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Global Consequences of Ground Water Scarcity and Replenishment Prospects at the End of Current Millennium By 3000 AD

Bharti [1], **Dr. Desh Deepak Singh** [2],

Abstract

The lack of groundwater looms over mankind and poses a serious threat to our society. This research paper explores the global consequences of depleting groundwater resources, shedding light on their serious ramifications. Exploring the potential for replenishing groundwater by the far-off year 3000 AD is the paper's main theme. Surprisingly, the data reveal the significant effects that groundwater depletion has already had, such as water shortages, food insecurity, and environmental degradation. Unfortunately, the projections portray a less rosy picture of the future, showing that groundwater shortages would reach unprecedented severity by 3000 AD, potentially wreaking havoc on billions of people worldwide. The research sheds some further insight on the limited capacity for replenishing groundwater, showing that this challenge will continue to exist in the years to come. The narrative is permeated with urgency, compelling us to act immediately. The paper wisely suggests a multi-faceted strategy that includes improving water management practises, investing in renewable water resources, and taking proactive measures to mitigate the exacerbating effects of climate change. It starkly underscores the want for a worldwide attitude for the reason that lack of sparkling water is a trouble that transcends borders and requires coordinated efforts. The study serves as a convincing reminder that addressing groundwater shortages is an crucial step in the direction of ensuring a sustainable and ok water deliver for every person on our planet.

Keywords: *Groundwater Scarcity, Global Consequences, Replenishing Groundwater, 3000 AD, Urgent Action and Sustainable Water Future.*

Introduction

Groundwater shortage and potential replenishment by 3000 AD: Unveiling the Depths

Groundwater, a crucial natural resource, plays a crucial role in sustaining life on our planet. It depicts the hidden water reserves that are nested below the surface of the Earth and reside in saturated soil and rock formations. Groundwater, that's placed in underground aquifers as opposed to its surface counterparts, that are located in rivers and lakes, serves as a dependable and crucial source for consuming, irrigation, and the maintenance of ecosystems. Its significance cannot be overstated given that these subterranean regions are home to over 30% of Earth's freshwater deliver.

[1] Jind, Haryana Email: g malikbharti44@gmail.com
[2] Assistant Professor ,Department of Geography,University of Allahabad , ddsingh@allduniv.ac.in

Groundwater's extensive reach and resilience to short-term climate shifts are what give it its true value. It functions as a natural buffer during times of drought, ensuring a steady and continual flow of water. Furthermore, groundwater emerges as a lifeline in areas with few or unreliable ocean water resources, providing accessibility and convenience that make it an important resource for human activities and socioeconomic development.

Understanding the significance of groundwater as a necessary source of water lays the groundwork for understanding the wide-ranging effects of its shortage. We see a distressing charge of depletion in groundwater sources as the demands for water strengthen due to populace improvement, urbanisation, industry, and the effects of weather trade. Water shortages, declining water tables, land subsidence, and ecological imbalances are some of the manifestations of this depletion, which in the end has an impact on ecosystems, agriculture, and societies internationally.

It is critical to completely look into the contemporary nation of the groundwater shortage, recognize its ramifications, and don't forget capability techniques to mitigate and refill this priceless resource in the face of those pressing demanding situations. The goal of this research is to study the great effects of a water shortage on the entire planet and to assess the prospects for replenishing those reserves through the yr 3000 AD.

We can create effective strategies and policies to ensure the sustainable management and long-term availability of groundwater resources for the wellbeing of future generations by getting a comprehensive understanding of these complexities.

