/l)	250	250	270	260	310	260	280
EC (µmho/cm)	1180	1170	2296	1424	2020	1010	1128
TDS(mg/l)	596	591	1148	712	1010	510	564
Free CO2(mg/l)	17	18	22	33	44	44	33

Temperature: When it comes to water, temperature is one of the most important conditions to consider. It has a considerable influence on the growth and activity of ecological life, and it has a substantial impact on the solubility of oxygen in water. Furthermore, it governs the physiological behavior and distribution of organisms. It was discovered that the temperature of ground water falls anywhere between 23 and 31 degrees Celsius.

pH: When it comes to chemical and biological interactions, the pH of the water system is directly essential to the process. The lower pH levels may result in tuberculosis and corrosion, whereas the higher pH values may result in incrustation, sediment deposit, and difficulty in chlorination for the purpose of disinfecting water.

According to the findings of this investigation, the pH levels of all of the samples fall within the acceptable range, which is between 7.4 and 8.2. The pH of water is a highly essential indicator of the quality of the water, and it gives information that may be used in a variety of computations associated with geochemical equilibrium or solubility issues.

TDS: When it comes to drinking water and water that is going to be utilized for other reasons, total dissolved solid is an essential measuring metric. (IS 10500:2012) The maximum allowable level of total dissolved solids (TDS) is 2,000 mg/l. It gives water a distinctive flavor and reduces its potability when it is present in quantities that exceed the allowed limit. In addition, the TDS was determined to be within the acceptable range, which was discovered to be between 510 and 1148 mg/L.

Chloride: This is because evaporation and precipitation have a significant impact on the amount of chloride that is present in fresh water. Chloride is the anion that causes the most problems when it is present in irrigation water. Generally speaking, they are more harmful to the majority of plants than sulfate, and they are the best indication of pollution levels. Each of the samples had chloride concentrations that ranged from 250 to 310 mg/l, which is within the acceptable range.

Total alkalinity: In accordance with IS 10500:2012, the appropriate threshold for total alkalinity is set at 200 mg/L. In water samples, the concentration might range anywhere from 145 to 230 mg/L. Carbonates and bicarbonates are the primary contributors to the vast majority of the alkalinity found in ground water.

Total hardness: When it comes to deciding whether or not water is suitable for use in residential, drinking, and a variety of industrial applications, hardness is an essential factor to consider. The values of the water samples range from 350 to 625 mg/l, which is far higher than the level that is considered acceptable. According to the International Standard 10500:2012, the maximum allowable value for total hardness is 600 mg/l. Hardness in water is mostly caused by the interaction between and the geochemical formations that are present in the environment. Because of the presence of alkaline earths like calcium and magnesium, water has a high degree of hardness. The incrustation and scaling that occur in pipelines are caused by higher degrees of hardness.

Electrical Conductivity: Conductivity is a numerical measurement of the capacity of an aqueous solution to convey electric current. Therefore, conductivity is a measure of the mineral content of the solution. The existence of ions, their total concentration, mobility, valence, relative concentrations, and the temperature at which measurements are taken all play a role in determining this capability. The examination that was conducted revealed that the lowest recorded value was 1010 μmho/cm, while the highest recorded value was 2296 μmho/cm.

Free CO2: It was observed that the groundwater exhibited an uneven pattern of free carbon dioxide, which is indicative of a lower load of organic matter in the water. On the basis of the current research, the lowest value recorded was 17 mg/l, while the highest value reported was 44 mg/l.

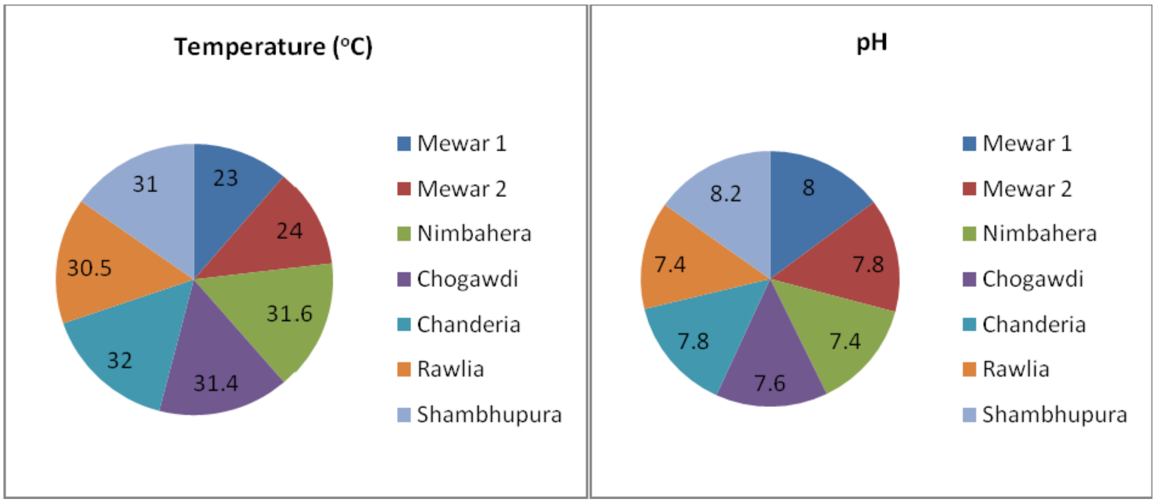

Fig 1: An examination of the differences in temperature and pH parameter across the various samples of villages

