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GROUNDWATER DEPLETION CAUSES IN INDIA AND POSSIBLE SOLUTIONS FOR SUSTAINABLE AGRICULTURE AND DEVELOPMENT

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ABSTRACT

The irregularity in monsoon has severely affected the water availability at surface and sub-surface systems. Diminishing surface and sub-surface availability has not only decreased the water availability, but it additionally affected the ecosystem and increased disastrous situations like floods and droughts, resulting problems of stress on groundwater recharge. Groundwater recharge is a technique by which infiltrated water passes through the unsaturated region of groundwater and joins the water table. It is based upon soil type, land use, land cover, geomorphology, geophysical and climate (viz. rainfall, temperature, humidity etc.) characteristics of a region. Over the years, due to variations in weather pattern and overexploitation of aquifers groundwater recharge has decreased and groundwater level has reduced in the most parts of the country. This has led to severe water deficit problems in several parts of the country. This can be solved by different direct and indirect methods of groundwater recharge technology. This technology can reduce the wastage of water and enhance groundwater availability for uses in different sector like irrigation, domestic and industrial uses.The conversation around India's diminishing groundwater sources is not new, but today due to the never-ending cycle of overuse and abuse of groundwater in the country, we have reached a critical point. With 16% of the world's population and only 4% of the world's freshwater resources, India has relied heavily on groundwater to meet its growing water demand for several decades. It is without a doubt that groundwater is a national lifeline in India. Inculcating the right mindset in people regarding usage and conservation of groundwater with focused and demonstrative education is essential. Ramifications for misuse of groundwater should also be introduced to make people; industries adhere to rules and processes.The major causes of ground water depletion are the followings: - (1) Agricultural crop pricing and water-intensive crops (2) Energy subsidies and groundwater extraction (3) Inadequate regulation of groundwater law (4) Expansion of irrigated agriculture in drylands (5) Population growth (6) Climate change (7) Overuse (8) Over extraction (over withdrawal) (9) Affluent lifestyle (10) Accelerated urbanization. (11) Lack of awareness of common people about groundwater wastage or overuse etc. The major solutions of ground water depletion causes are the followings: - (1) To limit water consumption in agriculture, the Commission on Price Policy for Kharif Crops (2015–16) has suggested setting quantitative restrictions on both water and power use per hectare. (2) Since water is a state subject, each state government is largely responsible for taking action to increase, conserve, and manage water resources effectively. (3) Jal Shakti Abhiyan (JSA): a time-limited initiative using a mission-mode strategy to enhance groundwater conditions in the water-stressed blocks of 256 districts in India. The "Jal Shakti Abhiyan is Catch the Rain" campaign. (4) Atal Bhujal Yojana**:** In the areas that have been identified as being overexploited and experiencing a water shortage, the Atal Bhujal Yojana (ABHY) scheme, which is co-funded by World Bank funding- is being implemented. (5) Restoring our natural water resources like ponds, lakes and water bodies will further help us in our endeavor against climate change while making a positive impact on our ecosystem. (6) Additionally, reforestation and afforestation programs help in maintaining the ecological balance and enhancing groundwater recharge. (7) Rainwater harvesting involves catching and storing rainwater before it reaches the ground. (8) Desalination: -One method that can actually increase the amount of freshwater on Earth is desalination, which involves removing dissolved salt and minerals from seawater or saline groundwater. (9) Groundwater governance process enable groundwater management, planning and policy implementation. (10) Digging sufficient numbers of ponds, ponds recharge the groundwater (11) Planning to plant more trees. (12) river-linking concept of India (13) An open/public database on all components of water resources could help policy makers and other stakeholders in proper management. (14). A major city-wide campaign is needed to aware the people on importance of groundwater proper use and need of groundwater conservation etc. The removal of causes of groundwater depletion, by possible solutions is need of the hour for sustainable agriculture, sustainable development of country and to save the present civilization.