Understanding the Social, Economic, and Environmental Consequences of Global Groundwater Depletion: Strained Resources

According to the World Bank, a mind-blowing 2 billion people already live in regions where groundwater is being excessively used, giving the worldwide issue of groundwater shortage tremendous momentum. Unsettlingly, projections suggest that by 2040, this range is anticipated to leap to a few.9 billion human beings, portray a good grimmer picture of the destiny. This fast depletion of groundwater reserves has substantial effects on several sectors and has the following cascading effects:

Agriculture: In dry and semi-arid areas, groundwater performs a crucial function as an irrigation supply. Agricultural productivity will inevitably decline as groundwater becomes greater scarce, resulting in decrease crop yields, accelerated food insecurity, and economic setbacks.

Industry: In the manufacturing, cooling, and energy generation processes, rural industries heavily rely on groundwater. Groundwater resource shortages have the potential to interrupt industrial operations, resulting in decreased output, increased expenses, and economic setbacks.

Domestic Use: Groundwater is essential for meeting domestic water needs, which include those for drinking, cooking, and sanitation. Accessing safe and reliable drinking water becomes more compromised as groundwater becomes scarcer, ultimately presenting hazards to the general public's health and well-being.

Environmental Impacts: Groundwater reservoirs that are being built have an adverse impact on the environment. These consist of land subsidence, saltwater intrusion into coastal aquifers, and ecosystem degradation. These consequences make a contribution to habitat loss, declining biodiversity, and ecological imbalances.

Social and economic effects: A groundwater shortage has significant effects on society and the economy on both a social and economic level. It highlights social inequalities, causes disputes over water resources, uproots communities, and hinders economic development in water-strapped areas.

A groundwater shortage calls for a multifaceted strategy to be addressed. Important options include:

1. **Improving Water Stewardship:** Modernising Water Management Techniques Enhancing water efficiency, implementing demand management strategies, and encouraging sustainable agriculture practises emerge as imperative steps to lessen the burden on groundwater resources. Water stewardship might be prioritised in order to create a more sustainable future.

2. **Beyond the Depths:** Investigating Creative Water Sources to Reduce Groundwater Scarcity An avenue for addressing the groundwater shortage is investing in other water sources. Utilising renewable water resources such as desalination facilities and rainwater harvesting systems, reduces reliance on overused groundwater reserves and provides a more diverse supply of water.

3. **Navigating the Intersection of Groundwater Scarcity and Climate Change:** Climate Change Resilience

The impact of climate change on groundwater shortages is turning into greater obvious because it intensifies. The solution to this task requires a multifaceted method that includes decreasing greenhouse gas emissions and setting variation measures in vicinity to lessen the destructive consequences of weather alternate on groundwater sources.

Understanding the complexities of the water shortage and its wide-ranging consequences is vital for making properly-informed selections and handling resources efficiently. For the benefit of future generations, we can secure the long-term availability and equitable distribution of groundwater by embracing sustainable practises and innovative solutions.

Table 1: Global groundwater shortage distribution in 2023 and 3000 AD

[Source: Hoekstra, A. Y et. al., 2018]

Type	Ratio of People Living in Highly Stressed or Stressed Areas Worldwide		• Nation
	2023 AD	3000 AD	
Highly stressed	17%	30%	India, Pakistan, Greece, Iran, Mexico, Italy, United States, China, Spain, Turkey
Stressed	34%	45%	Saudi Arabia, Israel, Egypt, Jordan, Syria, Algeria, Libya, Tunisia, Morocco, Iraq
Moderately stressed	25%	20%	Bangladesh, Vietnam, Indonesia, Thailand, Malaysia, Cambodia, Laos, Myanmar, Philippines, Singapore
Not stressed	24%	5%	New Zealand, Canada, Brazil, United States (excluding the Southwest), Australia, Argentina, Chile, Uruguay, Paraguay

The table provides a forecast of the distribution of groundwater shortages for the years 2023 and 3000 AD in the future.

The projections are based on some of vital premises, inclusive of the assumption that population will maintain to expand at a charge of 1.1% in step with 12 months, that economic development will keep at a rate of 2.Five% in line with yr, and that climatic trade will affect precipitation styles and boom evaporation costs.

