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Rich or Poor Nation: Water Scarcity is a Global Crisis

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ABSTRACT

Almost four billion people face severe water scarcity worldwide. This is not a problem of either rich or poor countries. Simply using more fresh water than is available for agriculture, industry, or domestic use has made the crisis critical. Climate change has degraded the patterns of fresh-water availability worldwide while population growth and rising standards of living have caused increasing demand on the supplies. This paper discusses only the supply and demand side of fresh water. The problems related to the distribution or quality of that water is beyond the scope of this study. Although citing examples of water-related crises in USA, Brazil, and North and North-Central Africa (hereafter referred to as NNCA), the main part of the paper deals with the causes and possible solutions for hydrological "emergency" in India. India provides a type example for the causes of water crisis and its possible solutions. Logical steps taken at one time to raise the standards of living and provide plentiful food for the population appear to have worsened the crisis many years later. Population growth, increased living standards, growing urbanization (considered public good) have all contributed to the water crisis not just in India, but worldwide. Perhaps the Indian example can serve as a "model" for what to do and perhaps more importantly, what not to do for other parts of the world.

In 1951 the Indian population stood at 361million; by 2023 it has exceeded China's at 1.461 billion. During this period, the per-capita water availability has decreased almost fourfold! The urban population has more than doubled (from less than 20% to 40%) causing metropolitan areas to grow outwards and upwards and reducing the recharge areas to provide for the water needs of the cities. To feed the growing population, during the "Green Revolution" in the 1960s, the government provided incentives to farmers to use mechanical pumps (subsidies for electricity and fuel), for water from canals, and for fertilizers. All of this made India not only self-sufficient in food, but the world's top producer of rice and the second largest producer of wheat. However, it has also made India *number one* out of 170 countries in total freshwater withdrawal (2.5 trillion m^3). As a result, the water table is dangerously low in many of the aquifers. In addition, pollution of surface and ground water, lack of storage capacity for the available water, and weakening of monsoons have added to the water crisis.

Steps to manage the surface waters by interlinking river systems, harvesting rain water, improving irrigation methods, changing crop patterns to reduce the use of groundwater and improving wastewater treatment may be parts of the solution not just in India, but worldwide. However, the key factors are political will and economic realities if the problem is to be tackled in a timely manner.

INTRODUCTION

The Hydrologic or "Water" Cycle is one of the basic natural cycles that describes the path of essentially each water molecule through the atmosphere, on the surface and in the subsurface of land areas, and through the oceans. The total available water supply is finite, and the freshwater which we consume for agricultural, industrial, and domestic use constitutes only 2.5% of Earth's water. Because most of the fresh water is trapped in ice sheets, the total water available for human use as surface or ground water at a given time is only 0.8% of the total water volume (Water Science School, 2019). In the pre-industrial era (mid-18th Century, as defined by Encyclopedia Britannica, 2024) when populations worldwide were small and the water usage for agriculture and industry was limited, the total available water supply was generally not a problem. However, today in the early 21st century, with the world's population having surpassed 8 billion (Worldometer, 2023), elevated living standards requiring increased water use for

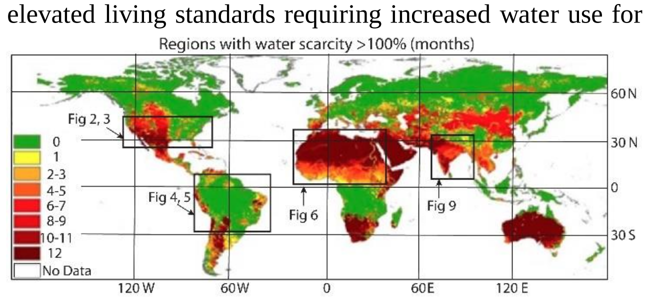

Figure 1: Map showing in colors ranging from green to red, areas where water scarcity lasts from 0 to 12 months/year. Red-colored areas are countries where water scarcity lasts at least six months or more. Darkest red areas have year-round scarcity >100% (Carrington, 2016). Locations of Fig 2,3,4,5,6, and 9 are also shown.

agriculture and industry, and large population concentrations in "mega cities" (populations generally >10 million), more than four billion people (50% of world's population) face *severe water scarcity* (Carrington, 2016) (Figure 1).

As shown in the Figure 1, the problem spans the globe and afflicts countries as disparate as the USA, Brazil, and India. In addition, multiple countries in North and Central Africa (hereafter referred to as NNCA and consisting of Egypt, Libya, Algeria, Morocco, Sudan, Chad, Niger, Mali and Mauritania) face year around water scarcity. The income level, industrial development and the population size in each of these areas is very different, yet each is facing water scarcity issues as discussed in this paper. However, the main discussion in this paper is centered on India as a "case study".