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INTRODUCTION

India has 16% of the global population but only 4% of the freshwater resources. Several reasons intensify groundwater depletion. In India, there is a lack of fresh water, but there is also a long-standing increase in groundwater exploitation. The need for groundwater for agriculture has expanded since the 1960s as a result of the government's encouragement of the "green revolution" to secure food security. To meet this demand, there are now more bore wells than ever before because of rapid rural electrification and the accessibility of modern pump technologies.According to the Central Groundwater Board of India, 17% of groundwater blocks are overexploited, meaning that the rate at which water is extracted is higher than the rate at which the aquifer can recharge.Groundwater resources, which support over 60% of irrigated agriculture and around 85% of domestic water supply in rural areas and 45% of it in urban areas, are already under pressure from groundwater pollution and the effects of climate change. The concept of sustainable development was brought to the forefront in 1987 by the United Nations World Commission on Environment and Development. The Brundtland Commission, as it came to be known, broadly defined sustainable development as that which meets the needs of the present without compromising the ability of future generations to meet their needs. The recent California Sustainable Groundwater Management Act defines sustainable groundwater management as a basin operated in such a way so as not to cause "undesirable results," such as chronic depletion of groundwater, seawater intrusion, or land subsidence. The definition used in U.S. Geological Survey Circular 1186, Sustainability of Ground-Water Resources, seems to be commonly accepted, that is, "development and use of groundwater resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences."Groundwater makes up about thirty percent of the world's fresh water supply, which is about 0.76% of the entire world's water, including oceans and permanent ice. About 99% of the world's liquid fresh water is groundwater.Global groundwater storage is roughly equal to the total amount of freshwater stored in the snow and ice pack, including the north and south poles. This makes it an important resource that can act as a natural storage that can buffer against shortages of surface water, as in during times of drought.The volume of groundwater in an aquifer can be estimated by measuring water levels in local wells and by examining geologic records from well-drilling to determine the extent, depth and thickness of water-bearing sediments and rocks. Before an investment is made in production wells, test wells may be drilled to measure the depths at which water is encountered and collect samples of soils, rock and water for laboratory analyses. Pumping tests can be performed in test wells to determine flow characteristics of the aquifer.The characteristics of aquifers vary with the geology and structure of the substrate and topography in which they occur. In general, the more productive aquifers occur in sedimentary geologic formations. By comparison, weathered and fractured crystalline rocks yield smaller quantities of groundwater in many environments. Unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins are included among the most productive sources of groundwater.Embedding technology into the very framework of groundwater distribution is also fundamental to increase groundwater accessibility and to ensure sustainability during future extractions of the resource.

IMPORTANCE OF GROUNDWATER: - Groundwater resources in India, a lifeline for millions of people and a driving force behind its economic growth, are under immense pressure due to population growth, climate change, and unregulated exploitation. They are crucial for several reasons. Groundwater resources are a critical component of the country's agricultural sector, which accounts for a significant portion of the country's economy and employment. Groundwater is used extensively for irrigation purposes, particularly in areas where rainfall is insufficient or unreliable. They are also a primary source of drinking water for millions of people, particularly in rural areas where access to surface water sources is limited.

Indian girl using hand pump for drinking water

Finally, groundwater resources are also important for industrial and commercial activities, including manufacturing, mining, and power generation. Thus, the availability and sustainability of groundwater resources in India have a significant impact on various aspects of the country's socio-economic development.Groundwater is the foremost supply of freshwater that caters to the demand of household, agricultural and industrial sectors. It has become an essential for domestic uses especially for drinking water and food security for billions of populations of the country. Approximately 70 percent water use in rural regions and approximately 50 percentage of water used in urban and commercial region are fulfilled by the sources of groundwater. The average annual per capita water availability has been steadily falling since 1991 (2300 m^3) to 2015 (1720 m^3) in the country and these are projected to reduce to 1400 m^3 and 1190 m^3 for the years 2025 and 2050, respectively. In last three decades an exponential growth in number of ground water structures has been observed, leads to enormous withdrawal of groundwater for various uses in different sectors. However, speedy urbanization and land use adjustments has resulted in decreased natural infiltration/recharge of aquifers. This has result in various issues related to quantity and quality of groundwater, the decline in water table levels and depletion of groundwater resources. Slow natural replenishment of groundwater reservoir is not able to keep pace with the excessive persisted exploitation of groundwater assets in numerous parts of the country. In order to increase the natural supply of groundwater, artificial recharge to groundwater has emerged as a vital and frontal management approach. So, the recharge of groundwater is performed by using various direct and indirect recharge technologies. The adoption of this technology depends on hydrology, geology andother factors of a region. Thus, artificial recharging of aquifer is one of the best options, in order to improve groundwater crises which are sustainable in the long term.Even the manufacture of vaccines requires water.

Women carrying drinking water from a long distance

Artificial groundwater recharge is becoming increasingly important in India, where over-pumping of groundwater has led to underground resources becoming depleted.

