Published by Avanti Publishers

Journal of Chemical Engineering Research Updates

ISSN (online): 2409-983X

Water Sustainability Initiatives to Meet the Water Crisis in India

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ARTICLE INFO

Article Type: Research Article

Academic Editor: Huachao Yang

Keywords:
Water crisis
Water security
Water sustainability
Water redistribution
Rain water harvesting

Timeline:
Received: July 07, 2023
Accepted: September 16, 2023
Published: November 16, 2023

Citation: Jena MC, Mishra SK, Moharana HS. Water sustainability initiatives to meet the water crisis in India. J Chem Eng Res Updates. 2023; 10: 18-30.

DOI: https://doi.org/10.15377/2409-983X.2023.10.2

ABSTRACT

One of the most pressing global challenges we face today is the rapid growth of the population. As the population continues to expand, the need for rapid industrialization has become paramount. However, this industrialization and urbanization have given rise to a significant and detrimental consequence: environmental pollution. This pollution, in turn, has led to various crises, including those related to water, food, and air quality. Water, being an essential element for human existence, is of utmost importance. Without access to clean and sufficient water, life on Earth would be unsustainable. Unfortunately, India has been grappling with a prominent water crisis, particularly during the summer seasons, resulting in the loss of countless lives each year. Even during other seasons, the availability of water is often satisfactory, but the quality of water remains a concern in many parts of the country. The shortage of water can be attributed primarily to the declining levels of underground water and the ever-increasing demand for this precious resource. India receives ample rainfall during the monsoon season; however, a significant portion of this water flows into the oceans, causing floods in various regions. Conversely, during the summer months, the scarcity of water leads to droughts in many areas. Therefore, it is imperative to initiate sustainable water management practices, including rainwater harvesting, to address this water crisis. This review article delves into various types of water sustainability initiatives with a structured approach and analyzes the associated challenges. Additionally, it proposes detailed systems that can be implemented to enhance water availability and distribution throughout the country. These measures are crucial steps toward mitigating the water crisis and ensuring a sustainable water future for India.

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1. Introduction

The ever-increasing global population growth and environmental pollution have given rise to a multitude of challenges, including global warming, ozone layer depletion, potable water scarcity, climate change, and various pandemics [1]. However, one of the most pressing issues humanity faces today is the scarcity of clean water sources in certain parts of the world. Water, as we all know, is more precious than anything else on Earth, including air, as life itself would be impossible without it. Astonishingly, approximately 97% of the Earth's total water exists in our vast seas, rendering it unsuitable for domestic or industrial use. Only a mere 3% of this water is freshwater found in ponds, rivers, and other sources, which can be used for various purposes. Nevertheless, this 3% is not distributed evenly across the globe.

In the present day, numerous regions around the world are grappling with severe water scarcity, affecting the livelihoods of approximately 2.5 billion people [2]. Alarmingly, a study by the International Food Policy Research Institute (IFPRI) suggests that by 2050, nearly half of global grain production will be jeopardized due to water shortages [2]. Water shortages, in general, pose the most significant socioeconomic and human development challenges. They can lead to the degradation of ecosystems, deteriorating health, and the loss of livelihoods [3, 4].

With the world's population and economic activity on the rise, water degradation has become a global concern [5]. More than half of the global population now resides in urban areas, but cities often struggle to provide basic water services to their growing populations [6, 7]. Consequently, there is an urgent need to enhance water supply and wastewater treatment systems as integral components of urban planning.

Water-related disasters, such as floods, droughts, landslides, and land subsidence, have been on the rise due to climate change, urbanization, and other factors [8]. Floods, in particular, are among the most devastating natural disasters worldwide. While they are often attributed to extreme weather events, human activities also play a significant role in altering the environment and water cycle, thus exacerbating flooding risks. Land-use changes, including urbanization and agriculture, have contributed to flood risks in vulnerable areas [9].

Drought, on the other hand, has far-reaching physical and social consequences. Insufficient precipitation can severely impact water resources and agricultural systems, leading to conflicts over competing water uses [10]. Groundwater has become increasingly important for drinking water, food security, and sustainable living, as it offers better quality and availability even during droughts [11]. Managing both the quantity and quality of water resources is crucial worldwide, particularly in developing nations.

Achieving water security remains one of the most critical challenges of our time [12]. It involves providing clean drinking water, efficient wastewater management, and basic sanitation facilities for sustainability and human progress [13, 14]. Meeting the United Nations Sustainable Development Goals for 2030 hinges on achieving a water-secure world.

Addressing water security requires a multifaceted approach. Resource allocation and competition are key challenges, but so are extreme events. Thus, it is vital to design sustainable solutions that encompass a wide range of water-related issues. The term "water security" is increasingly used by policymakers, organizations, and individuals to express their opinions on solving various water-related problems. However, achieving a consensus on the concept of water security remains a challenge. Employing interdisciplinary approaches can serve as a starting point for addressing these issues [15, 16].

