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Should Rainwater Harvesting be Made Mandatory in India

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Abstract

According to the World Bank, India is among the most water stressed countries in the world. India's water crisis is a complex issue that stems from a combination of multiple factors mainly rapid and unplanned urbanization and industrialization, unsustainable agricultural practices, climate change, water mismanagement, poor urban and rural planning rising sea levels and increasing pollution. The looming water crisis cannot be left ignored as it can impact the health of the population and the nation's economic adversely. Among proposed solutions, rainwater harvesting emerges as a cost-effective solution that can be undertaken at the grass root level by the citizens themselves too. This paper analyses its advantages and challenges in an Indian context.

Keywords: *Water crisis, climate change, urbanisation, agriculture, pollution, urban planning, mismanagement, rainwater harvesting*

Introduction

The country has 18 percent of the world's population, but only 4 percent of its water resources, making it among the most water-stressed in the world [1]. The UNICEF report of 2013 had cautioned India on an impending water crisis. Its report stated that "by 2030, the country's demand for water is likely to be twice the available supply. As a result of rapid development, increasing population, and inequitable distribution, the demand for water will far outweigh supply" (UNICEF et al. 2013) [2]. A decade later, the caution has become a bitter reality.

With over 75 million people lacking access to clean drinking water, India lags most of its Asian neighbours in terms of access to safe potable water [3,4]. According to a World Bank study, 163 million Indians lack access to safe drinking wate, making it the highest in the world. 210 million Indians lack access to improved sanitation; 21% of communicable diseases are linked to unsafe water and approximately 500 children under the age of five die from diarrhoea every day in India [5].

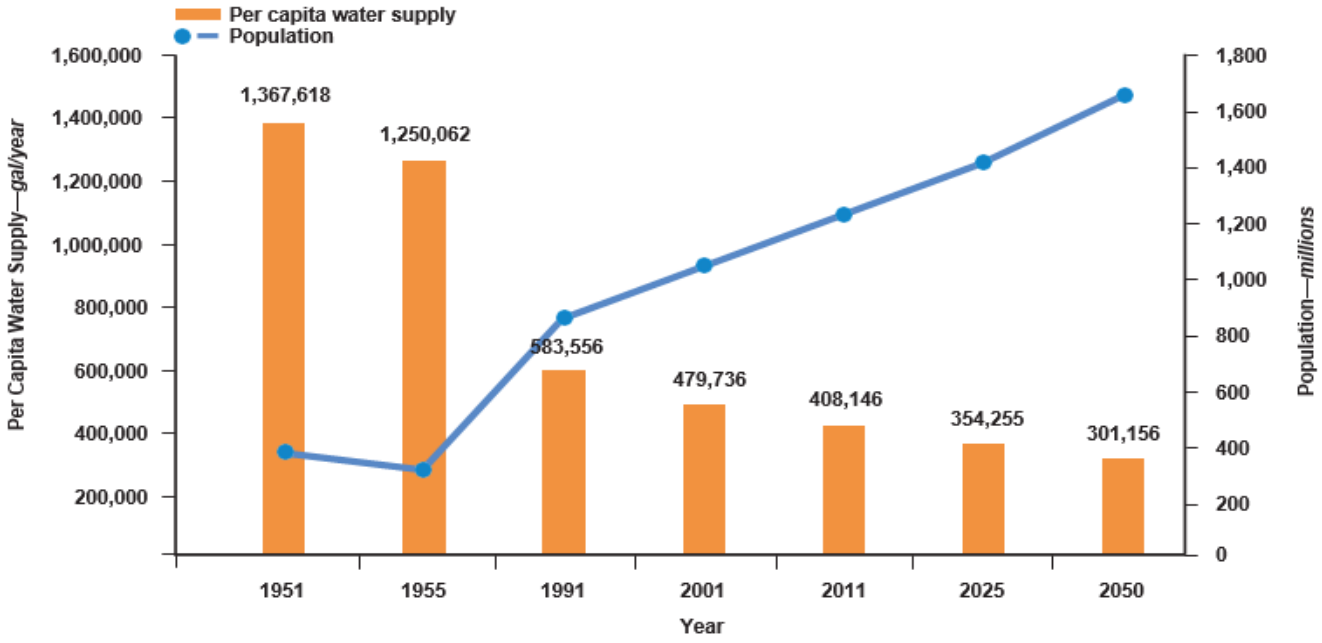
Data from India's Ministry of Water Resources, River Development, and Ganga Rejuvenation indicate per capita water availability in 2025, and 2050 is estimated to decrease from 2001 levels by 36 and 60%, respectively. The figure below illustrates the declining projected population and per capita water supply per year in India ratio until 2050 [6]:

These projections are a code red that the nation cannot afford to ignore as water shortage can inflict irreparable damage to both the national economy and the health of its citizens. Lack of proper infrastructure and historic overdependence on monsoons has worsened the situation as climate change had made the monsoon patterns increasingly unpredictable. Rapid and unplanned urbanisation and increasing population has led to an unprecedented increased demand [7]. The problem becomes enhanced by the uneven geographical distribution of water. More than two-thirds of water resources are confined to about one-third of the land area. The Ganges–Meghna–Brahmaputra River basin in the east contains 60% of available freshwater [8,9].

In the absence of a clear-cut uniform water governance policy across India, there is unchecked rampant exploitation of both surface and groundwater.

India lags in water governance for a variety of reasons such as the poor water capacity of Indian states, the complexity of the Indian decision-making system and poor accountability framework, conflicts between states over water rights, and most importantly, the lack of water-related expertise and a sense of urgency among Indian political leaders and policymakers [10,11].

FIGURE 2 Population and per capita water supply per year in India



Data sources: KPMG International 2010; Office of the Registrar General & Census Commissioner, India

Given the scale of the crisis, India needs urgent and cost-effective intervention. Rainwater harvesting can make a crucial difference. It is a comparatively cost effective, sustainable and efficient means of water management which can empower people at the grass-root level by making them water sufficient.

Advantages of rainwater harvesting:

Rainwater harvesting is not new to India. It is an ancient practice that was used for centuries to supplement water needs in dry areas. It has the following advantages that make it a favourable option to tide over the impending water crisis:

(a). Better management of over dependence on the monsoons:

More than 75% of fresh water of India is sourced through the monsoons. The monsoon patterns however are becoming increasingly unpredictable over the last two decades on account of climate change, impacting India's water supplies [12]. Consequently, the groundwater recharge has been reduced and water discharge in streams and springs has diminished by 35%, decreasing irrigation potential (15%), declining agricultural productivity (25%) and undermining food and livelihood security [13]. Apart from the seasonal character there is uneven distribution of rainfall over different regions of the country creating huge national level disparities in Annual Average Runoff, Usable flow and Fresh Water Resources in India [14]. The climate of India is characterised by both spatial and temporal mismatches in water stress and availability. Erratic monsoon patterns can create high rates of runoff leading to flood events and high short-term availability during wet seasons, followed by severe water stress during dry periods [15]. Such temporal mismatches, paired with a shortage of surface water storage, have been linked to both reduced incomes and a lack of food security [5]. With such limited annual water availability and the extreme intra-annual rainfall variability, there have been ongoing efforts in India to increase storage capacity and additional water supplies for agricultural production and economic development [16]. Over the last century, such efforts have focused primarily on large-scale projects designed to ensure higher levels of water storage and availability, such as the building of large dams and canal systems [17]. However, the growing demand for water has rendered sole dependence on these measures impractical. For millennia, however, India has met the demand for seasonal water storage and increased water availability at the local level via the building of village-scale rainwater harvesting (RWH) structures, often referred to as tanks [18]. Unfortunately, this system did not make its way into mainstream water policy measures and saw a huge decline as a result of increasing reliance on groundwater pumping, and cheap access to electricity [19]. This measure can be used effectively to store water during the rainy season for use during dry spells and thus reduce the pressure on ground water that is becoming a matter of concern for everyone [20].