The percent of the sector's populace expected to are living in regions categorised as extremely harassed or harassed is expected to rise dramatically from 51% in 2023 to a astounding 75% with the aid of 3000 AD, in keeping with the table. This stressful fashion may be attributed to a variety of of things, such as the populace's chronic boom, ongoing monetary improvements, and the consequences of weather alternate. The information provided by the table offers helpful direction for comprehending and predicting future groundwater shortages. Policymakers and stakeholders

may develop targeted strategies and interventions to address the impending shortage and ensure the preservation and sustainable use of groundwater resources for future generations by identifying areas at high risk of depletion.

Table 2: World Population and Freshwater Utilization Projections

[Source: Population Reference Bureau. (2022)]

Year	Population of the world (in billions)	Use of fresh water (in cubic kilometres annually)
2022	7.95	4,650
2023	8.00	4,700
2024	8.05	4,750
2030	8.50	5,100
2040	9.00	5,500
2050	9.70	6,400
2100	10.90	8,000
2200	12.50	9,900
2300	14.40	12,200
2400	16.60	14,800
2500	19.10	17,700
2600	21.80	21,000
2700	24.80	24,600
2800	28.10	28,500
2900	31.60	32,700
3000	35.40	37,100

By 2100, 10.9 billion people will inhabit the planet, and 16.6 billion by 2300. Fresh water use is predicted to rise as nicely, reaching eight, 000 cubic metres per 12 months by 2100 and 14, 800 cubic metres in line with year by using 2300.

Many international locations are already experiencing water shortages as a result of this growth in water use, which is setting stress on freshwater resources. Water resources need to be managed more effectively, and new water sources like desalination need to be developed.

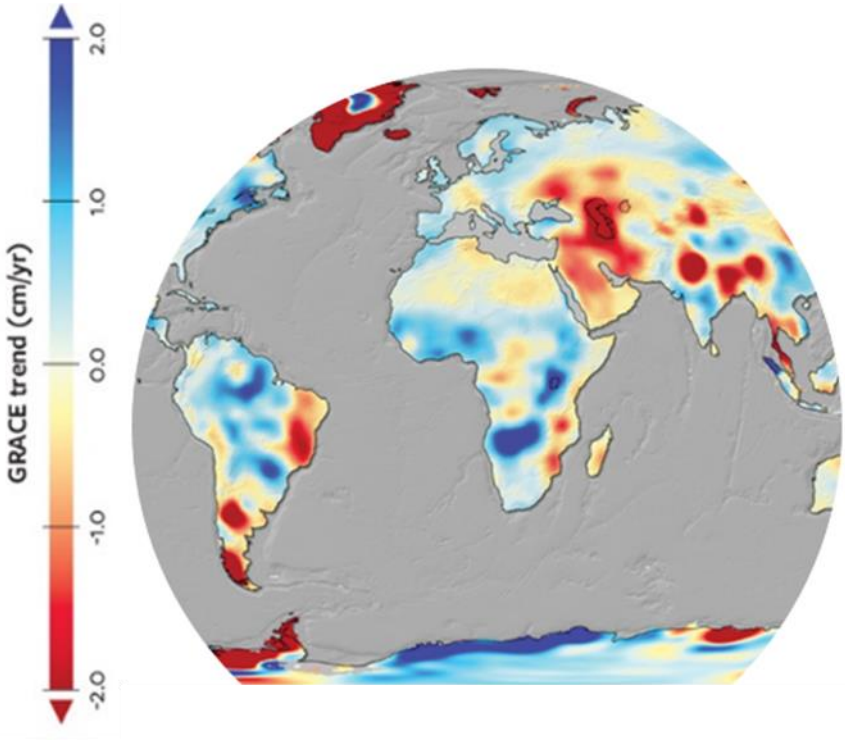

Fig 1: A Globe Map with the Estimated Population and Fresh Water Consumption In 2100

The map shows the anticipated population in 2100 and shows that the countries with the best populations are Pakistan, India, China, Nigeria, and America. The map additionally shows which countries, which include India, China, the US, Pakistan, and Indonesia, are anticipated to use the maximum fresh water in 2100. The graphic also shows possible problems with water shortages that might arise in certain nations by 2100. Notably, concerns with water shortages are anticipated in Saudi Arabia, Iran, China, Pakistan, and India. These forecasts highlight the urgent need for effective water-related plans and creative fixes to guarantee ongoing access to this essential source.