Efforts to improve water security have intensified in recent years. This includes the sustainable use and protection of water systems, safeguarding against water-related hazards, and the responsible development of water resources [15]. Holistic approaches that consider social, economic, and environmental dimensions at various scales are essential to making progress in areas such as public health, energy security, climate resilience, and poverty reduction [17, 18]. The spatial and temporal aspects of water security are crucial determinants. Supply problems arise when water is genuinely scarce, while demand problems occur when sufficient water is available but not used sustainably [19]. Hydrological extremes like floods and droughts can affect the same location in the same year. The uneven distribution of water resources is further exacerbated by climate change, increasing the challenge of addressing water scarcity [20, 21].

In conclusion, this paper examines conventional methods of water sustainability initiatives, highlights the challenges associated with them, and proposes strategies to improve water conservation efforts. The multifaceted nature of the water security challenge calls for comprehensive solutions that consider social, economic, and environmental factors at multiple scales to ensure a sustainable and water-secure future for all.

2. Materials and Method

Different water sustainability initiatives that are already in place are studied and gaps have been identified. Some additional water sustainability initiatives have been proposed which can be implemented for the betterment of the water scenario in India.

3. Water Sustainability Initiatives

To safeguard human life on Earth, we must take steps to ensure the sustainable use of water resources. The relationship between water and sustainable development is deeply interdependent, as clean and unpolluted water is a prerequisite for sustainable progress [22, 23]. In regions where food and agriculture are paramount, it is essential to prioritize the availability of water resources through thorough study and well-planned arrangements [24]. Addressing the challenge of providing clean drinking water to households is of utmost importance, particularly in areas where people live below the poverty line, as it directly impacts public health [25, 26].

Managing water resources effectively requires a comprehensive and integrated approach; otherwise, preserving water in its usable form becomes exceedingly challenging [27, 28]. In this thesis, various methods for achieving water sustainability will be examined in detail. These methods encompass recycling, regeneration, recharging, recollection, and redistribution of water resources. The thesis will also address the challenges associated with implementing these approaches in different contexts.

4. Recycling

Efficient water management is crucial for reducing the environmental footprint of industrial processes. One effective strategy is the treatment and recycling of water within the system, a practice commonly employed in Effluent Treatment Plants (ETPs) and various industrial processes. Numerous plants also recover condensates, which can be recycled within their systems. For example, in boiler circuits, steam trap condensates are collected and reintroduced into the circuit.

Businesses and industries must adopt a proactive approach, rethinking their processes to facilitate water recycling. This not only reduces net water consumption but also contributes significantly to mitigating the environmental impact associated with water use. By implementing such measures, industries can play a pivotal role in conserving this precious resource and minimizing their water footprint, ultimately promoting sustainability and environmental responsibility.

5. Regeneration

Collecting and utilizing water from moist air or air conditioning systems is an excellent example of water regeneration and sustainable water management. In regions characterized by hot and humid climates, the atmospheric air is laden with a significant amount of moisture. When this moist air is processed through an air conditioning system, it is typically dehumidified to improve comfort.

In the dehumidification process, water droplets condense from the air. These collected water droplets can then be effectively reused, reducing the demand for traditional water sources. This practice not only conserves water resources but also contributes to greater water sustainability.

Additionally, in areas facing water scarcity or stress, water regenerators are deployed to extract water directly from atmospheric air for various domestic purposes. This technology helps alleviate water shortages by harnessing moisture from the air, demonstrating a valuable approach to sustainable water supply solutions.

By incorporating these techniques into water management strategies, regions can make efficient use of available resources and contribute to a more sustainable and environmentally responsible approach to water usage.

6. Recharging

Recharging is indeed the process of replenishing water sources for future use, ensuring the availability of water resources. While natural rainfall is a primary and essential method of recharging all water sources on Earth, it's important to note that due to declining groundwater levels and increasing water demand, artificial recharging methods are becoming necessary. These artificial recharging methods are employed to supplement natural recharge processes and maintain the health of groundwater reservoirs. Several techniques are utilized for artificial recharging:

Recharging Through Bore Wells: This method involves injecting rainwater or treated water directly into underground aquifers through boreholes. Bore wells act as conduits to deliver water to the subsurface, helping to replenish groundwater.

Recharging Through Recharge Pits: Recharge pits are constructed to capture and channel rainwater into the ground. They are designed to allow water to percolate into the soil and eventually reach the groundwater table [29, 30].

Recharging Through Dug Wells: Dug wells, which are typically used for accessing groundwater, can also serve as recharge points. Rainwater collected in these wells can seep into the ground and recharge the aquifers [31, 32].

Soak Ways or Recharge Shafts: Soak ways are structures designed to collect surface runoff or rainwater and channel it into vertical shafts, which then allow water to percolate into the ground. This method helps in recharging groundwater.

7. Recollection and Reuse

The concept you're describing involves reusing water that has been used once in domestic or industrial applications, often referred to as "greywater" recycling. Greywater, when properly treated, can indeed be reused for various purposes, such as gardening and irrigation. Rainwater harvesting and collection in watersheds or dams are also part of sustainable water management initiatives.