Importance of ground water balance

- Due to increasing population, the national per capita annual availability of water has reduced by 15% from 2001 to 2011.
- The number of over exploited districts have increased by 5 times between 1995 and 2011.
- 89% of groundwater extracted is used in the irrigation sector, 9% is for domestic use and 2% is for industrial use.
- 50% of urban water requirements and 85% of rural domestic water requirements are fulfilled by groundwater.
- Nearly 60% of all districts have issues related to availability or quality of groundwater, or both

For instance, in 2017, 30% of the population in Jakarta relied on groundwater due to the poor planning of water infrastructure. This had a direct impact on the livelihood of poor residents with 88% of them having to buy water from neighbours, spending upwards of 25% of their monthly income.Similarly, the 2019 water scarcity in Chennai highlighted the need for planned industrialization and urbanization to avoid crisis like water shortage. Denmark's drinking water comes entirely from the groundwater resources.The Atal Bhujal Yojana, India's largest community-led groundwater management program, is helping improve rural livelihoods and build resilience in 7 Indian states which have the highest rates of groundwater depletion.

RESULT OF GROUND WATER DEPLETION: -Already, almost two-thirds - 63 percent - of India's districts are threatened by falling groundwater levels. Worryingly, poverty rates are 9-10 percent higher in districts where groundwater tables have fallen below 8 meters, leaving small farmers particularly vulnerable. If current trends persist, at least 25 percent of India's agriculture will be at risk.

- **Lowering of the water table: -**Pumping has removed water from storage in basalt aquifers and caused declines in many areas. The most severe consequence of excessive groundwater pumping is that the water table, below which the ground is saturated with water, can be lowered. For water to be withdrawn from the ground, water must be pumped from a well that reaches below the water table. If groundwater levels decline too far, then the well owner might have to deepen the well, drill a new well, or, at least, attempt to lower the pump. Also, as water levels decline, the rate of water the well can yield may decline.
- **Reduction of water in streams and lakes: -**There is more of an interaction between the water in lakes and rivers and groundwater than most people think. Some, and often a great deal, of the water flowing in rivers comes from seepage of groundwater into the streambed. Groundwater contributes to streams in most physiographic and climatic settings. The proportion of stream water that comes from groundwater inflow varies according to a region's geography, geology, and climate. Groundwater pumping can alter how water moves between an aquifer and a stream, lake, or wetland by either intercepting groundwater flow that discharges into the surface-water body under natural conditions, or by increasing the rate of water movement from the surface-water body into an aquifer. A related effect of groundwater pumping is the lowering of groundwater levels below the depth that streamside or wetland vegetation needs to survive. The overall effect is a loss of riparian vegetation and wildlife habitat.
- **Land subsidence:-**The basic cause of land subsidence is a loss of support below ground. In other words, sometimes when water is taken out of the soil, the soil collapses, compacts, and drops. This depends on a number of factors, such as the type of soil and rock below the surface. Land subsidence is most often caused by human activities, mainly from the removal of subsurface water.
- **Increased costs for the user; -**As the depth to water increases, the water must be lifted higher to reach the land surface. If pumps are used to lift the water (as opposed to artesian wells), more energy is required to drive the pump. Using the well can become prohibitively expensive.
- **Deterioration of water quality: -**One water-quality threat to fresh groundwater supplies is contamination from saltwater intrusion. All of the water in the ground is not fresh water; much of the very deep groundwater and water below oceans is saline. Under natural conditions the boundary between the freshwater and saltwater tends to be relatively stable, but pumping can cause saltwater to migrate inland and upward, resulting in saltwater contamination of the water supply.

CAUSES OF GROUNDWATER DEPLETION: -There are several natural and anthropogenic reasons for the depletion of groundwater. This depletion is mainly caused by:

- **Agricultural crop pricing and water-intensive crops: -**The primary cause of over-exploitation has been the rising demand for groundwater from agriculture.A shift toward water-intensive or cash crops for financial gain has become a reason for the depletion of groundwater.
- **Energy subsidies and groundwater extraction: -**The practice of giving power subsidies to agriculture has been a significant contributor to India's declining water levels. A total of 89% of the groundwater extracted in 2009 was used for irrigation, while 11% of it was used for home and industrial purposes.The availability of cheap/subsidized power in many regions encourages further extraction of this resource.To limit water consumption in agriculture, the Commission on Price Policy for Kharif Crops (2015–16) has suggested setting quantitative restrictions on both water and power use per hectare.
- **Inadequate regulation of groundwater law:-** In most urban and rural regions, private ownership of groundwater is common due to the lack of regulations that prevent excessive exploitation of this resource, which has made the problem worse.
- **Green Revolution:-**Groundwater was over-extracted as a result of the Green Revolution, which allowed for the cultivation of crops that required a lot of water in areas that were prone to drought and water shortages.
- **Quality of groundwater: -** In its Performance Audit of Water Pollution in India, 2011–12, the Comptroller and Auditor General (CAG) of India noted that despite increasing contamination of groundwater sources and the presence of contaminants like arsenic, nitrate, fluoride, salinity, etc., no program is being implemented at the central or state level to control pollution and restore groundwater.
- **High MSP (Minimum Support Price):-**High MSP draws farmers' attention toward those crops for which MSP is provided by the government.That includes cash crops and other crops that require intensive irrigation, which further deteriorates the condition of groundwater.The need for groundwater for agriculture has expanded since the 1960s as a result of the government's encouragement of the "green revolution" to secure food security. To meet this demand, there are now more borewells than ever before because of rapid rural electrification and the accessibility of modern pump technologies.
- Expansion of irrigated agriculture in drylands
- Arid and semi-arid regions lacking sufficient surface water.
- Population growth
- Land use changes
- Overuse
- Over extraction (over withdrawal)
- Due to more groundwater being used for irrigation activities in agriculture
- Climate change causes changes to the water cycle which in tern affect groundwater in several ways.
- More intense drought periods could result in soil drying out and compaction which would reduce infiltration to ground water.
- For the higher altitude regions, the reduced duration and amount of snow may lead to reduced recharge of groundwater in spring.
- Lack of awareness of common people about groundwater wastage or overuse.
- Political and administrative will to stop excess water use.
- Accelerated urbanization.
- Little control over its extraction.

- Triggered by the green revolution, groundwater use has exploded in India since the 1970s.
- Availability of cheap electricity shifted farmers' dependency from surface water to groundwater.
- Out of total irrigated area in Punjab, only 26.2 % is irrigated by surface water. Despite five rivers flowing through the state.
- Poor knowledge of groundwater management systems.
- Role of panchayats in groundwater management has been negligible or at best casual.
- Disturbances in the hydrological cycle causing long spells of floods and drought.
- Heavy subsidies on irrigation pumps.
- Access to cheap electricity.
- Groundwater depletion as long- term water level declines caused by sustained groundwater pumping.
- Periods of drought also have an effect on groundwater levels, as replenishing water infiltrating into the aquifer would be reduced.
- Shrinking Himalayan glacier.
- Built dams to stop the flow of rivers.
- Over-extraction of non-renewable aquifers is the major cause of the depletion of groundwater in the Ganga basin.
- Road networks and infrastructure within cities prevents surface water from percolating into the soil.

Over-exploitation of groundwater

- More intense drought periods could result in soil drying-out and compaction which would reduce infiltration to ground water.
- Reduction in groundwater recharge.
- Decline in groundwater storage.
- Rates of groundwater recharge are difficult to quantify. This is because other related processes, such as evaporation, transpiration (or evapotranspiration) and infiltration processes must first be measured or estimated to determine the balance. There are no widely applicable method available that can directly and accurately quantify the volume of rainwater that reaches the water table.
- Groundwater quantity and quality is relatively constant compared to surface water.
- We considered and still consider rivers as water channels; rather than living systems.
- The Pradhan Mantri Kisan Urja Suraksha evam Uttlaan Mahabhiyan (Pm-KUSUM) may accelerate ground water depletion.
- The Green Revolution of the 1960s ushered agricultural productivity but also led to a surge in groundwater extraction through borewells.
- Commercial agriculture
- Faulty agricultural practices
- Affluent lifestyle
- The inter-sectoral competition for water — agriculture (89 per cent), industry and domestic (11 per cent) — exerts heavy pressure on water availability in India
- The concept of 'rainwater harvesting' is commonly associated with residential land uses and its applicability in the industrial sector is often neglected.
- Paddy cultivation in the state Punjab is the fundamental cause of this problem. But farmers are the victims of the problem, not offenders.
- High-yielding varieties of paddy have a higher irrigation requirement than the other *kharif* competing crops such as cotton, maize and many others.
- Excessive groundwater pumping for irrigation purposes
- The rapid growth of urbanization and industrialization has increased water demand,
- The absence of effective water management practices
- Lack of awareness among the public,
- Inadequate regulation of groundwater extraction
- Size of landholdings
- Water users' behaviour
- Lack of legislation and administration of ground water.
- Power subsidies for pumping irrigation.
- Lack of suitable economic policies
- Washing of cars
- Overwatering gardens
- Letting home water tanks overflows
- Dams reduce water flow downstream, which could lead to political conflicts when rivers span states or countries.