Use of Fresh water Withdrawal by Sector (2019)

Table 1: Comparison of use of fresh-water withdrawal in agriculture, industry, and domestic consumption for the USA, Brazil, North and North-Central Africa* (NNCA includes Egypt, Libya, Algeria, Tunisia, Morocco, Sudan, Chad, Niger, Mali, and Mauritania), and India (data from Ritchie and Roser, 2024). Agriculture, by far, uses an overwhelming share of the available water except in the richest countries.

Sector%	USA	Brazil	NNCA*	India
Agriculture	40	61	84	90
Industry	47	15	3	2
Domestic	13	24	13	8

With the exception of air, water is the most important commodity for human survival. Hence, understanding and managing the risks imposed by water scarcity worldwide is critical for the global future. Table 1 shows the use of fresh-water withdrawal in each of the areas mentioned. Of the three primary sectors where freshwater is consumed worldwide, agriculture is the dominant sector (Ritchie and Roser, 2024). In developed countries, the industrial sector (including power generation) consumes as much as the agriculture, or more, whereas the domestic use is a relatively minor component. Thus, although water scarcity in mega cities makes the headline news, any efforts to conserve and streamline the use of freshwater in agriculture will produce the largest impact.

This paper describes in brief various factors affecting water availability in the USA, Brazil and NNCA first. It then describes the water crisis in India as a "type example". Some of the factors that have caused the crisis in India are more or less the same as those affecting many other countries worldwide. However, India's population and the size of its GDP (Gross Domestic Product; 2019 ranking: 5th in the world in nominal dollars, and 3rd in Purchasing Power Parity, Wikipedia 2024) makes the problem not only critical for India, but for the whole world. Also, perhaps some of the approaches to tackle this crisis, if successful in India, may be applied to other smaller populations and economies as well.

WATER CRISIS IN THE UNITED STATES

With one of the highest standards of living in the world, we normally do not associate the United States with having a water scarcity or water crisis. However, in reality, the pattern of usage which allows higher withdrawal rates than natural replenishment, especially in the western parts of the country has created conditions of severe to extreme drought (Wyler, 2013).

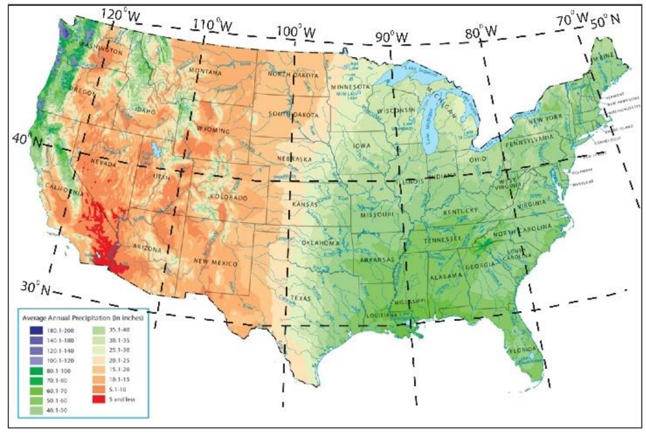

Figure 2. Map showing the US annual rainfall in inches (1 inch = 25.4 mm). Almost the entire Western half of the United States (areas in earth colors) has rainfall less than 500mm/year (20 inches) and is classified as semi-arid or arid (GIS Geography, 2015).

As shown in Figure 2, almost the entire western one-half of the US is either arid or semi-arid (rainfall <250 mm or <500mm). Yet, these western states have grown in population and have become some of the primary agricultural states in the country. "Overcoming the nature" has been considered almost an American tradition and thus, through dams, canals, pipelines, and groundwater withdrawals, this half of the country has been able to essentially "ignore" the lack of water. However, during the last thirty years, whereas the eastern half of the country has become wetter, the western half has become drier. The

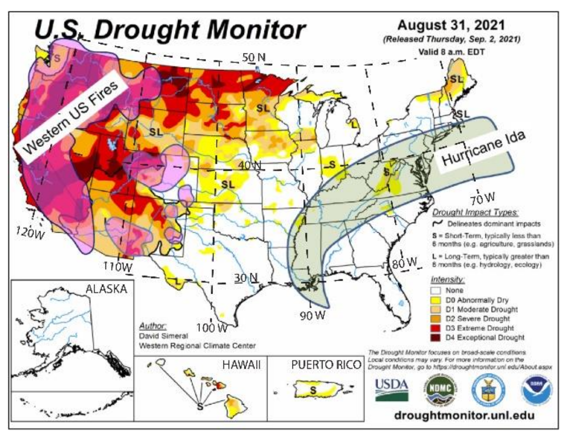

Figure 3. Map for the week of August 31, 2021 showing moderate to exceptional drought throughout most of the western US (US Drought Monitor, 2021). Map also shows the locations of forest fires during the same week as well as the path of Hurricane Ida, which created extreme flooding conditions in parts of the eastern US (taken from various news sources for that week).