Here's a breakdown of the key points you mentioned:

Greywater Recycling: Greywater refers to wastewater generated from sources like sinks, showers, and washing machines, which can be treated and reused for non-potable purposes like watering plants, flushing toilets, or cleaning. Greywater recycling is an environmentally friendly practice that reduces the demand for freshwater resources.

Rainwater Harvesting: Rainwater harvesting involves collecting and storing rainwater that falls on rooftops or other surfaces. This harvested rainwater can be used for various applications, including irrigation, landscape watering, and even for non-potable indoor uses when treated appropriately.

Watershed and Dam Collection: In some regions, large-scale collection of rainwater and runoff occurs in low-lying areas or specially constructed dams. These collected waters can serve multiple purposes, such as agricultural irrigation during dry seasons or flood control.

Dam Construction: Dams are often built with concrete or other materials to collect and store large quantities of water in low-lying areas. Proper design ensures that the dam can hold the required volume of water while preventing excessive overflow that could lead to flooding.

Flow Control: In some cases, gates or other mechanisms may be used to control the flow of water in and out of dams. This helps manage water levels and releases it as needed for various purposes.

Sustainable water management practices like these are crucial for conserving freshwater resources, reducing water wastage, and ensuring water availability for various needs, including agriculture and environmental conservation. They play a vital role in enhancing water security and minimizing the environmental impact of water use.

Figure 1: Water shade for irrigation.

8. Rainwater Harvesting

Rainwater harvesting may be defined as the technique of collection and storage of rainwater at surface/sub-surface aquifer or overhead before it becomes unusable passing through drains and surface runoff. The collected water can be used whenever needed. [33, 34].

It has many advantages like the Enhancement of groundwater through water recharging and saving energy during water lifting as the groundwater level increases. Soil erosion will be minimized through water accumulation. It reduces the chance of a flood situation. It prevents the drought situation. It improves groundwater quality by decreasing salinity due to freshwater charging. In coastal areas, seawater cannot be ingested in subsurface aquifers. It decreases the load on the stormwater disposal system. Through groundwater recharging a huge amount of water is stored without wasting any land. Underground water storage is environment-friendly and safe.

Due to various losses i.e. evaporation loss, spillage, etc., all rainwater cannot be harvested 100% [35].

Rainwater harvesting potential can be calculated by using the following formula,

Harvesting quantity(Q) = Ar X Ac X Rc

Where

Ar= Amount of rainfall

Ac= Area of catchment

Rc= Runoff coefficient of the catchment surface

The runoff coefficient for various surfaces can be obtained from different reliable sources which is determined through experiments [32].

The calculation of rainwater harvesting can be understood with the help of the following example:

Consider a building with a rooftop area (A) of 100 sqm located in Bhubaneswar.

The average annual rainfall (R) in Bhubaneswar is approximately 1000 mm=1meter

If the run-off coefficient is considered as 0.85.Annual rainwater harvesting potential from 100 sqm roof,

As we know Q = Ar X Ac X Rc = 100 x 1x 0.85 = 85 m^3, this is equal to 58000 liters of water

9. Methods of Rainwater Harvesting

Rainwater harvesting can indeed be categorized into two distinctive methods: rooftop rainwater harvesting and surface runoff rainwater harvesting. Here's an explanation of each:

10. Surface Runoff Rainwater Harvesting

In this method, rainwater that falls on the ground or surface level is collected through various techniques. These techniques can include building structures like swales, trenches, or berms to direct and collect rainwater, as well as using natural depressions or specially designed catchment areas to gather runoff water. Surface runoff harvesting is particularly useful for capturing rainwater from open areas and landscapes.

11. Roof Top Rainwater Harvesting

This method involves collecting rainwater that falls directly on rooftops. The rainwater is channeled through a network of pipes and gutters and eventually collected in a storage tank. The collected rainwater can then be used for various purposes, including household or industrial needs, irrigation, or groundwater recharge. A bypass line with valves can also be incorporated into the system to facilitate underground recharge when the harvested water is not immediately required. Roof-top rainwater harvesting is known for its effectiveness and cost-efficiency.

The proposed design for a rooftop rainwater harvesting system typically includes components like roof catchment, gutters, downspouts, pipes, a first-flush device to divert initial runoff, a filtration system to ensure water quality and a storage tank. This design allows for the efficient collection and storage of rainwater, making it readily available for use while also promoting groundwater recharge and reducing reliance on external water sources [30, 32].

The various components and systems involved in rainwater harvesting play critical roles in ensuring the quality and efficient collection of rainwater. Here's a breakdown of some key terms and components:

Catchment Area: The area where rainwater initially falls and is collected is referred to as the catchment of the rainwater harvesting system. This can include courtyards, rooftops, and unpaved or paved open grounds. Rooftops can be constructed from different materials, such as sheeting structures or concrete structures.