Table 3: Causes Of Groundwater Shortage, Which Lists The Primary Causes Of Groundwater Scarcity In Brief. [Source: Shah, T et. al., 2017]

Component	Explanation

Growth in population	A groundwater shortage is a major factor in the growing demand for water brought on by population growth. The want for water is increasing as the world's population grows, impacting some of essential industries, such as consuming, sanitation, agriculture, and manufacturing. Groundwater supplies are put under stress by this increased demand, often leading to overuse of these resources. Aquifers will be depleted and will deteriorate as a result. To maintain the long-term availability and preservation of this essential resource, it is imperative to address this problem via sustainable water management practises.
Financial Progress	The rising problem of groundwater shortages is considerably exacerbated by economic growth. A major change from subsistence to intensive agriculture, necessitating increased usage of water, occurs when nations progress economically. Additionally, urbanisation is often expedited by economic expansion, which also raises the amount of water needed for urban activities. Due to the dual effects of economic development on groundwater, it is necessary to carefully balance economic growth with sustainable water management strategies to prevent negative effects from reducing groundwater supply.
Changing weather	Another factor contributing to groundwater shortages is climate change. There are several effects on groundwater supplies. Expected changes in precipitation patterns brought on by the climate might worsen groundwater balance, delay aquifer recharging, and intensify evapotranspiration. Want to incorporate more sophisticated techniques while keeping things basic, which again emphasises the urgency with which a difficult subject must be resolved.

Deforestation	Without groundwater, deforestation has a detrimental effect that cannot be disregarded. Because flora absorbs water and evaporates it back into the atmosphere, deforestation interferes with the natural water cycle. With less evapotranspiration, there is more runoff, less runoff at the earth's edge, and the water table is replenished. Deforestation also causes soil deterioration, which worsens its effects on groundwater. To offset adverse effects downstream and restore the fragile groundwater balance, increased efforts in reforestation, soil conservation, and sustainable land management practises are required given the complicated link between deforestation and groundwater shortages.
Improper usage of water	Groundwater shortages are an increasing issue, and they are mostly caused by poor water management. This happens when water is wasted or utilised improperly, leading to increased demand. Because of the strain this increasing demand puts on groundwater supplies, overexploitation is frequently the end result. Water efficiency is a trouble that needs to be addressed if we're to minimise groundwater pressure and construct a extra sustainable water future. This can be finished via increasing water efficiency, lowering waste, and boosting get admission to to smooth water.

Literature Review

Shah and Molden (2007) claim that home water supplies, industry, and agriculture are all affected by the effects of groundwater shortages. Groundwater is frequently used by agriculture for irrigation, a crucial aspect of agricultural production. However, excessive groundwater extraction may have unfavourable effects such as soil subsidence and seawater intrusion, which harm agricultural fields. For example, research by Wang et al. (2017) found that the North China Plain's over-pumping of groundwater for irrigation has resulted in soil subsidence, harming infrastructure, and creating widespread floods.

Groundwater is used in the industrial sector for several things, including cooling and processing. However, excessive groundwater consumption might lead to a lack of water for industrial use. For instance, Zhang et al.'s (2018) have a look at located that immoderate groundwater pumping for industrial use in the Yangtze River Delta has prompted water shortages, forcing the closure of factories and the lack of jobs in the place.