average precipitation in the western US has decreased by up to 100mm (20% to 40% less than the average during the twentieth century) (Bhatia and Popovich, 2021). This has led to declarations of "drought" or "extreme drought" in much of the western half of the country (Figure 3). In fact, 2021 being an exceptionally dry year, the 22-year-long drought in the western US has been the worst in 1,200 years (Harvey and E.E. News 2022). In addition to stress on agriculture and domestic use, these drought conditions have led to extreme fire conditions along the same western states.

In fact, in order to support the population growth and support the agriculture for the western US, giant dams and hydroelectric projects have been built along the Colorado River in the states of Arizona and Nevada. Water supplied from these projects support farming, especially in California, which does not have enough of its own ground water to support the level of its agriculture industry. While this has worked reasonably well for more than 80 years (with many years of shortage in between), because of long-term drought a first-ever water "shortage" was declared for the Colorado River (Munch, 2021). The water levels in the reservoirs behind some of the largest dams ever built in the US have dropped by almost 50 meters in 2021 from their highest levels in 1983. This type of declaration may result in cutback in water supply and power generation and may affect more than 40 million people who live in the areas supplied by the Colorado River (Munch, 2021, Harvey and E&E News, 2022).

One of the side effects of water scarcity in the western US is also the severe forest fires that have occurred for many years. During the years 2020 and 2021, more than seven million hectares have been destroyed by fires (Insurance Information Institute, 2022) and the economic damage from 2021 fires alone is estimated at US $70 to 90 billion out of which $45 to $55 billion is in the state of California alone (Puelo, 2021).

Regardless of where a country fits on the economic scale, the basic reason for water shortage is simple: *demand outstripping supply*. Whereas a discussion of climate change is beyond the scope of this paper, long-term droughts have occurred in all the countries that are discussed in this paper. It is not the *average* shortage of water in a given year that should be of most concern, but the "*cumulative deficit*" caused by long-term reduction in replenishment over draw-down that should be most worrisome (Shi et al., 2013). Using this parameter, almost half of the United States, including the central part that produces a large amount of national agricultural products, is facing critical water shortage (Shi et al., 2013). In fact, "overdrawing" on the ground water has caused the declining of wells in almost half the sites throughout the country, especially in the agricultural land in the center (Rojanasakul et al., 2023). For example, in the state of Kansas, almost a million hectares (2.6m acres) of aquifer can no longer support industrial-scale agriculture. Every year since 1940, more wells have had falling water levels than rising levels, and this makes it almost impossible to replenish the aquifers (Rojanasakul et al., 2023).

SCARCITY AMONG PLENTY IN BRAZIL

It is ironic that with one of the highest per-capita renewable freshwater resource among large-population countries in the world (26,553 m^3 in 2020, Ritchie and Roser, 2024), Brazil should even be listed among the countries with water "scarcity". In fact, the water resource for Brazil is three times that of United States, and 25 times that of India on a per-capita basis (Ritchie and Roser, 2024). Using the parameter of freshwater per capita, Brazil would be considered "low stress", whereas the United States falls in the "low-to-medium stress" and India and NNCA fall into "high-stress" category. However, a prolonged drought in the south and southeast of the country, coupled with an increase in population and domestic and industrial use, has created severe shortages especially in the São Paulo region (Figure 4, Getirana et al., 2021).

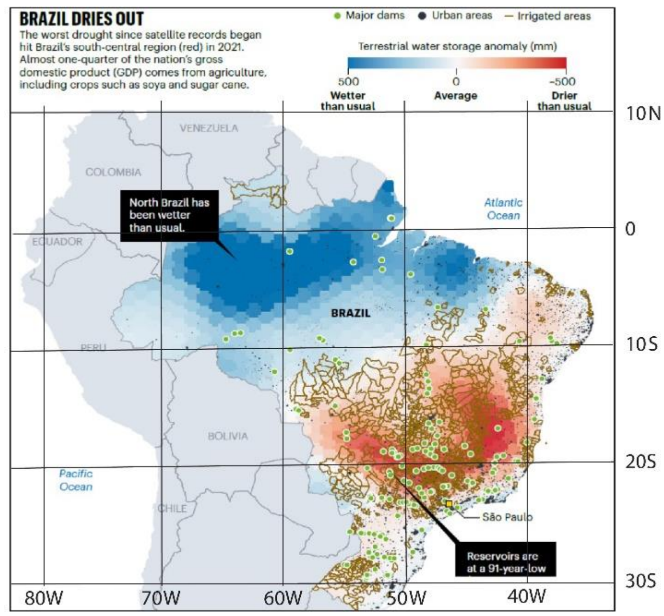

Figure 4. Map showing the terrestrial water storage anomaly. Southeast Brazil has an anomaly of as much as 500mm (drier than normal). Map also shows major dams (green dots) and areas under irrigation (brown outlines) (Getirana et al., 2021).