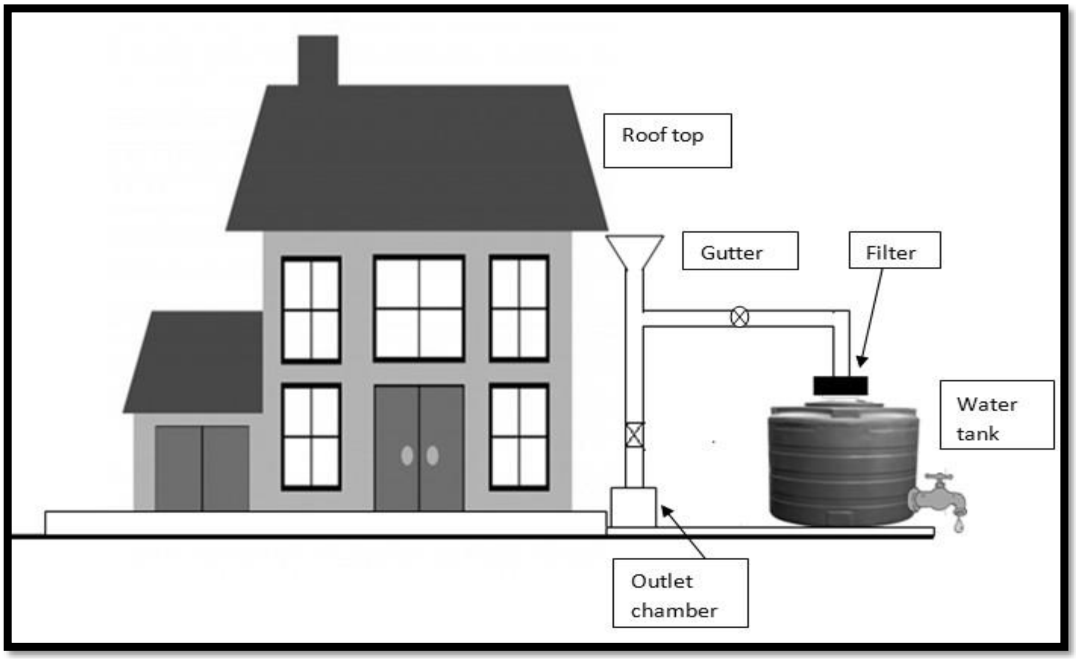

Figure 2: Components of Rainwater harvesting.

Transportation System: The transportation system consists of pipelines and conduits that carry rainwater from the catchment area to the storage tank or an underground recharging pit. It plays a vital role in channeling rainwater efficiently to its destination.

Gutter and Wire Mesh: Rainwater from rooftops is typically collected using gutters, which guide the water into the pipelines. To prevent unwanted debris and materials from entering the pipelines and potentially causing blockages, the mouth of the gutter is often fitted with wire mesh or screens.

First Flush Device: The first flush device is an important component designed to divert the initial rainwater runoff. This is done to separate and discard the initial flow, which may contain impurities, dust, or contaminants washed off from the catchment surface.

Filtration System: To ensure the quality of harvested rainwater, a filtration system is employed. This system filters out impurities and particles from the rainwater before it enters the storage tank or groundwater recharge pit. Regular cleaning of the filter element or media is necessary to prevent clogging and maintain the effectiveness of the filtration process.

These components collectively ensure that the collected rainwater is clean, free from contaminants, and suitable for its intended purpose, whether that is for direct use or for recharging groundwater. Proper maintenance of these systems is essential to ensure the efficient and reliable operation of rainwater harvesting systems while maintaining water quality standards.

12. Methods of Rooftop Rainwater Harvesting

The rainwater harvesting system you describe involves collecting rainwater in a water tank for immediate use in domestic applications. This system is designed to meet the specific water requirements of a household or facility. Here are the key elements of this system:

Rainwater Collection: Rainwater is collected from a catchment area, typically a rooftop or another surface, and directed into a storage tank.

Storage Tank: The collected rainwater is stored in a tank, which is sized to accommodate the required water quantity for domestic use. The tank is an integral part of the system and is designed to safely store the harvested rainwater.

Bypass System: A bypass system is an important component of the rainwater harvesting system. It allows for flexibility in managing excess rainwater. In cases where the storage tank is full or when there is more rainwater than immediate domestic use demands, the excess water can be bypassed by either of the following:

a. Groundwater Recharging: Excess rainwater can be directed to an underground recharging pit or system, contributing to the replenishment of groundwater resources. This is an environmentally sustainable option.
b. Runoff Drainage System: If there is no provision for groundwater recharging, the excess rainwater can be safely directed to the existing runoff water drainage system or stormwater drains. This ensures that excess water does not lead to waterlogging or other drainage issues.

This rainwater harvesting system is designed to optimize the use of collected rainwater for domestic purposes while also providing a mechanism for managing surplus water to prevent wastage or flooding. It offers a sustainable approach to water management and can help reduce reliance on external water sources for household needs.