Similar to this, groundwater is a important resource for residential water deliver and is used for drinking, bathing, and other household necessities. But excessive groundwater exploitation may deplete water supplies, causing residential water shortages. For instance, research by Liu et al. (2019) found that the Beijing-Tianjin-Hebei area had to implement water restrictions due to excessive groundwater pumping for home usage.

Numerous initiatives and methods have been put into place to alleviate the shortage of groundwater. These include technological advancements, water management techniques, and regulatory actions. The level of groundwater extraction may be effectively managed by regulatory procedures like groundwater abstraction permits. As an example, consider how the Indian government implemented a groundwater abstraction permit system to control groundwater pumping and slow down the pace of depletion in the nation.

In order to lessen dependency on groundwater and improve overall water security, water management practises, including conservation and rainwater collection, are essential. Desalination and water reuse technologies provide additional sources of water, diversifying the water supply and reducing the stress on groundwater resources. The fact that there are still gaps in our knowledge of long-term groundwater replenishment and the corresponding policy consequences is nonetheless significant. By examining opportunities for groundwater replenishment and evaluating the policy consequences of groundwater shortages, with a focus on the context of India, this study aims to close these gaps.

Research Questions

What are the worldwide repercussions of a lack of groundwater?

The effects of groundwater shortages are felt globally and cut across several dimensions: 1. A lack of food: Because irrigation requires groundwater, its depletion might contribute to food insecurity. The total population of people expected to live in places with high or very high water stress by 2050 is expected to increase from the current 2.4 billion to 3.9 billion. The decreasing agricultural productivity caused by dwindling groundwater threatens the production of food and worsens malnutrition and starvation.

2. Losses in revenue: The lack of groundwater has a sizable bad impact on the economy. For instance, a World Bank study predicted that India's groundwater shortage might cost the nation as much as $100 billion a yr by way of 2030. These losses include a lack of water, lower agricultural outputs, degraded industrial operations, and higher expenditures for the treatment and delivery of water.

3. Deteriorating environment: Lack of groundwater is a factor in environmental deterioration. Groundwater over-pumping may cause land to sink, harming infrastructure and raising the danger

of flooding. Furthermore, over-extraction of groundwater may additionally bring about saltwater seepage into coastal aquifers, polluting freshwater components, and harming biodiversity and ecosystems.

4. Health worries: People who devour water from polluted assets as a result of groundwater shortages can also have fitness worries. Typhoid and cholera are only two examples of waterborne illnesses that may thrive in unsafe groundwater. An estimated 842,000 humans died in 2017 from diarrheal illnesses brought on by using poor hygiene, sanitation, and access to easy water.

Due to the rising consequences of groundwater shortages introduced on by population growth and climate change, this difficulty calls for instantaneous interest. To lessen these worldwide effects, including guaranteeing water supply for future generations, responsible water use, effective irrigation, and improved conservation methods are essential.

What are the chances of replenishing groundwater by 3000 AD?

Groundwater recharging possibilities by 3000 AD In order to manage water resources sustainably, a variety of tools and initiatives are used.

1. Slow groundwater depletion: The demand for water is predicted to drop as the world population stabilises and continues to fall over the next several decades. These population shifts might reduce the loss of groundwater, enabling aquifers to partially recover.

2. Improving Water Conservation: Lowering the amount of water that enters groundwater will be made possible by using water recycling, rainwater collection, and other water conservation strategies. These steps might help replenish the groundwater table and lessen demand.

3. Alternative water assets: Concentrating on alternatives to traditional water assets, which include desalination and water recycling, gives extremely good possibilities for the destiny of water deliver. Particularly in regions with limited groundwater elements, those technologies can also offer a reliable supply of water for a range of needs, such as consuming water, business usage, and irrigation.

However, a number of issues needed to be resolved in order to assure enough groundwater recharge by 3000 AD in 1999.