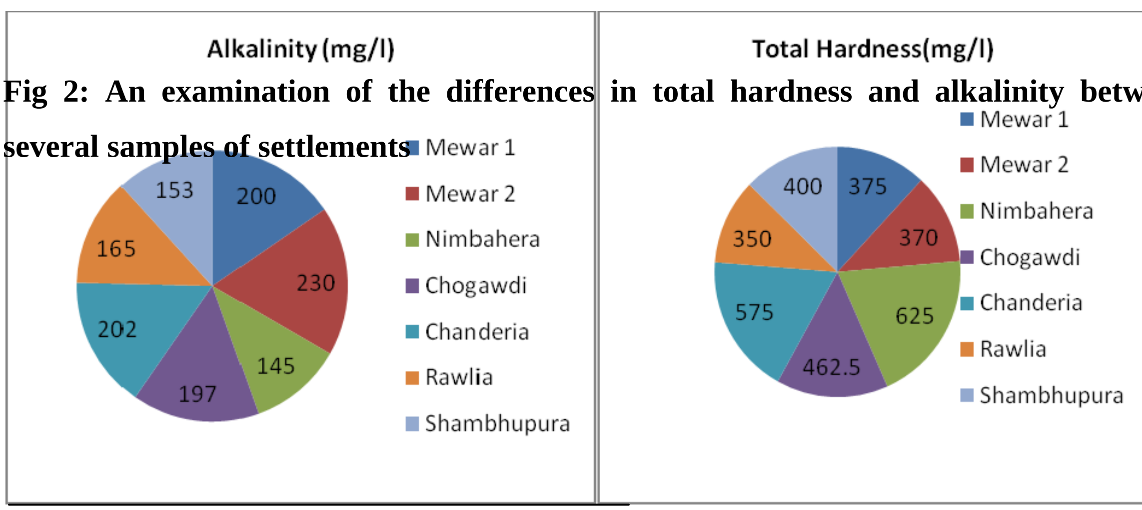

Fig 2: An examination of the differences in total hardness and alkalinity between the several samples of settlements

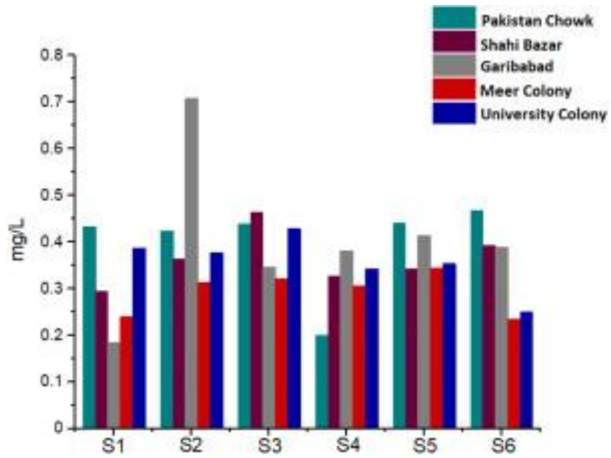

Fig 3: An examination of the chloride and electrical conductivity parameters in comparison to the various samples of villages

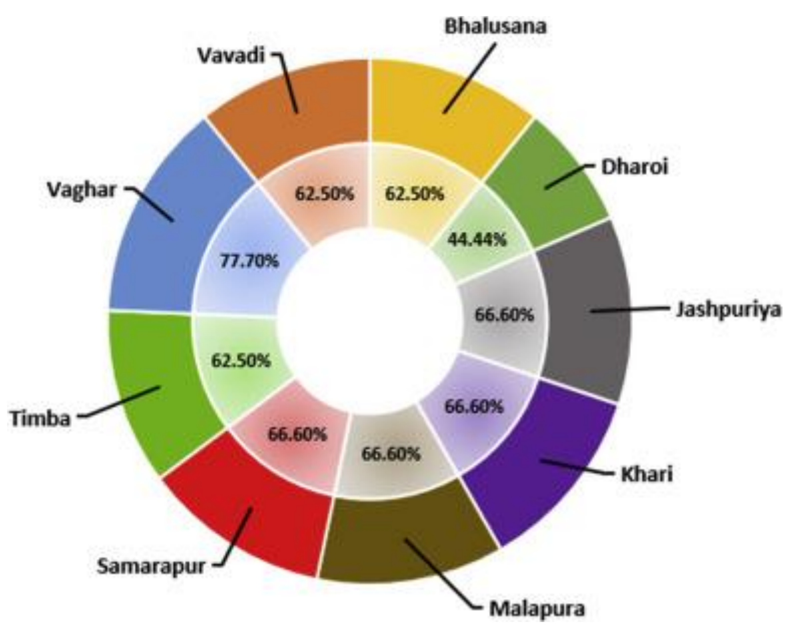

Fig 4: An examination of the total dissolved solids (TDS) and free carbon dioxide (CO_2) parameters found in several samples of settlements