(b). Mitigation of Flood damage:

Floods, cyclones, earthquakes and other disasters triggered over half a million internal displacements in India in 2023, says Geneva-based Internal Displacement Monitoring Centre (IDMC) [21]. The monsoon has become more erratic and unpredictable, with floods and droughts coming most unexpectedly. Worryingly, India's drought-prone area has increased by 57 percent since 1997 [22], while instances of heavy rainfall have risen by almost 85 percent since 2012. This can have far-reaching impacts, affecting lives and livelihoods [23]. Unfortunately, despite massive investments for flood-control efforts, the socioeconomic damages and death toll continue to remain high [24].

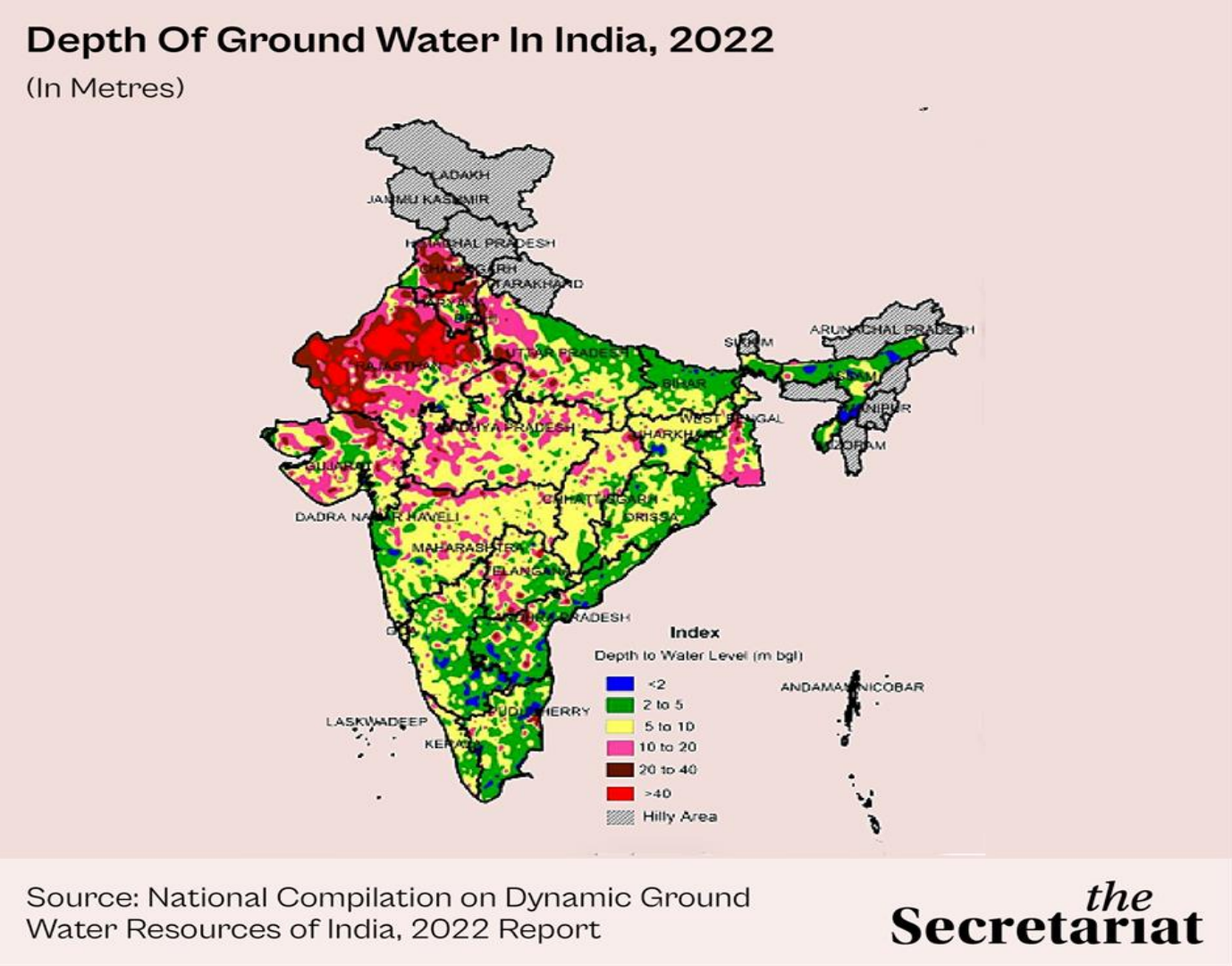
This is also owing to the fact that the process of flood management in India is very complex due to the influence of several socio-hydro climatological factors, such as climate change, sea level rise, and socioeconomic dynamics [25]. Experts feel that reviving the traditional structural measures like rainwater harvesting tanks can help mitigate and even adapted to reduce the risk of flooding in the rainy season and water crisis in the dry season, we seek to provide an intervention using 'Rainwater harvesting. According to UNEP, while rainwater harvesting by individuals on the roof or other areas is effective for personal use, building larger catchment