SOLUTIONS

- In many areas also people draw more water from the ground, so the groundwater is decreasing over time.
- To limit water consumption in agriculture, the Commission on Price Policy for Kharif Crops (2015–16) has suggested setting quantitative restrictions on both water and power use per hectare.
- Since water is a state subject, each state government is largely responsible for taking action to increase, conserve, and manage water resources effectively.
- The Central Government offers technical and financial support to the State Governments through a variety of schemes and programs to supplement their efforts in the field of water harvesting, groundwater depletion, and contamination.
- The Central Government has taken several actions to guarantee water security in different regions of the country.
- The Central Ground Water Authority (CGWA) was established to regulate and oversee groundwater development and management throughout the country.
- The CGWA has recommended States and UTs develop policies that will encourage artificial groundwater recharge and rainwater collection.
- **Central Ground Water Board:** CGWB's "Master Plan for Artificial Recharge to Ground Water in India" 2013- The Master Plan calls for the construction of 1.11 crore artificial recharge and rainwater harvesting structures across the country. The increased groundwater resources will increase the supply of water for irrigation, residential use, industry, and drinking.
- **Jal Shakti Abhiyan (JSA):** a time-limited initiative using a mission-mode strategy to enhance groundwater conditions in the water-stressed blocks of 256 districts in India. The "Jal Shakti Abhiyan – Catch the Rain" campaign has also been introduced. Recognizing the severity of the depleting groundwater crisis, the Indian government has taken several initiatives to address the issue. The **"Jal Shakti Abhiyan"** launched in 2019 aims to enhance water conservation and management across the country. The government has focused on promoting rainwater harvesting, implementing watershed development projects, and encouraging efficient irrigation practices.
- **National Water Policy (2012):** It emphasizes the necessity of increasing water availability through the direct use of rainwater and was developed by the Department of Water Resources. In addition, encroachment and diversion of water bodies and

drainage systems must not be permitted, and when they have occurred, they must be adequately restored and maintained.