13. Redistribution

The concept of interlinking rivers and canals is a large-scale water management strategy aimed at transferring water from one region to another to address water scarcity, promote irrigation, and generate hydroelectric power. Here are some key aspects of this approach:

Interlinking Rivers: The interlinking of rivers involves connecting rivers from one region to another through a network of canals and water infrastructure. This can help transport water from water-rich regions to water-deficient regions, thereby addressing water scarcity issues.

Canal Construction: U-shaped canals, as shown in Fig. (**3**), can be constructed within the riverbeds to facilitate the transfer of water. These canals act as conduits for transporting water from one river to another or from a river to a specific region.

Irrigation: The transferred water can be used for irrigation purposes in the recipient regions. This can significantly enhance agricultural productivity and contribute to food security.

Dams with Gates: Dams can be constructed along the canals to control the flow of water. Gates fitted in these dams allow for the regulation of water flow, ensuring that the water is distributed as needed to different areas. Dams can also serve as reservoirs to store water during surplus periods for use during dry spells.

Hydroelectric Power Generation: As an additional benefit, small turbines can be installed within these dams to generate hydroelectric power. This clean and renewable energy source can contribute to the region's energy needs and sustainability.

It's important to note that interlinking rivers and canals is a complex and multifaceted project that requires careful planning, engineering expertise, and consideration of environmental and ecological impacts. Such projects can have significant social, economic, and ecological consequences, and their feasibility and impact must be thoroughly assessed before implementation.

Additionally, interlinking rivers has been a subject of debate and controversy due to potential ecological disruptions, displacement of communities, and other environmental concerns. Comprehensive studies, environmental impact assessments, and stakeholder consultations are typically essential components of evaluating and implementing such projects.

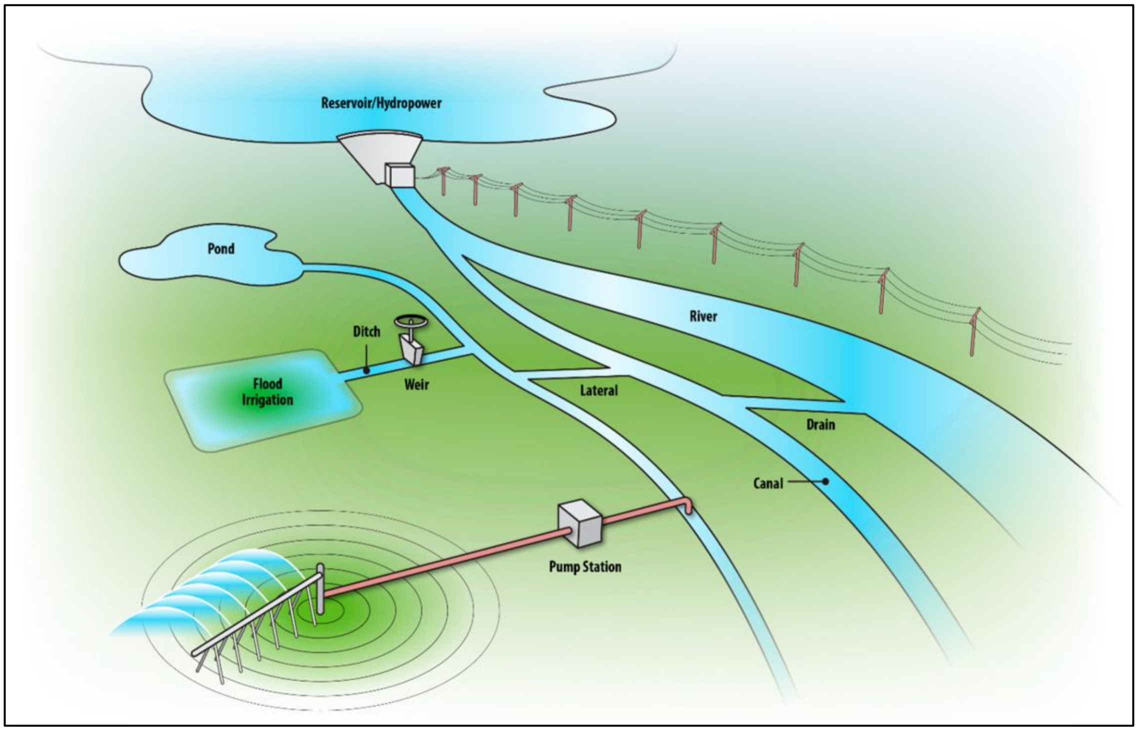

Figure 3: Canal for irrigation and power generation.

14. Interlinking of Rivers through Canals

The interconnection of rivers through an extensive network of canals in India, as depicted in Fig. (**4**), is a large-scale water management concept aimed at addressing various water-related challenges in the country or region where all the major river basin and its tributaries are interlinked with each other for proper water. Here are some key points regarding this approach:

Water Distribution: The primary objective of this system is to ensure the equitable distribution of water resources across different parts of the country. This can help mitigate both flood and drought situations by efficiently managing water availability.

Preventing Floods: By diverting excess water from water-rich regions to areas prone to flooding, this system can help prevent destructive flood situations that often result from heavy rainfall and overflowing rivers.