Because most of the Amazon Basin is located in Brazil, the surface and groundwater flow within the boundaries of Brazil counts as part of Brazil's resource. However, the largest cities of Brazil and a great majority of the population is located thousands of kilometers away. Indirectly, climate change and deforestation in Amazon region affects the hydroclimate in the south-central region where 70% of Brazil's gross domestic product (GDP) is generated. Brazil depends on hydroelectricity for as much as 70% of its electric needs. As the reservoir levels have gone down, generation and consequently, industrial and agricultural production may be in jeopardy (Brandimarte and Freitas Jr., 2021).

According to Slater (2019), Brazil has experienced one of the worst droughts in its history since 2015. This has been caused by a combination of natural and man-made causes including climate change, environmental degradation, poor urban planning, a lack of maintenance of existing infrastructure and the mismanagement of water resources. The effects of climate change in agricultural production in Brazil can be severe. A 1^0 C change in temperature could decrease the Brazilian coffee production by as much as 24%, and soybean production by 14% (Getirana et al., 2021). These crops represent some of the most valuable crops in Brazil. Of course, the urban areas, such as the city of São Paulo, have suffered severe consequences of this drought as well. During this period, one of the main water reservoirs of this city was functioning at only 5.4% of its capacity (Getirana et al., 2021).

In addition, the Amazon Basin itself has also been facing a long-term drought despite the 2021 "wetter than normal" season as shown in Figure 4. In 2023, the entire Amazon Basin was facing "severe to exceptional" drought (Poynting, 2024) (Figure 5).

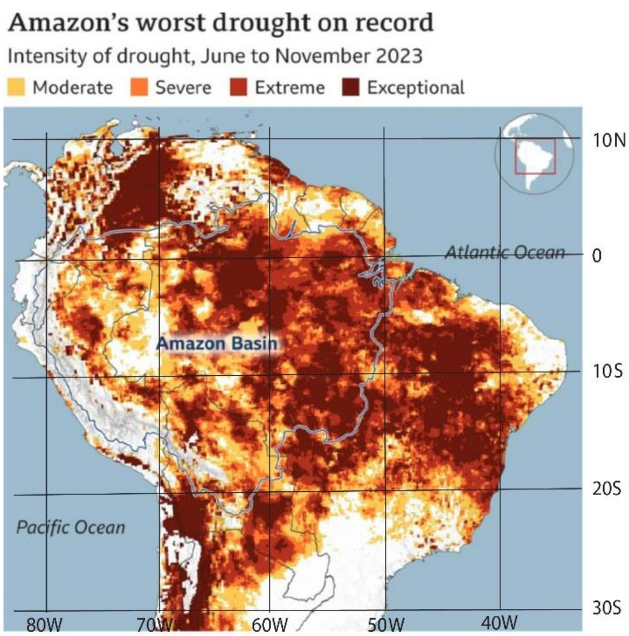

Figure 5. Intensity of drought as measured by SPEI (Standard Precipitation Evapotranspiration Index) for Brazil and surrounding countries (Poynting, 2024) from June to November 2023. The boundaries of the Amazon Basin, which covers a majority of the territory of Brazil, is shown in dark outline.

In April and May 2024, southern Brazil state of Rio Grande do Sul had historic floods, the worst in at least 70 years (Ledur, 2024). The state received roughly eight months' worth of average rainfall in just the first half of May. More than 450 municipalities were flooded causing death and destruction and thousands of people were displaced (Ledur, 2024). However, such sudden events do not change the trajectory of regional droughts because the excess water is not captured and flows back to the ocean rapidly. The regions to the north of Rio Grande do Sul in south-east and central Brazil continued to be hot and dry in mid-May and early June, 2024 (Climate Impact Company, 2024).

As we have seen from the discussion on the USA and on Brazil, meteorological droughts (dry-weather patterns due to periods of little rainfall or high temperatures) can cause hydrological droughts (water shortages on land surfaces such as rivers and lakes) which can dry out shallow aquifers and lower the regional water table. Consequent decline in soil-moisture levels jeopardizes food production (Getirana et al., 2021) and may cause other socio-economic disruptions.