structures like tanks or reservoirs, can divert excess water and break the excessive flow from water bodies and drainage systems during heavy precipitation, mitigating the risk of flooding. As water is directed into these structures, the volume of water flowing into rivers and streams and drains is reduced [25,26]. This is especially useful in reducing stormwater runoff in urban environments and rocky and hilly terrains, where the impervious cover and slopes produces a higher rate of runoff which is the main cause of the frequent flash floods in urban areas and hilly terrains [27]. Diversion of water into reservoirs that follow the right gradient also breaks the force of the flow of water which can otherwise become very corrosive and cause irreparable erosion and damage the soil cover [28].

(c). Aids in groundwater recharge:

According to the United Nations World Water Development Report 2022 India's groundwater depletion rate could triple by 2080 due to farmers' adaptation to warming climate, threatening food & water security and their overdependence on ground water for their farming needs. Moreover, 85% Of Rural India Survives on Groundwater. It goes to state that India consumes more groundwater than the US and China combined and warns that its groundwater levels will hit an all-time low by 2025. Significantly, India's north-western region is landlocked and serves as the breadbasket for the nation's growing 1.4 billion people, with the states of Punjab and Haryana producing 50 per cent of the country's rice supply and 85 per cent of its wheat stocks, both water intensive crops. Erratic rainfall patterns and extreme heat caused by climate change has forced them to increase their dependence on ground water. It reports that 78 per cent of wells in Punjab are considered overexploited, and the north-western region is predicted to experience critically low groundwater availability by 2025, a fact that could adversely impact India's food security.

Despite records showing that there has been a slight increase in rainfall over the past four decades, groundwater levels in India continue to decline. This because the precipitation patterns have become erratic and more sporadic with intense rain on fewer days rather than being spread over the traditional rainy season. This increases surface overflow and in the absence of planned contrition of reservoirs to tap into this surface flow, this precious resource becomes destructive and can cause flash floods and further erosion of the soil surface. Secondly, construction on catchment areas and ground surfaces, once available for groundwater recharge, has cut the natural process of replenishment and further worsened the situation particularly in urban areas where shortage of land is failing to meet the ever-growing demand, forcing planners and builders to encroach upon green cover and natural catchment areas [30]. The figure below gives a complete picture of the impending water crisis:



Source: National Compilation on Dynamic Ground Water Resources of India, 2022 Report

the Secretariat

Rainwater harvesting is very useful in recharging aquifers. By directing excessive rainwater into the ground through recharge wells, percolation pits, or infiltration trenches, the water gradually infiltrates the soil and replenishes the groundwater table. This process is very useful in those areas which are reporting dangerously declining water tables due to over-extraction [32,33].

(d). A cost-effective urban water management tool

Rapid and unplanned urbanisation and expansion of urban clusters in India has created a serious water crisis in most urban areas of India. They are largely dependent on water from their underground water table which in most cases has been so over-extracted that it may become financially unviable to tap further. For example, the IT city of Bangalore, known to be the Indian equivalent of the Silicon Valley has tripled its population for 1990 to 13.6 million, which has led to rampant unplanned townships encroaching on lakes and green belt areas worsening an already existing water crisis. Since Urban areas have more paved and hard surfaces and high deforestation to meet the needs of infrastructure, they generally experience high surface runoff (have low permeability) which leads to decreased groundwater recharge making the principal source weaker.