Mitigating Droughts: Conversely, the system can alleviate drought conditions in water-scarce regions by providing a more reliable source of water for agriculture, industry, and domestic use.

National Water Development Agency: In many countries, including India, government agencies like the National Water Development Agency are responsible for studying the feasibility and designing of river interconnection projects. These agencies conduct extensive research and assessments to determine the viability and potential impact of such projects.

Challenges: Implementing river interconnection projects on a national scale is a complex and challenging endeavor. It involves the construction of extensive canal networks, dams, and infrastructure. Environmental and ecological concerns, displacement of communities, and water quality issues must all be carefully addressed.

Government Initiatives: Governments may initiate specific projects to interconnect rivers within their jurisdictions. These projects can have a substantial impact on water resource management, agriculture, and regional development.

It's important to note that river interconnection projects are often subject to significant debate, controversy, and scrutiny due to their potential environmental and social impacts. Thorough feasibility studies, environmental impact assessments, and consultations with stakeholders are essential steps in the planning and execution of such projects.

Additionally, long-term sustainability, ecological preservation, and the interests of local communities should be carefully considered when undertaking large-scale river interconnection initiatives.

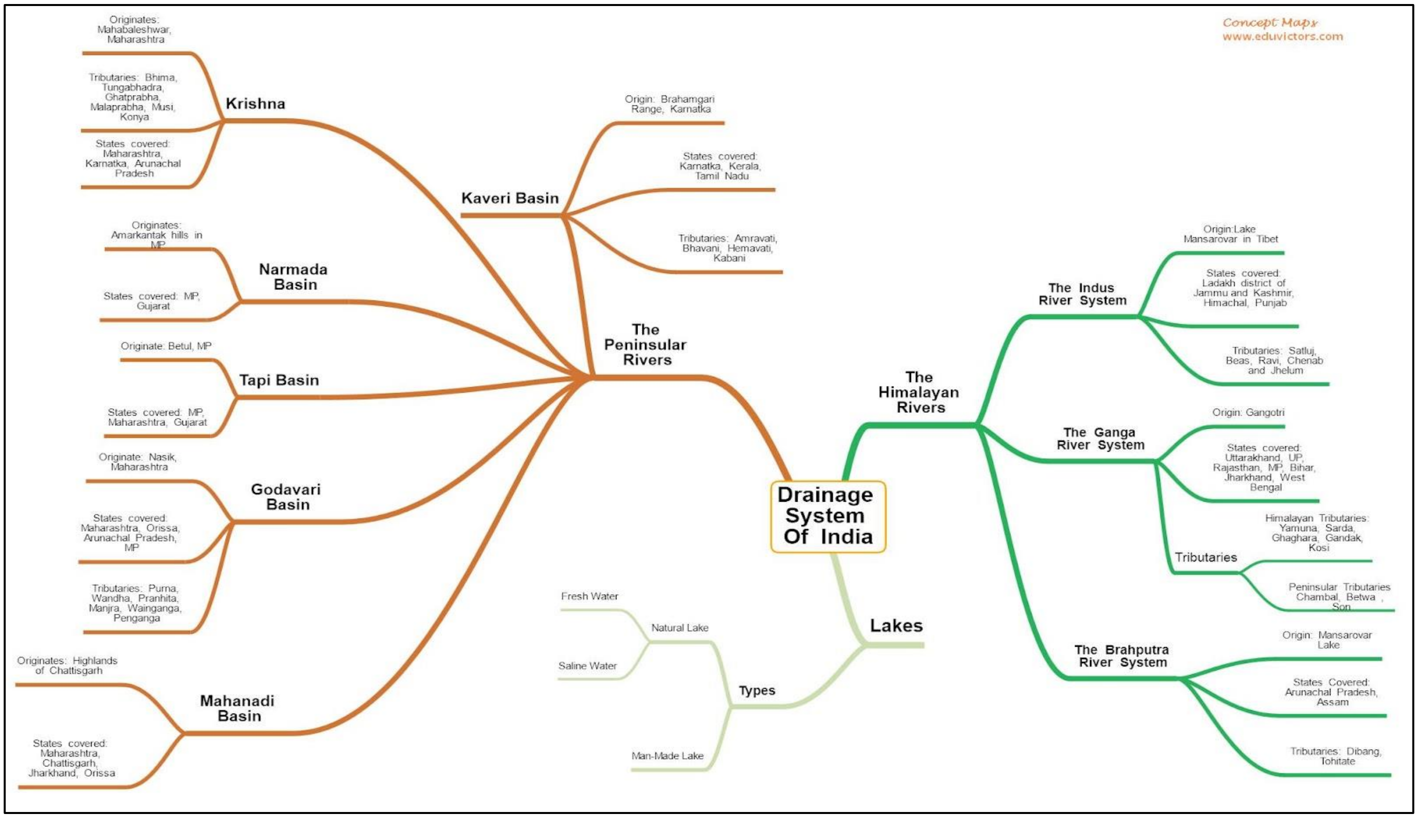

Figure 4: Interlinking of rivers through canals in India.