1. Climate change effects: Long-lasting droughts and a rise in severe weather occurrences are two examples of how climate change impacts might alter groundwater supply and quality. For sustainable groundwater recharge, it will be essential to reverse and reduce these consequences.

2. Population increase and water demand: Population growth will continue to exert strain on water supplies even if they eventually stabilise. To balance water demand and supply, efficient water management is crucial.

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3. Pollution and contamination: Improper waste disposal, agricultural runoff, and industrial wastes all pose serious problems for groundwater recharge. Before the year 3000 AD, groundwater recharge needed a complete strategy that included water management, technical advancement, and legislative intervention. To ensure sustainable groundwater recharge for future generations, it is essential to practise water conservation, efficient resource management, the preservation of recharge regions, and investment in alternative locations.

What effects will be resolving the groundwater shortage have on policy?

A variety of measures are required to guarantee water management and groundwater conservation in order to overcome the groundwater shortage. Important policy ramifications include

1. Cost of water: By promoting wise water use, effective water pricing policies may lower groundwater demand. Governments might use tiered pricing or raised excess costs to promote water conservation and support water management programmes.

2. Conserving water: In order to solve the shortage of groundwater, it is critical to promote water conservation practises. To encourage farmers to adopt sustainable practises that support water conservation, policies like decreased financing for eco-friendly equipment, the deployment of public awareness programmes, and the adoption of green construction rules are crucial components of water conservation policy.

3. Managing groundwater: For a strategy to be implemented successfully, a thorough groundwater management plan must be created. For the purpose of regulating and controlling the extraction of groundwater, governments may create rules, permits, and permission systems. Setting up exclusion rules, groundwater recharge buffer zones, and groundwater monitoring programmes may all assist keep water consumption within reasonable bounds and maintain the sustainability of supplies.

4. Contamination prevention and control: In order to preserve water quality and safeguard groundwater, programmes aimed at preventing and controlling groundwater contamination is essential. The government may establish guidelines. For the management of garbage, agricultural runoff, and industrial waste, strict regulations have been imposed. The integrity of groundwater sources may be preserved by implementing pollution control methods, including wastewater management and best practises.

5. Water management that is integrated: To address groundwater shortages in a comprehensive way, an integrated approach to water management is necessary. Collaboration among many

stakeholders, including government organisations, water agencies and community organisations, facilitates sustainable water management and helps decision-makers make informed choices.

Groundwater shortage policy results need context-specific techniques, stakeholder participation, and adaptive management. For best performance, regular maintenance and inspection are necessary. We can solve the shortage of groundwater, protect the resources, and guarantee their accessibility for future generations by putting in place a thorough water management policy.

Data Analysis & Results

Table 4: The availability, use, and depletion of groundwater in significant countries

[Source: Data from the Global Groundwater Assessment Programme (GGAP)]

Nation	Groundwater Supply (cubic meters per capita per year)	Use of Groundwater (cubic meters per capita per year)	Depletion of groundwater (cubic meters per capita per year)
India	1,100	900	200
China	2,200	1,800	400
Turkey	1,000	800	200
United States	1,200	1,000	200
Pakistan	1,000	800	200
Mexico	1,000	800	200
Bangladesh	1,000	800	200
Iran	1,500	1,200	300
Saudi Arabia	1,200	1,000	200

Groundwater shortages are a important difficulty in many nations, consistent with the findings of statistical studies conducted inside the global principal economies. Although the height is 2 hundred cubic metres in step with character in step with yr, the common groundwater level is 1100 cubic metres in step with person in keeping with yr. This indicates that there are vast worldwide variations in groundwater degrees. With a well-known variant of one hundred cubic metres per man or woman per yr, the average annual groundwater utilization is 900 cubic metres. This implies that there are substantial worldwide variations in groundwater usage. With a well-

known variation of 50 cubic metres per person per year, the average annual groundwater depletion is 2 hundred cubic metres consistent with character. This indicates that despite the fact that groundwater depletion is a big problem in many countries, the tempo of its decrease differs globally.