The World Bank says that by 2036, towns and cities of India will collectively have 600 million people, which would be roughly 40 per cent of its population [35]. At present, the status of water in urban areas of India is not at all assuring. For example, nearly 42 per cent of households in urban areas didn't have access to piped water connections inside their premises as per the 78th round of the National Sample Survey Organisation (NSSO) of 2020-21 and 24 per cent urban households were without access to an 'improved source of drinking water' that provided enough water throughout the year [36]. As per a report of the Worldwide Fund for Nature (WWF) published in 2020, thirty cities in India will be facing 'severe water risk' by 2050. This included the leading commercial hubs like Bengaluru, Bhopal, Delhi, Mumbai, Rajkot and Vadodara [37]. According to another global study, India could soon become the most severely affected country in terms of growth in water-scarce urban population by 2050 [38]. The over dependence on ground water for urban usage has already been red flagged. By the Composite Water Management Index (CWMI) developed by NITI Aayog 2018 that has gone on record to state that 21 major cities are expected to run out of groundwater thereby creating a situation of severe water scarcity for hundreds of millions living in those urban centres [39]. The report warns that 72 per cent of all water sources in the country are contaminated because wastewater is released untreated to the open spaces which pollutes the surface (viz., ponds, lakes, wetlands and rivers) as well as groundwater. India is already the world's largest consumer of groundwater [40].

India cannot afford to ignore this urgency as these urban centres are the main drivers of its economic growth. Rainwater harvesting can be an economical solution where individual citizens can also largely resolve their own demand putting less pressure on the city's resources.

The following Rainwater Harvesting techniques can help both individual and group users (in building complexes) to alleviate their water woes [41,42]:

- Rooftop- storing rainwater for direct use.
- Recharging ground water aquifers, from roof top run off.
- Recharging ground water aquifers with runoff from ground area through a network of pipes.

Some of this stored rainwater can be sued for non-drinking purposes. This is the most cost effective individual and community solution to catering for soft water devoid of dissolved minerals or salts, arsenic and other heavy metals.

(e). For helping alleviate water stress in agriculture:

India has 18% of world population, having 4% of world's fresh water, out of which unproportionately large amount is used in agriculture. While FAO puts this figure at 90%, Indian Central Water Commission says it is 78%. Even though India receives an average of 4,000 billion cubic meters of precipitation every year, only 48% of it is used in India's surface and groundwater bodies. Lack of poor storage infrastructure and lack of efficient water management procedures is largely responsible for this mess [43]. According to the Council on Energy, Environment and Water (CEEW), one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks, India is principally dependent on its monsoons for fresh water supply and are regarded as the backbone of the agricultural sector, which employs over half of India's population.

Current climate change trends suggest that global warming records could be breached sooner than anticipated, leading to heightened climate variability and more frequent and intense extreme weather events, which will impact an even larger population (WMO 2023). This has a direct bearing on India's monsoons, as evidenced in 2023, when unpredictable rainfall patterns triggered severe floods in some cities due to unprecedented heavy downpours, while core monsoon states faced notable rainfall deficits. Some areas received nearly half of its total annual rainfall in just 50 hours, while others like Kerala and Maharashtra encountered deficits of around 46 per cent and 60 per cent in June, respectively (IMD 2023). This has made the farmers depend even more on the already depleting ground water. What are the root causes of India's water crisis? This unchecked and unplanned over extraction of water is dwindling groundwater supplies. Over the last 50 years, the number of borewells has grown from 1 million to 20 million, making India the world's largest user of groundwater. The Central Groundwater Board of India estimates that about 17% of groundwater blocks are overexploited (meaning the rate at which water is extracted exceeds the rate at which the aquifer is able to recharge) while 5% and 14%, respectively, are at critical and semi-critical stages. The situation is particularly alarming in three major regions – north-western, western, and southern peninsular [47].

Groundwater pollution and the effects of climate change, including erratic rainfall in the drier areas, put additional stress on groundwater resources which serve about 85% of domestic water supply in rural areas, 45% in urban areas, and over 60% of irrigated agriculture [48]. This overexploitation can very soon begin to threaten livelihoods, food security, climate-driven migration, sustainable poverty reduction and urban development [49].