WATER CRISIS IN NORTH AND NORTH-CENTRAL AFRICA (NNCA)

The countries included in this discussion (Egypt, Libya, Algeria, Tunisia, Morocco, Sudan, Chad, Niger, Mali, and Mauritania) with a total population of 337 million (Worldometer, 2023), are some of the most arid places in the world. However, because all of them are also very sparsely populated (with the exception of Egypt, 35% of the total), the aquifers in some of these countries have not been overdrawn but the withdrawal in these areas is considered "uneconomic". Thus, the challenge in parts of Africa is of drawing the water from aquifers in appropriate amounts to meet the domestic, industrial, and agricultural needs of the population. Therefore, the water scarcity has been classified as "physical" or "economic" (Lai,2022) (Figure 6).

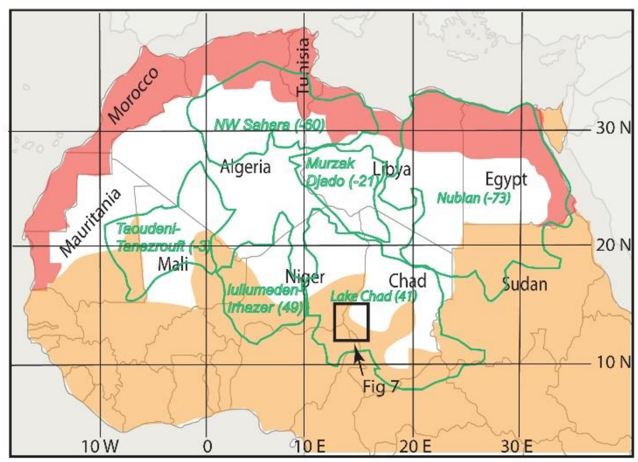

Figure 6. Map of NNCA countries showing physical (red) or economic (orange) water scarcity at basin level on the African continent (Lai, 2022). Blank areas have little data on water availability. Green outlines show major aquifers in the region and the numbers within show the change in TWS (Total Water Storage) in these aquifers as derived from satellite data between 2002 and 2020 (TWS = surface water+ soil moisture + shallow and deep ground water, storage units in cubic kilometers) (Scanlon et al., 2022). Location of Figure 7 is shown by a black rectangle.

Out of the countries mentioned above, only Egypt, Tunisia, Algeria and Morocco represent countries with "modest" relative water security and Libya and Mali have "slight" water security. On the other hand, Sudan, Chad and Niger are some of the least water-secure countries on the

African Continent (Oluwasanya et al., 2022). However, as shown in Fig. 6, the three northern aquifers, Nubian, Murzak-Djado, and NW Sahara have lost 73, 21, and 60 cubic kilometers of water storage (TWS), respectively during the eighteen years between 2002 and 2020 (Scanlon et al., 2022). As a reference, the maximum capacity of Lake Mead in United States, one of the largest man-made lakes in the world is 35 cubic kilometers (Britannica, 2024). Egypt is facing an annual water deficit of about 7 billion cubic meters and with rising population it could face severe water shortage as early as 2025 (Unicef, 2022). As everywhere in the world, the cause of water scarcity is primarily

Figure 7. Lake Chad, spanning parts of Niger, Chad, Nigeria, and Cameroon has shrunk in surface area by almost 90% between 1972 and 2007 (Lai, 2007). Regional location shown on Figure 6.

overexploitation driven by rise in population and the rate of urbanization along with drought conditions exacerbated by climate change (Scanlon et al., 2022).

Lake Chad (Fig. 7), deemed Africa's largest freshwater body, has shrunk during last several decades. The water body of the lake has diminished by 90% since the 1960s, with the surface area of the lake decreasing from 26,000 km^2 in 1963 to less than 1,500 km^2 in 2018 (Lai, 2022, Oluwasanya et al., 2022). However, as shown in Fig 6, the three southern aquifers have either actually increased their water storage or have remained relatively stable during the years 2002 to 2020. Specifically, the Lake Chad aquifer has grown its TWS by 41 cubic kilometers (Fig. 6, Scanlon et. al., 2022), a counterintuitive observation given the shrinkage of the surface water in Lake Chad. This increase is explained by Scanlon et. al. (2022) to increased recharge from land-use change and cropland expansion. As the cropland expands, only the surface water and shallow ground water is used while the deep ground water may actually expand. In fact, Pham-Duc et. al. (2020) monitored the hydrology of Lake Chad using satellite data and found that "in tandem with groundwater and tropical origin of water supply, over the last two decades, Lake Chad is not shrinking" and that it seasonally recovers its surface water extent and volume, at least since the 2010s.