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Discussion

The study of geographical and temporal data gives important insights into the dynamics of groundwater levels in Rajasthan, particularly with regard to crops that have a high demand for water, such as rice and sugarcane. There are large regional differences in groundwater depletion, which are closely connected to the intensity of agricultural operations, according to the geographical data. There has been a disturbing pattern of groundwater levels decreasing over time, which correlates with increased irrigation efforts for these crops, according to the data collected throughout time. This connection exemplifies the unsustainable nature of the techniques that are currently being used to utilize water, in which the high water requirements of particular crops worsen the already stressed groundwater supplies. These findings highlight the need of gaining a comprehensive understanding of the ways in which particular crop kinds impact water consumption and, as a result, groundwater levels. Furthermore, they highlight the crucial need to adopt agricultural techniques that are more environmentally friendly.According to the findings of this study, there are significant policy implications for the sustainable use of water in agricultural settings. One of the recommendations is to encourage agricultural diversity in order to lessen reliance on crops that require a lot of water, which would alleviate the strain that is being placed on groundwater supplies. The implementation of modern irrigation techniques, such as sprinkler and drip systems, can improve the efficiency with which water is used and reduce the amount of water that is wasted. In addition, the procedures for the management and conservation of groundwater should include the construction of regulatory frameworks that monitor and restrict the extraction of groundwater. When it comes to developing a more resilient agricultural system in Rajasthan, it is crucial to have policies in place that provide incentives to farmers to embrace sustainable practices. Some examples of these activities include rainwater gathering and ways for conserving soil moisture. Furthermore, in order to accomplish long-term water conservation objectives, it is essential to raise environmental consciousness among farmers and provide them with training on sustainable water management.

Challenges and Limitations

In spite of the significant insights that were obtained, this study is subject to a number of difficulties and constraints. Inconsistent groundwater monitoring across various regions may result in data restrictions, which may lead to the introduction of biases into the study. By relying on secondary data from a variety of sources, there is the potential for inconsistencies in the accuracy of the information. The unwillingness of farmers to change as a result of perceived economic risks or a lack of access to contemporary irrigation equipment are two examples of the socio-economic issues that frequently provide the impetus for the difficulties that arise when attempting to implement sustainable practices. Additionally, there is a possibility that institutional frameworks are not sufficient in terms of enforcing sustainable practices, which creates obstacles for groundwater conservation initiatives. In order to effectively address these difficulties, it is necessary for policymakers, agricultural stakeholders, and communities to collaborate in order to establish an environment that is conducive to the implementation of sustainable farming practices and efficient groundwater management management.

Conclusion

This study offers useful insights on the dynamics of groundwater in Rajasthan, particularly with regard to crops that have a high need for water, such as rice and sugarcane. The spatio-temporal analysis reveals that there is a substantial association between intensive agricultural practices and dropping groundwater levels. This reveals that the patterns of water consumption that are not sustainable are contributing to the worsening of groundwater depletion. Because of the strong connection between these agricultural methods and environmental consequences, such as the deterioration of soil and the loss of biodiversity, there is an urgent need for water management solutions that are consistent with sustainable practices. In light of these findings, it is clear that the irrigation practices and crop choices that are now in use are not suitable for sustainably increasing agricultural output or maintaining environmental health. In order to overcome these difficulties, it is necessary to develop policies that are successful in water management. Among the recommendations is the encouragement of agricultural diversity in order to lessen reliance on crops that require a significant amount of water and the implementation of modern irrigation techniques, such as drip and sprinkler systems, which improve the efficiency with which water is used. In addition, the establishment of regulatory frameworks to monitor groundwater extraction and the provision of incentives to farmers to adopt sustainable techniques, such as rainwater collecting, are key steps toward the development of an agricultural system in Rajasthan that is more robust. In order to expand upon these discoveries, future study ought to concentrate on a number of important areas. It will be essential to develop more effective methods of data collecting in order to ensure reliable groundwater monitoring. Additionally, increasing the scope of the study to include other places that are experiencing water scarcity challenges that are comparable might give significant comparative insights. Additionally, the investigation of the socio-economic aspects that impact the decisions of farmers to adopt sustainable practices would be of assistance in the development of tailored interventions. Future research have the potential to make a substantial contribution to a complete knowledge of groundwater dynamics by focusing on these regions. This, in turn, will make it easier to apply successful methods for long-term conservation and sustainable agriculture practices. The adoption of this comprehensive strategy is very necessary in order to guarantee the continued sustainability of agricultural systems as well as groundwater resources in the face of continuous environmental difficulties.

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