- **Atal Bhujal Yojana:** In the areas that have been identified as being overexploited and experiencing a water shortage, the Atal Bhujal Yojana (ABHY) scheme, which is co-funded by World Bank funding- is being implemented. Additionally, the Atal Bhujal Yojana has been launched to promote sustainable groundwater management through community participation and the creation of water user associations. These initiatives provide a framework for collective action and aim to raise awareness about the importance of conserving and replenishing groundwater resources.
- Vegetation like trees and grasses and bunds are used to enhance groundwater.
- We follow watershed development projects: -Under these projects trees and grasses are planted on the hill slopes from where a stream starts and small bunds are built across streams to stop the flow of water.
- The people store rainwater in tanks and not dig wells too deep in the ground.
- Tanks should be developed in our village which helps the people not only in giving them and their animals drinking water, but also irrigating their fields in such a way that even in drought years people could raise at least some crops.
- The initiation of rainwater harvesting measures.Rainwater harvesting has benefits ranging from reduced energy use, non-potable water usage for commercial and domestic purposes including economic benefits. For example, drought prone villages in Maharashtra have integrated traditional and modern methods of water conservation to overcome water crisis. Proper planning at the local level along with state and central schemes have motivated community participation through installation of rooftop rainwater harvesting systems, enabling 1,00,00 villagers across four villages in the state to have access to water throughout the year.
- Restoring our natural water resources like ponds, lakes and water bodies will further help us in our endeavor against climate change while making a positive impact on our ecosystem.
- The implementation of water-efficient irrigation techniques, such as drip irrigation and sprinkler systems**,** which reduce water wastage.
- Rainwater harvesting, both at the individual and community levels, can significantly contribute to recharging groundwater.Rainwater harvesting involves catching and storing rainwater before it reaches the ground.
- Additionally, reforestation and afforestation programs help in maintaining the ecological balance and enhancing groundwater recharge.
- Strict regulations on groundwater extraction, coupled with effective monitoring and enforcement mechanisms, are essential to ensure the sustainable use of this precious resource.
- Technology also plays a crucial role in managing and monitoring groundwater levels. The use of remote sensing and satellite imagery enables the assessment of groundwater availability and identifies areas of concern.
- Geographic Information System (GIS) mapping helps in visualizing and analyzing groundwater data, aiding in decision-making processes. Furthermore, the installation of real-time groundwater monitoring systems provides up-to-date information on water levels, enabling timely intervention and effective management.
- Additionally, the development of mobile applications and online portals facilitates the dissemination of information and promotes citizen participation in water conservation efforts.
- Water Governance is crucial to ensuring equitable, efficient, and sustainable management of water resources, promoting community participation and accountability, and addressing the complex challenges of water scarcity, quality, and management in India. Effective water governance can help to conserve and manage the country's water resources, ensure access to safe and sufficient water for all, and contribute to sustainable development for the country.Groundwater governance process enables groundwater management, planning and policy implementation.
- In Gujarat, for instance, farmers are beginning to understand the need to move away from water-guzzling crops such as cotton and wheat to pomegranates and cumin, which not only use less water but also fetch good prices.
- Use native plants in your landscape.Choose grass varieties for your lawn that are adapted for your region's climate, reducing the need for extensive watering or chemical applications.
- Don't Let It Run.Shut off the water when you brush your teeth or shaving, and don't let it run while waiting for it to get cold.
- Fix the Drip.Check all the faucets, fixtures, toilets, and taps in your home for leaks and fix them right away, or install water conserving models.
- Wash Smarter. Limit your water consumption when at shower.Run full loads when running a washing machine.
- Water Wisely.Water the lawn and plants during the coolest parts of the day and only when they truly need it.
- Dams and Reservoirs: -Reservoirs (artificial lakes) dams reduce water flow downstream, which could lead to political conflicts when rivers span states or countries.
- Aqueducts: -Aqueducts can move water from where it is plentiful to where it is needed. Aqueducts can be controversial and politically difficult especially if the water transfer distances are large. One drawback is the water diversion can cause drought in the area from where the water is drawn.
- Desalination: -One method that can actually increase the amount of freshwater on Earth is desalination, which involves removing dissolved salt and minerals from seawater or saline groundwater All of these procedures are moderately to very expensive and require considerable energy input, making the water produced much more expensive than freshwater from conventional sources. Desalination is most common in the Middle East, where energy from oil is abundant but water is scarce.
- Water Reuse (Water Recycling): -Water recycling refers to reusing water for appropriate purposes such as agriculture, municipal water supply, industrial processes, and environmental restoration.
- Water Conservation: -Water conservation refers to using less water and using it more efficiently. Around the home, conservation can involve both water-saving technologies and behavioral decisions. Choosing foods with a low water footprint (like eggs) over those with a high-water footprint (like beef) can also conserve water and no-till farming, which reduces evaporative losses by covering the soil.
- Using water-efficient plants
- Domestic laws and regulations regulate access to groundwater as well as human activities that impact the quality of groundwater.
- Conservation and management of soil and water are central to groundwater recharging.
- There is thus need for better agriculture planning and land use management. This could be crucial to improving both groundwater quantity and quality.
- Process of natural percolation is vital for ensuring the replenishment of groundwater tables.
- The creation of a high density of recharge wells.
- Employment of a low maintenance, low energy treatment facility which made wastewater reuse viable.
- Integrated water resource management (IWRM) is needed.
- Reexploring the water histories of cities, so as to understand their potential as part of the larger integrated resource networks.
- Preventing water bodies encroachment.
- Preventing solid waste dumping in waterbodies.
- Drain storm water/rainwater into the lakes of the city.
- A major city-wide campaign is needed to aware the people on importance of groundwater proper use and need of groundwater conservation. Educate the villagers on water management.
- NOC requirement for industries, housing societies, water supply tankers, now is mandatory by new guidelines of central government.
- Attracting penalty fees in case of non-compliance.