Thus, in countries with "physical" scarcity of water in North Africa, the emphasis needs to be on conservation of irrigation water and recycling of domestic and industrial water, and desalination if feasible. On the other hand, countries with "economic" scarcity of water, the emphasis needs to be on accessing the available natural water storage and efficient management of surface and ground waters.

BACKGROUND AND MAGNITUDE OF THE CRISIS IN INDIA

India's per capita water availability is one of the lowest in the world (Pulakkat, 2017). With 2.4% share of global land area, 4% share of world's water resources, but 17% of the world's population, India ranks 132nd in water availability (this paper is concerned primarily with water availability; but water quality is another issue and India ranks 122nd in the world in that parameter). Whereas in 1951 the water availability per capita stood at almost 5,000 meters^3, by 2001 it was already below 2,000 meters^3. Water availability at 1,800 meters^3 per capita is considered "Water

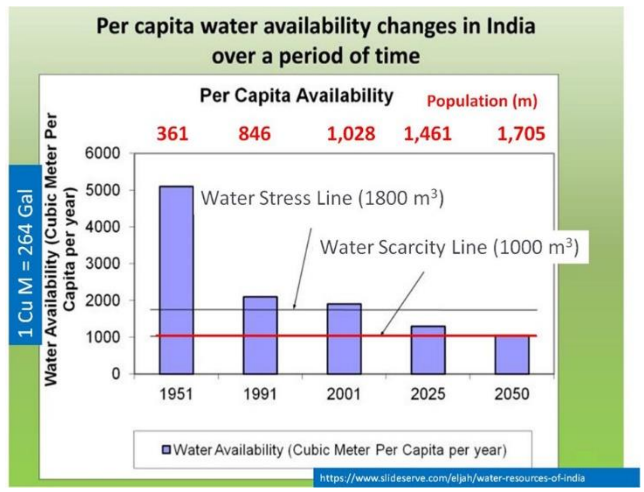

Figure 8. As the population of India has almost quadrupled in last 75 years, the water availability per capita has been cut by more than two-thirds. This has caused High to Extremely High-water stress in more than half of the country (Josue, 2008)

Stress" and below 1,000 meters^3 is considered "Water Scarcity" (Josue, 2008). By 2025, almost the entire Indian population will approach the water scarcity level (Josue, 2008) (Figure 8).

Additionally, whereas the domestic and industrial use of water accounts for approximately 15% of consumption, irrigation consumes more than 85% of the total water used (Josue, 2008). These percentages are slightly different from those shown in Table 1 for which the data is from Ritchie and Roser (2024). Demographic pressures and policy incentives introduced to increase the food production for an increasing population and rising living standards are responsible for this profligate use of water. The excessive withdrawal of water compared to available supply has resulted in 54% of the Indian landmass facing high (40-80% of available supply) to extremely high (>80% of available supply) water stress. These areas also happen to be some of the most populous and agriculturally most productive parts of the country (Shiao et al., 2015) (Figure 9).

Although still a poor country on a per-capita basis, Indian GDP has increased almost one hundred-fold since the 1950s (World Bank, 2023). In the 1950s, the industrial basis was small, and agriculture was almost entirely based on rainfall, surface water from canals and rivers, and well water. And water was pumped mostly by human- and animal-power. However, facing food shortages in India during 1960s, the government promoted a "green revolution" through improved seeds, providing subsidies for farmers for fertilizers, and essentially free water from canals, and free electricity for pumps. Thus, whereas in 1951 there were perhaps only 2,500 tube wells in all of India, currently at least 20 million (or more) tube wells exist in the country (Mukherji, 2012). As mentioned earlier, this has boosted the food production tremendously, but as the farmers have "overdrawn" on cheap (or free) water and

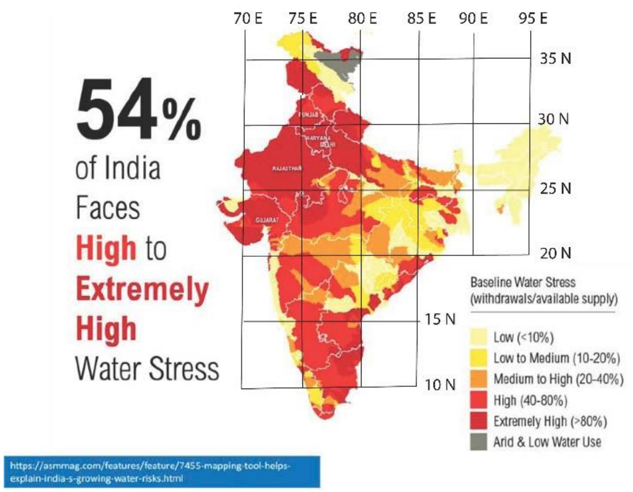

Figure 9. Areas in India facing "High" to "Extremely High" Water stress. In the darkest red areas (Extremely High) the withdrawal to available supply is >80% (Shiao et al., 2015).

electricity, the water table in most agricultural areas has not been able to keep up with natural recharge and has continued to drop over last several decades. Deficit recharge causes farmers to dig deeper and further draw down the water table in a vicious cycle (Figure 9).