The declining water tables increase the cost of pumping and the salination and presence of impurities and heavy metals etc, escalate the cost of crop production and adversely impact the quality of the produce. It is in the farmer's interest to make efforts to build their own water security through simple measures like rainwater harvesting. They can use the In-situ rainwater harvesting technique which involves capturing and storing rainwater directly within the agricultural fields by building contour bunds or using trench farming, and mulching or work together as a community to use Ex-situ rainwater harvesting to capture and store rainwater outside the agricultural fields, in structures such as ponds, tanks, or check dams, for irrigation purposes [50]. These techniques can be well planned by altering natural conditions to increase infiltration — to also replenish an aquifer [51].

Larger catchments can be used for collecting runoff into village ponds and reservoirs through watershed management methods like percolation tanks, which are an artificially created water body to allow surface runoff to percolate and recharge groundwater. On

gentle slopes with smaller streams, generally check dams are constructed and recharge pits are made to recharge shallow aquifers [52].

Rainwater harvesting helps increase the overall arable area by improving otherwise unproductive land [53]. The quality of fresh water made available through this method is much better than ground water which is often impacted by surface pollution and is known to enhance cropping intensity and yields significantly. The saved water can be utilized in dry spells for irrigating crops and could result in additional returns. It also encouraged the framers to experiment with crops rather than be restricted by a water cycle that is becoming increasingly unpredictable. Moreover, structures like percolation tanks, check dams help in checking soil erosion by reducing surface runoff and keep the quality of the soil intact, besides the farmers are able to conserve energy used to operate pumps to extract ground water. Use of this method has shown considerable improvement in biodiversity with a significant increase in the vegetation cover due to more water availability, thereby improving the flora/fauna, including migratory birds [54,55]. This improvement in the natural ecosystem is good for agriculture overall contributing to more sustainable farming practices.

(f). For Industrial use:

Industries such as agriculture, mining, oil production, and manufacturing form the backbone of the Indian economy but compete for a larger share in India's water resources. The largest consumers of industrial water include power plants, steel mills, aluminium smelters, petroleum refineries, chemical producers, cement factories, and fertilizer makers. This hasn't escaped the notice of global bodies who are closely watching the Indian economy and its growth trajectory. There is a cautionary note in the 2024 Moody's Ratings which warns that among industrial sectors, coal-based power plants and steel-makers were most vulnerable to water stress in India [57]. A 2023 vulnerability assessment by the Ministry of Power's Central Electricity Authority showed India's major power grids were dependent on 14 major river basins — all of which are under 'high water stress'. Companies including Tata and JSW Steel, have led the way in building new water reservoirs in their plants and investing in water treatment plants and rainwater harvesting systems to ensure uninterrupted water supply.

Rainwater harvesting helps plants become self-sufficient and not overly dependent on Municipal water supply and depleting ground water supplies which disrupts their operations. It also saves them the cost of extracting water by pumping, which reduces their operational costs significantly. Moreover, rainwater is soft and more suited for industrial usage. As this water has less contaminants and hard metals they are better suited for machines and help improve their fife span. This system is particularly useful for water-intensive industries and helps them promote sustainability and take a more responsible approach to water usage in their operations.

Challenges in Rainwater harvesting:

Despite its proven utility, rainwater harvesting also comes with its share of challenges that can render even the most well-planned efficient systems ineffective, the principal being:

(a): Initial investment and topographical and landscape limitations:

The installation cost of the rainwater harvesting system which includes tanks, gutters, filters, pumps, and plumbing, can be a deterrent for some unless they have witnessed firsthand the difference that they make in terms of long-term savings on water bills that can offset the initial investment and the self-sufficiency they provide when there is water shortage. Moreover, urban areas with high density population may make it challenging to provide space for the installation of this system. Even in other open areas a good study of factors like the slope gradient, soil permeability, rain catchment surface can make a huge difference in the final efficacy of the installation. Poorly planned installation can cause inefficient draining and erosion due to stagnant water [58,59].

(b): Maintenance and water quality challenges:

Rainwater Harvesting tanks demand regular maintenance as water can become turbid due to contamination with ground impurities, growth of microorganisms, algae, pathogens and bacteria in the storage tank or the connecting pipes [60].