- Programmes emphasized by the Central Ground Water Board as the participatory groundwater management.
- Using artificial groundwater recharge through canals, infiltration basins, or ponds, adding irrigation furrows or sprinkler system.
- Flooding temporarily increase river bed permeability.
- Artificial groundwater recharge is becoming increasingly important in India, where over-pumping of groundwater by farmers has led to groundwater resources becoming depleted.
- On the recommendations of the IWMI, the Indian government allocated Rs. 1800 crore in 2023 to fund dug-well recharge projects in 100 districts.
- More rain events are capable of contributing to groundwater supply.
- Flooding events appear to lead to more groundwater recharge.
- Managements of river catchments, surface waterbodies, wastewater and the agricultural sector.
- Avoiding cultivation of water extensive crops.
- Use of treated waste water for irrigation should be adopted.
- An open/public database on all components of water resources could help policy makers and other stakeholders in proper management.
- We can revive India's groundwater if we make dead rivers come alive and manage and conserve water.
- World water Day / groundwater day celebration is needed to aware the people of grass-root level.
- Implementation of River-linking concept of India
- More research on groundwater, river water, all available water sources and precipitation.
- Let us live in harmony with nature.
- Need innovations in agriculture and industrial processes, those are designing water –smart technologies.
- Local water management is crucial. Switching off a tap is common measure.
- Community based water management, recharge key to solving water crisis.
- Planning to plant more trees.
- Digging sufficient numbers of ponds, ponds recharge the groundwater.
- **Other country situation: -**For example, in a country like Denmark, drinking water comes entirely from the groundwater resources. Denmark has been successfully protecting its resources through mechanisms like groundwater modelling, helping authorities with information for optimized groundwater abstraction. Danish utilities have been using the Danish-developed Well Field Model to plan the abstraction from the reservoir with considerations of groundwater reservoir preservation, acceptable water quality, and optimization of energy consumption.
- **CONSIDERATIONS: -** While states are gathering the necessary data to inform decision making, no state has met its groundwater data collection goals. Only 2 of the 28 states responding to an NGWA survey are very confident that they know the potential yield from all of the state's major aquifers. We lack fundamental data necessary to adequately understand the nation's groundwater resources and make informed decisions regarding its use and management. Intervention programs will aid in protecting our natural resources by fostering groundwater recharge through natural as well as artificial methods. The Central Groundwater Board under Ministry of Jal Shakti needs to implement projects in mission mode like a National Groundwater Renewal Mission to provide the much-needed impetus to groundwater conservation across districts. Such an initiative should also consider the integration of technology with traditional methods to protect groundwater sources.
- Industries should /must develop RWH infrastructure in its premises. If it does not, must provide groundwater using tax and government will develop RWH infrastructure day by day or gradually.
- Similarly, the renewal mission can introduce measures to simplify and address the needs of smart water meter installation, educating farmers on the benefits of growing less water intensive crops and large-scale implementation of solar pumps. Another initiative that will drastically help is to include the mandatory adoption of recharging wells for farmlands. Since farmlands require an abundance of groundwater, recharging wells will help in the replenishment of aquifers and enhance groundwater levels.
- Educate and engage to make society more aware about groundwater.
- Farmers do not pay for the two most important resources in Indian agriculture: water or electricity to power well pumps. India water law also gives landowners the right to use as much of the water beneath their land as they want without any regulation or control.
- Because, if groundwater is managed carefully, it can not only provide a much-needed buffer when the monsoons fail but help mitigate the far-reaching impacts of climate change on India's most vulnerable people.
- The ability to clearly articulate and communicate the groundwater problem is the key to implementing processes of groundwater management.
- **Aggregate micro-level solutions to construct a larger picture that can inform policy:** Groundwater in India is rather disaggregated in terms of its occurrence, usage, and problems. Hence, we need disaggregated approaches leading to customized solutions that are appropriate to locations and situations of groundwater problems. Further, it is important to pull together these smaller solution pieces to construct a larger picture. This is the reason why we need practitioners who have worked on the ground and attempted to solve the problems, to be actively involved in policy framing; else, things will not change and the divide between policies, and practices on groundwater management will only continue to widen further.
- **Stronger public institutions dedicated to groundwater management:** Additionally, we have an institutional vacuum when it comes to dealing with groundwater. Let us consider an example from Maharashtra. More than 80 percent of Maharashtra's rural drinking water supply comes from groundwater wells. Protecting and sustaining this source is a function of how groundwater is used in agriculture so that drinking water supply in the villages of the state remains secure.
- The Ground Water Survey and Development Agency (GSDA) falls under the ambit of the Ministry of Drinking Water and Sanitation. Organizations like GSDA must be strengthened and encouraged to engage in partnership models of working with grassroots organizations that are working on community-level water management. This is just one example of how a lack of institutional thinking impacts solutions. Many states don't even have a GSDA equivalent. Strengthening agencies dealing with groundwater becomes quite important in this regard.
- **To demystify the science and involve people in solution-making:** Some important questions we need to consider include: How does one get people to participate and cooperate in efforts dealing with groundwater management? How do communities convert competition and conflict to participation and cooperation? Our experience at ACWADAM is that when you undertake an effort in demystifying science, and involve communities and committed people in the development of that science, you can achieve improved decision making at any level. And once you achieve this, your outcomes automatically change even though they are often not ideal. However, even such imperfect outcomes significantly enhance water security in regions that depend on groundwater.
- **More attention and investment in promoting partnerships and collaborations:** There is a grave need for infusing interdisciplinary science in the processes of groundwater management and governance. Only if and when such science is made to bear upon achieving decentralized water governance, will we be able to solve many problems on groundwater. It is important, therefore, to realize that no single agency holds the key to problem identification and resolution in the sector of groundwater. Hence, catalyzing collaborations that integrate the many disciplines required to develop sustainable groundwater management solutions, is needed; such partnerships must form

the backbone of public efforts to protect, restore, and manage groundwater resources.