Although the domestic and industrial use of water is a much smaller percentage than the agricultural use, it is also facing a crisis. According to Torkington (2016) there are five "mega cities" in India (New Delhi, Mumbai, Kolkata, Bengaluru, and Chennai), with two more expected by 2030. Three of these cities (Delhi, Bengaluru, and Chennai) have had major water crises during the last several years with water taps going dry and water distribution relying on tankers for months on end. For example, in 2019 the city of Chennai supplied water to its residents through 8,000 water trucks and brought water by railroad cars from more than a hundred miles away (Subramanian, 2019). Similar crisis management has been carried out in Delhi and in Bengaluru (Joshi et al, 2018, Jal Tarangg, 2016). This has happened through decades of unplanned growth, paving of natural recharge areas in watersheds near these cities, weak monsoon rains, and very little water treatment or recycling.

POSSIBLE APPROACHES TO SOLVING THE CRISIS

Water management is a multi-dimensional challenge that requires a comprehensive, multidisciplinary approach. In the past, in a large country like India, various local-, state- and federal-level authorities have managed surface- and subsurface-water usage and consumption in an ad-hoc manner. However, in May 2019, the Government of India formed a Ministry of Jal Shakti (Water Power) with an overall responsibility to implement a "National Water Mission" for an integrated water resource management to conserve water, minimize wastage and ensure more equitable distribution across and within the states (National Water Mission, 2019; NITI, 2019). Fortunately, over the years through various educational and government agencies' efforts, India does have good data on water budgets at the level of various catchment basins. These data bases can help guide the national policy.

Although the average annual rainfall in India is 300-650 millimeters (11.8-25.6in), almost 70% takes place during the summer monsoon (June-Sept) with a minor amount falling during the winter monsoon (Nov-Feb) (The Economist, 2019). Thus, if the monsoon is "less than average" for a year or two, and the surface-water irrigation is not sufficient, the surface reservoirs and aquifers are overdrawn and can be filled only if a "better than average" monsoon compensates for the deficit. At the Columbia Water Center of the Earth Institute of Columbia University, researchers have looked at water balance (rainfall vs ground water withdrawal) at multiyear scale and have mapped areas that, in order to avoid water scarcity, either need to have (a) excess surface storage capacity, or (b) should receive water through "inter-basin transfer" or (c) should carry out shift in crop patterns (Polycarpou, 2010; Devineni et al., 2013). All of these approaches have been tried in different parts of India at local or regional scales.

Unlined water storage structures have been built in the state of Rajasthan to store excess surface runoff and help replenish the local water table. According to Saini (2018), almost 100,000 water structures were built which reportedly, besides storing the water, also helped raise the ground water by 138 cm (almost 4 feet 8 inches) within a couple of years in certain districts.

An ambitious interbasin-transfer project in progress is the creation of nationwide "water-transfer links" comprising almost 15,000 km of canals and reservoirs, which would link rivers carrying excess of surface water during the rainy season to areas of water deficit where the surface water can be used and stored for agricultural and industrial uses. However, besides the cost ($168 billion), such a project requires careful attention to minimize the environmental impact of such an undertaking (Langar, 2017). Almost half of the proposed links have been completed.

Polycarpou (2010) has described the Columbia Water Center's pilot programs in India to encourage efficient use of water in agriculture as well as the proposed changes in crop patterns at a regional scale that would utilize available water optimally. In one case, rice farmers cut their water use by 30% using fairly low-cost methods (Polycarpou, 2010). Devineni et al. (2013), utilizing district-level data from all over India, describe a model which shows that crops like rice, sugarcane, lentils, and oil seeds should be grown where soil, climate, and water availability were best suited for those particular crops (Figure 10). Currently farmers grow crops wherever the subsidies for electricity, canal water, and fertilizers encourage them even at the cost of wasting precious water resources. Figure 10 illustrates how certain degree of regional shifting from current patterns of crops could optimize water usage while maintaining food security (Devineni et al., 2013).