Indeed, the interconnection of rivers through canal networks can have several positive impacts on a country's development and water resource management:

Promoting Agriculture: By providing a reliable source of water for irrigation, water-stressed regions can enhance agricultural productivity. This, in turn, can contribute to food security and boost the agricultural sector, which is often a significant part of a country's economy.

Economic Growth: Increased agricultural productivity, improved access to water resources, and enhanced transportation through waterways can stimulate economic growth and development. These projects can create jobs and generate economic opportunities in rural and urban areas.

Flood Control: The efficient distribution of water resources can help control flood situations by diverting excess water away from flood-prone areas. This can reduce the damage caused by flooding and protect communities and infrastructure.

Drought Mitigation: While river interconnection may not eliminate drought situations, it can help minimize their impact by ensuring a more consistent supply of water for various uses, including agriculture and domestic needs.

Waterway Transportation: Improved waterway connectivity offers an economical and environmentally friendly mode of transportation. It can reduce the cost of transporting goods and commodities, making trade more convenient and efficient.

Fisheries: The availability of water resources can support fisheries and aquaculture, providing a source of income and sustenance for local communities. This can enhance food security and create livelihood opportunities.

Regional Development: River interconnection projects can lead to balanced regional development by distributing water resources more equitably across different regions. This can reduce disparities in access to water and economic opportunities.

It's important to emphasize that while these benefits are significant, the planning and execution of river interconnection projects must be carried out with careful consideration of environmental sustainability, social impacts, and potential ecological disruptions. Thorough assessments, environmental safeguards, and community consultations are essential to ensure that the positive outcomes outweigh any potential negative consequences.

15. Conclusion

The adoption of water-saving initiatives at various levels, from individuals to industries and organizations, is crucial for mitigating the water crisis in India and ensuring sustainable water management. These initiatives offer multiple benefits beyond just increasing water availability. Water-related initiatives can create job opportunities, especially in sectors like rainwater harvesting, fisheries, and aquaculture. This can contribute to employment and income generation, particularly in rural areas. By reducing the need for energy-intensive water pumping and treatment, water-saving initiatives can lead to energy savings. This, in turn, can lower electricity consumption and reduce greenhouse gas emissions. Enhancing water transport infrastructure can make transportation more convenient and cost-effective, benefiting trade and commerce by reducing transportation costs. Collecting rainwater and adopting water treatment measures can result in better water quality. This can reduce the risk of waterborne diseases and improve overall public health. Water-saving initiatives can have positive environmental impacts, such as groundwater recharge, reduced soil erosion, and the preservation of aquatic ecosystems. However, these initiatives need to be widely adopted and implemented sincerely. Government regulations and enforcement play a role, but a collective understanding of the importance of water conservation and responsible water management is equally crucial.

Failure to adopt these initiatives can indeed lead to severe water crises in some regions, exacerbating related problems like waterborne diseases, agricultural losses, and social unrest.

The future scope of the study you mentioned, focusing on the groundwater scenario and rainwater runoff in a particular region to create a water balance, is a valuable research direction. Such studies can provide valuable insights into the effectiveness of water-saving initiatives and guide future water resource management strategies tailored to specific regions' needs and challenges. This holistic approach is essential for addressing water scarcity issues sustainably and proactively.

Conflict of Interest

The authors declared no conflict of interest.

Funding

No funding was received for this research work.

References

[1] Avery DT. Global warming every 1,500 years: Implications for an engineering vision. Leadership Manag Eng. 2008; 8: 153-9. https://doi.org/10.1061/(ASCE)1532-6748(2008)8:3(153)

[2] Telang S. Earth's water distribution and Indian scenario. Environment 2011. Available from: http://greencleanguide.com/earths-water-distribution-and-indian-scenario/ (Accessed on June 28, 2023).

[3] Hanjra MA, Qureshi ME. Global water crisis and future food security in an era of climate change. Food Policy. 2010; 35: 365-77. https://doi.org/10.1016/j.foodpol.2010.05.006

[4] Guppy L, Anderson K. Water crisis report. Hamilton: United Nations University Institute for Water, Environment and Health; 2017.

[5] Biswas AK, Tortajada C. Water quality management: a globally neglected issue. Int J Water Resour Dev. 2019; 35: 913-6. https://doi.org/10.1080/07900627.2019.1670506

[6] UN-Water. Coping with water scarcity: Challenge of the twenty-first century. vol. 24. Geneva: 2007.

[7] Majumder M. Impact of urbanization on water shortage in the face of climatic aberrations. Singapore: Springer; 2015. https://doi.org/10.1007/978-981-4560-73-3

[8] Masago Y, Mishra BK, Jalilov S, Kefi M, Kumar P, Dilley M, *et al.* Future outlook of urban water environment in Asian cities. Tokyo: United Nations University; 2019.