Major institutions/programmes/policies etc. related with groundwater

S1.	Abbreviation	**Major institutions/programme/policy etc.**
1	IWMI	International Water Management institute
2	SWSSSDRP	Shimla Water Supply and Sewerage Service Delivery Reform project
3	CGWB	Central Ground Water Board
4	WVI	World Vision India
5	NGP	Namami Ganga Project
6	MoEF &CC	Union Ministry of Environment, Forest and Climate Change
7	CSE	Centre for Science & Environment
8	SAWP	South Asia Water Programme
9	PMSIP	Punjab Municipal Services Improvement Project
10	IWRM	Integrated Water Resource Management
11	CGWA	Central Ground Water Authority
12	UNU-EHS	United Nations University-Institute for Environment and Human Security
13	NWP	National Water Policy
14	PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
15	AIBP	Accelerated Irrigation Benefits Programme
16	JSA	Jal Shakti Abhiyan
17	ABY	Atal Bhujal Yojana
18	NAQUIM	National Aquifer Mapping & Management Programme
19	GSDA	Groundwater Survey and Development Agency
20	MDWS	Ministry of Drinking Water and Sanitation
21	URWSSP	Uttarakhand Rural Water Supply and Sanitation Project
22	KWSIP	Karnataka Water Supply Improvement Project
23	KUWSMP	Karnataka Urban Water Supply Modernization Project
24	ACWADAM	Advanced Centre for Water Resources Development and Management.

CONCLUSION

All the noise and worries about water scarcity and river pollution notwithstanding, we are making things worse for the conservation of the valuable resource. Water is not just important for economic growth but also for the survival of life on this planet. Population increase, affluent lifestyles, industrialisation also contribute towards the looming water crisis. Shimla, for instance, receives 20 million tourists every year. It is 10 times the population of the city. Such high influx increases the demand of water and if this continues, 'Day Zero' will not be far away. The city reported an acute water crisis, especially during the last few summers. The United Nations General Assembly in 2010 recognised the right to clean and safe water as a human right. In many cases, social elements such as race, gender, ethnicity and socioeconomic status influence the exercise of this right. Local water management is crucial. Switching off a tap in Delhi will not solve the water scarcity problem in Chennai. Water is a local resource and depends on the hydrology, climate, terrain and geography of a particular area. Even without being alarmist, today we have reached a consensus on declaring water issues as a non-negotiable agenda. Let us understand that even the manufacture of vaccines requires water. With the ongoing threat of future pandemics, we can no longer ignore this vital gift of nature.

The union ministries for water, tourism, health and family welfare, environment, forest and climate change, urban development as well as rural development, which are related to water use and consumption, must come together and work on a common agenda. The Indian government has also given impetus towards conservation practices with projects of national importance like National Spatial Data Infrastructure and National Hydrology Project. These projects are specifically designed to garner data and help policy makers take informed decisions at the local and national level on natural resource management, environment restoration, disaster mitigation among others. For advanced analysis of data, Government can also partner with private players to strengthen this ecosystem. Such a move will provide further boost to schemes for rainwater harvesting, watershed management, aquifer recharging and surface water restoration activities.

Key Groundwater Quotes & Slogans

- "Groundwater is like a savings account; if you withdraw more than you deposit, you eventually go bankrupt." — Unknown
- "When the well is dry, we know the value of water." — Benjamin Franklin
- "A drop of water is worth more than a sack of gold to a thirsty man." — Proverb
- "Groundwater is Precious, Use it Judiciously." — Unknown
- "Conserve Groundwater, Secure Our Future." — Unknown
- "If there is magic on this planet, it is contained in water." — Canadian Wildlife Federation
- "Don't let rain water run away, let it run to the earth again." — Brainly.in user
- A great thing about these trees is that they are excellent for cleaning, both groundwater, and of course, air.--Mike Lowry

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