As mentioned earlier, although the domestic and industrial use of water is a much smaller component of the total water usage, its scarcity has caused major disruptions in Indian megacities in the last few years. In order to mitigate the crisis, cities need to protect the recharge areas from development, maintain and build additional reservoirs and of course, enhance their water-treatment capacity.

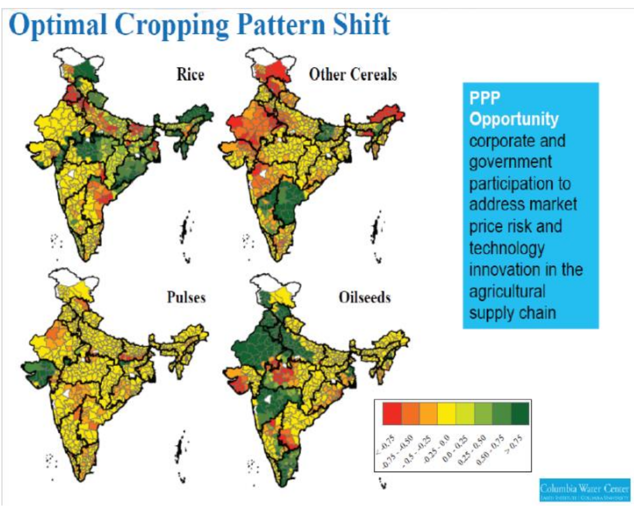

Figure 10. Maps showing district-level cropping patterns that would optimize water usage and would not jeopardize food security. However, this would require change in incentives to farmers to convince them to shift the crops planted without risking their economic gains (Devineni et al., 2013)

Whereas there are almost 16,000 treatment plants in the US serving more than 75% of the population, India has only 269 plants, of which only 231 are operational (Kamyotra and Bhardwaj, 2011) and which barely cover 21% of the generated sewage. Obviously, this would require a huge commitment of resources but it has the potential of generating tremendous rewards. For example, in a city like Bengaluru, treating waste-water could not only satisfy all the local needs and reduce water pollution, but also could generate up to 283 million m^3 (10 billion cubic feet) surplus treated water per year (Aravind, 2018).

SUMMARY

Mitigation of the water crisis needs to be carried out as one of the highest priorities for the population and economy not only for India but for the rest of the world. Of course, with the largest population in the world and the fifth-largest economy, whatever happens in India has global implications. But as described in this paper, the situation is quite dire in regions as diverse as NNCA, Brazil and the USA. Water scarcity is a global issue indeed.

Many problems can be tackled with invention of a new technology or an alternative approach. However, the problems related to water are multifaceted and have economic, legal and political dimensions. Hence solutions have to be also multidimensional and holistic. Water availability is obviously a very emotional issue and hence the "buy in" of general public is critical, if any of the proposed solutions are to be successful.

The solution lies in *conservation, storage, redistribution, and recycling* of available resources. Technology, and more than likely resources, are available to carry out all of these approaches at a national scale. However, governments at all levels, private industry, and the average citizen need to work together for mitigation of the crisis. Unfortunately, in most countries, policy makers are generally not inclined to work for long-term solutions. Tress (2010), based on a global survey, has listed 19 ways to solve the freshwater crisis. These solutions include educating the population to reduce consumption, recycling wastewater, improving water catchment, improving infrastructure, pricing water appropriately and developing public policy and legal framework to achieve these objectives. Each item on the list has a political, economic, legal and social component. And all of these require participation starting from a single household to the highest levels of national governments. Until all the stakeholders in this crisis work together, world will continue to face a risk of major disruptions emanating from the water scarcity.

CONCLUSIONS

1) Water scarcity is a worldwide concern demanding immediate attention from the people and leaders of all the nations in the world.

2) The crisis has been exacerbated by the growth in worldwide population, rising living standards, migration to large cities, and the change in weather patterns as a result of the climate change.

3) Water scarcity affects rich nations, such as the USA and the poor nations, such as those in the North and North Central Africa, as well as those in the middle, like Brazil and India.

4) India is a "poster child" of this crisis because many of the policies adopted to dramatically increase the food

production for its growing population have contributed to the crisis itself.

5) As agriculture is the largest consumer of fresh water in all economies, reducing the use of water in agriculture would produce the most relief. This could include crop rotation, crop redistribution, use of seed varieties using less water, and avoiding "over watering".

6) In large megacities, ground-water recharge areas must be protected and water treatment, storage, and conservation must be accelerated. These measures would help conserve the domestic and industrial use of fresh water.

7) Measures to alleviate water scarcity mostly require "common sense" solutions. However, they need consensus from individual citizens as well as from decision makers at all levels of the government. As vested interests would always resist change, public pressure and sound policy decisions are needed to avert a worldwide disaster.

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