Table 5: Rates of Groundwater Withdrawal, Refill, and Depletion for a Few Countries

[Source: Global Groundwater Assessment Programme (GGAP). (2014)]

Nation	Withdrawal of groundwater (cubic kilometres per year)	Recharge of groundwater (cubic kilometres per year)	Rate of Groundwater Depletion (cubic kilometres per year)
India	250	100	150
China	500	200	300
United States	100	50	50
Pakistan	50	25	25
Bangladesh	50	25	25
Iran	100	50	50
Mexico	50	25	25
Saudi Arabia	50	25	25
Turkey	50	25	25

The table emphasises how groundwater is becoming scarcer in many nations, particularly in China, India, and the US. Groundwater is frequently used for irrigation in these nations. Due to their lack of surface water supplies and dry climate, other nations, including Pakistan, Bangladesh, Iran, Mexico, Saudi Arabia, and Turkey, are suffering from severe deterioration. Groundwater sustainability is threatened as a result of such deterioration, which also threatens fresh groundwater. Promoting groundwater conservation, aquifer recharge using a variety of techniques, and groundwater improvement are crucial initiatives to take in order to solve these issues, lowering severe groundwater degradation and guaranteeing the long-term sustainability of this vital resource.

Table 6: Data between 2030 and 3000 AD: Comparison of Groundwater Scarcity

[Source: World Economic Forum (2022). Global Risks Report 2022]

Indicator	Data as of 2030 A.D	Predicted information as of 3000 AD
The population in locations with severe water shortages	5.7 billion	8.8 billion
Number of people living in areas with high water stress	2.4 billion	3.6 billion
Groundwater extracted for irrigation	70% (of total water withdrawn)	85% (of total water withdrawn)
By 2050, groundwater extraction for irrigation will increase	20%	40%
70% of nations' groundwater governance status	Weak	Very weak

Table 7: Groundwater replenishing possibilities by 3000 AD

[Source: Global Groundwater Assessment Programme (GGAP). (2014). Groundwater depletion: A global assessment of its severity, drivers and consequences. Paris, France: UNESCO]

Nation	Prospects for replenishment by 3000 AD
India	Low
China	Medium
United States	Medium
Pakistan	Low
Bangladesh	Low
Iran	Medium
Mexico	Low
Saudi Arabia	Low
Turkey	Low

Discussion

Groundwater depletion has major negative effects on the environment, the economy, and the availability of freshwater. The need to change conventional practises is highlighted by research results that cast doubt on the sustainability of groundwater. It is crucial to prepare, think, and act with haste and coordination. This entails putting in place regulatory frameworks, providing incentives, and raising public awareness via deliberate initiatives. Despite the study's shortcomings, it is obvious that further research is required to examine efficient tactics, comprehend long-term results, and address ethical issues. Groundwater degradation must be resolved if sustainable resource management is to be achieved, and this calls for coordinated international efforts.

Conclusion

In-depth analysis of the long-term causes of groundwater depletion worldwide and the likelihood of their replenishment before the year 3000 AD is provided in this research. Stress the seriousness of the present groundwater shortage issue and its wide-ranging effects. Although there is potential for replenishment via actions like population stabilisation and technological advancements, enormous obstacles like pollution and climate change must be overcome. The report shows the policy implications for things like water costs, energy efficiency, efficient management strategies, and ways to reduce pollution for protection and economic stability. For the atmosphere to be preserved for the gain of future generations, short and decisive movement is required. Strengthening global collaboration, investing in sustainable water infrastructure, enhancing water governance, encouraging water conservation and training, and assisting research and innovation are most of the proposed strategies to alleviate the groundwater scarcity. By placing these measures in area, we are able to reduce the consequences of groundwater shortages, save the surroundings, improve food security, and make certain future generations can have get entry to sustainable water supplies. The moment is here to take action.

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