Issues regarding rainwater quality mainly arise from contamination at the collection stage, when rainwater is in contact with hard surface roofing materials, which are often covered with contaminants from dry (e.g., dust and particulates) and wet precipitation (e.g., rain and fog), animal urine and feces, and plant (e.g., debris). These contaminations will then be accumulated in the collected rainwater [60,61,62,63]. The pH of the harvested water, for instance, is affected by the roof material; iron-zinc, aluminum, galvanized iron, zinc or wood shingles [64]. A variety of roofing materials comprised of alkaline materials such as concrete, gravel, asphalt shingles, clay, or pantile can cause significant increase in the pH of the harvested rainwater [64,65]. Meanwhile, pH of running rainwater over the roof surface increases the reactivity between the rainwater and the roofing materials (especially metal type roofing) and particulates accumulated on the roof surface from atmospheric deposition which cause undue reaction of chemicals and metals creating toxicity and eroding the system itself [65]. Poor quality of water can become a health hazard and may cause more harm in industrial use too, making filtration an added expense.

(c): Uncertain precipitation patterns:

The uncertainty around precipitation pattern has increased with climate change. Since the systems are dependent on rainfall, the most efficient systems can become disappointingly unreliable and ineffective, making consumers see it is a futile investment [66].

Conclusion:

With water crises plaguing most of the cities in India, there is a need for urgent action. With consequences of climate change becoming increasingly visible on the precipitation patterns across India, the situation needs immediate intervention as majority states of the country are dependent on the monsoons for their fresh water supply. Dr. Sejal Worah, Programme Director, WWF India, said "The future of India's environment lies in its cities. As India rapidly urbanizes, cities will be at the forefront both for India's growth and for sustainability. For cities to break away from the current vicious loop of flooding and water scarcity, nature-based solutions like restoration of urban watersheds, ground water and wetlands could offer solutions. This is our chance to re-evolve and re-imagine what the future of the cities could be [67]."

The rapid increase of urbanisation and the growing population in urban areas has put a lot of pressure on the ground water tables under most urban areas outing them at high water risk levels. Rainwater harvesting can help replenish this groundwater and ease

the water scarcity considerably while also safeguarding urban areas from flash floods that are becoming increasingly frequent due to the climate change and rise in land and water surface temperatures.

Rainwater harvesting is by far the simplest strategy by which rainfall is gathered and stored for future usage. The process involves collection and storage of rainwater with help of artificially designed systems, that runs off natural or man-made catchment areas e.g. rooftop, compounds, rocky surface, hill slopes or artificially repaired impervious/semi-pervious land surface. The collected rainwater from surfaces on which rain falls may be filtered, stored and utilized in different ways or directly used for recharge purposes [68]. Since individual users may not be able to install these structures due to paucity of funds and space, a well-planned private and government partnership can go a long way in ensuring that these facilities be integrated into urban planning. It is also important to create a centralised support system to ensure their maintenance and upkeep. Multi-stakeholder engagement and ownership involving local communities is key in creating and conserving sustainable water infrastructure and rejuvenating urban freshwater systems, without which the initiative could be poorly implemented and maintained causing more harm than good [70]. Lack of government support limits the larger impact of this simple mechanism. Lack of acceptance, motivation and involvement among users in the absence of adequate support in planning, design and implementation of RWH systems [71] .

India cannot afford to see any setback to its agricultural economy as it needs to ensure food security for a huge population. Since more than three fourth of the country's water resources are taken up by agriculture, it become even more important to incorporate this system in large and medium farms even making it mandatory and subsidising their installations. The use of RWH expands the irrigation area, converting more 'blue' water into 'green' water. This has a favourable influence on groundwater recharge but reduces stream flow downstream, enhancing the groundwater system's resilience and sustainability [72]. Farmers benefit from this as it minimizes the risk of crop loss due to spatial or temporal drought, gives them more alternatives by extending the growing season, provides more 'rainfall' to allow them to produce a wider variety of crops, and allows them to cultivate 'abandoned' land [73].

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