[9] Wheater H, Evans E. Land use, water management, and future flood risk. Land Use Policy 2009; 26: S251-64. https://doi.org/10.1016/j.landusepol.2009.08.019

[10] Grafton RQ, Ward MB, To H, Kompas T. Determinants of residential water consumption: Evidence and analysis from a 10-country household survey. Water Resour Res. 2011; 47: 1-14. https://doi.org/10.1029/2010WR009685

[11] Jimenez-Cisneros B. Responding to the challenges of water security: the eighth phase of the international hydrological program, 2014-2021. In Proceedings of the 11th Kovacs Colloquium, Paris, France, June 2014. IAHS Publ; 2015; 366: 10-9. https://doi.org/10.5194/piahs-366-10-2015

[12] IPCC. Climate Change 2014: Synthesis Report. Contribution of working groups I, II, and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Pachauri, R.K. Geneva: 2014.

[13] United Nations University (UNU). UN-Water analytical brief: Water security and the global water agenda. Hamilton: 2013.

[14] Tremblay H. A clash of paradigms in the water sector? Tensions and synergies between integrated water resources management and the human rights-based approach to development. Nat Resour J. 2011: 307-56. https://doi.org/10.2139/ssrn.1661146

[15] Schultz B, Uhlenbrook S. Water security: What does it mean, what may it imply? In: Alaerts G, Dickinson N, Eds. Water for a Changing World - Developing Local Knowledge and Capacity. London: Taylor & Francis; 2007. https://doi.org/10.1201/9780203878057

[16] Jayawardena A. Challenges for sustainable water management. In: Proceedings of the International Symposium on Advances in Civil and Environmental Engineering Practices for Sustainable Development (ACEPS-2012), Galle, Sri Lanka: March 19, 2012, p. 24-30.

[17] Cook C, Bakker K. Water security: Debating an emerging paradigm. Glob Environ Chang. 2012; 22: 94-102. https://doi.org/10.1016/j.gloenvcha.2011.10.011

[18] Jiang Y. China's water security: Current status, emerging challenges, and prospects. Environ Sci Policy. 2015; 54: 106-25. https://doi.org/10.1016/j.envsci.2015.06.006

[19] Rijsberman FR. Water scarcity: Fact or fiction? Agric Water Manag. 2006; 80: 5-22. https://doi.org/10.1016/j.agwat.2005.07.001

[20] Kovats S, Akhtar R. Climate, climate change and human health in Asian cities. Environ Urban. 2008; 20: 165-75. https://doi.org/10.1177/0956247808089154

[21] Oki T, Kanae S. Global hydrological cycles and world water resources. Science. 2006; 313: 1068-72. https://doi.org/10.1126/science.1128845

[22] Koudstaal R, Rijsberman F, Savenije H. Water and sustainable development. Nat Resour Forum. 1992; 1992: 277-90.

[23] Grey D, Sadoff CW. Water for growth and development. Thematic Documents of the IV World Water Forum. Mexico: Comision Nacional del Agua; 2006.

[24] Food and Agriculture Organization of the United Nations. Review of world water resources by country. Rome: 2003.

[25] United Nations Children's Fund. JMP progress on household drinking water, sanitation, and hygiene 2000-2017. 2019.

[26] National Bureau of Statistics [NBS], United Nations Children's Fund [UNICEF]. Multiple indicator cluster survey 2016-17, survey findings report, National Bureau of Statistics, and United Nations Children's Fund. Abuja, Nigeria: 2017.

[27] Mishra B, Kumar P, Saraswat C, Chakraborty S, Gautam A. Water security in a changing environment: Concept, challenges and solutions. Water. 2021; 13(4): 490. https://doi.org/10.3390/w13040490

[28] Cap-Net UNDP Tutorial on basic principles of Integrated water resources management Available online: http://www.archive.cap-net.org/iwrm_tutorial/mai nmenu.htm (Accessed on Nov 4, 2018).

[29] National Green Tribunal 2018. Available from: https://greentribunal.gov.in/sites/default/files/news_updates/ACTION%20PLAN%20BY%20CGWA%20IN%20OA%20NO.%20673%20of%202018.pdf (Accessed on June 2023).

[30] TERI - The Energy and Resources Institute. Available from: http://www.teriin.org/energy/waterhar.htm (Accessed on June 2023).

[31] Indian Rivers Interlinking Project. Available from: https://en.wikipedia.org/wiki/Indian_rivers_interlinking_project (Accessed on June 2023).

[32] Rain Water Harvesting. Available from: https://www.cseindia.org/rainwater-harvesting-system-at-centre-for science and environment-6390 (Accessed on June 28, 2023).

[33] Centre for Science and Environment. Available from: https://www.cseindia.org/rainwater-harvesting-system-at-centre-for science and environment-6390 (Accessed on June 28, 2023).

[34] Rainwater Harvesting. Available from: http://www.rainwaterharvesting.org/urban/Components.htm (Accessed on June 28, 2023).

[35] Cgwa India. Available from: http://www.cgwaindia.com/suo/home.htm (Accessed on June 28, 2023).