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Looming Crisis for Humanity not Oil but Water: The Indian Example

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Search and Discovery Article #80736 (2021)**
Posted October 25, 2022

*Adapted from oral presentation accepted for the 2020 AAPG Annual Convention and Exhibition online meeting, September 29 – October 1, 2020

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Abstract

Almost four billion people face severe water scarcity worldwide. India provides a type example for the causes of this crisis and possible solutions. "Sensible" 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.

In 1951 the Indian population stood at 361million; by 2025 it is expected to exceed China's at 1.461 billion. During this period, the per capita water availability will have 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 1960s, 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 (170 trillion gallons). 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.

Although India issued a "National Water Policy" in 2012 and created a Water-Power Ministry in 2019, it is not clear that water crisis is being treated as a national emergency. Steps to manage the surface waters by interlinking river systems, harvesting rain water, improved irrigation methods, changing crop patterns to reduce the use of groundwater and improved wastewater treatment all may be parts of the solution. However, the key factors would be 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 hydrologic cycle also states that the total available water supply is finite, and the freshwater which we consume for domestic, agricultural, and industrial 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 (Perlman and Evans, 2019). In the pre-industrial era (Encyclopedia Britannica, 2019 ; mid 18th Century) 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 approaching 8 billion, elevated living standards requiring increased water use for 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)

This paper 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 2019) 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.

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 is 122nd in the world). Whereas in 1951 the water availability per capita stood at almost 5,000 cu meters, by 2001 it was already below 2,000 cu meters. Water availability at 1,800 cu meters per capita is considered "Water Stress" and below 1,000 cu meters is considered "Water Scarcity". By 2025, almost the entire Indian population will approach the water scarcity level (Josue, 2008) (Figure 2). 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). 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 (ASTM, 2015) (Figure 3).

Although still a poor country on a per-capita basis, Indian GDP has increased almost one hundred fold since the 1950s (World Bank, 2018). 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 which 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. 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 free water and 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 3).

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). 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 carryout shift in crop patterns (Polycarpou, 2010 and Devineni et al., 2015). 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. (2015), 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 that particular crop (Figure 4). 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 4 (Devineni et al., 2013) illustrates how certain degree of regional shifting from current patterns of crops could optimize water usage while maintaining food security.

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. 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 10 billion cubic feet surplus of 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 of India. With the second-largest population and fifth-largest economy in the world, whatever happens in India has worldwide implications. 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, a holistic approach needs to have the government at all levels, private industry, and the average citizen work together. Unfortunately, it is not clear whether the political leadership in India is taking the water crisis (as well as other environmental issues) as urgently as needs to be done to avert dire consequences. However, if India paves the way in solving the water crisis, other countries could follow its model and the effort would be certainly a benefit to the entire world.

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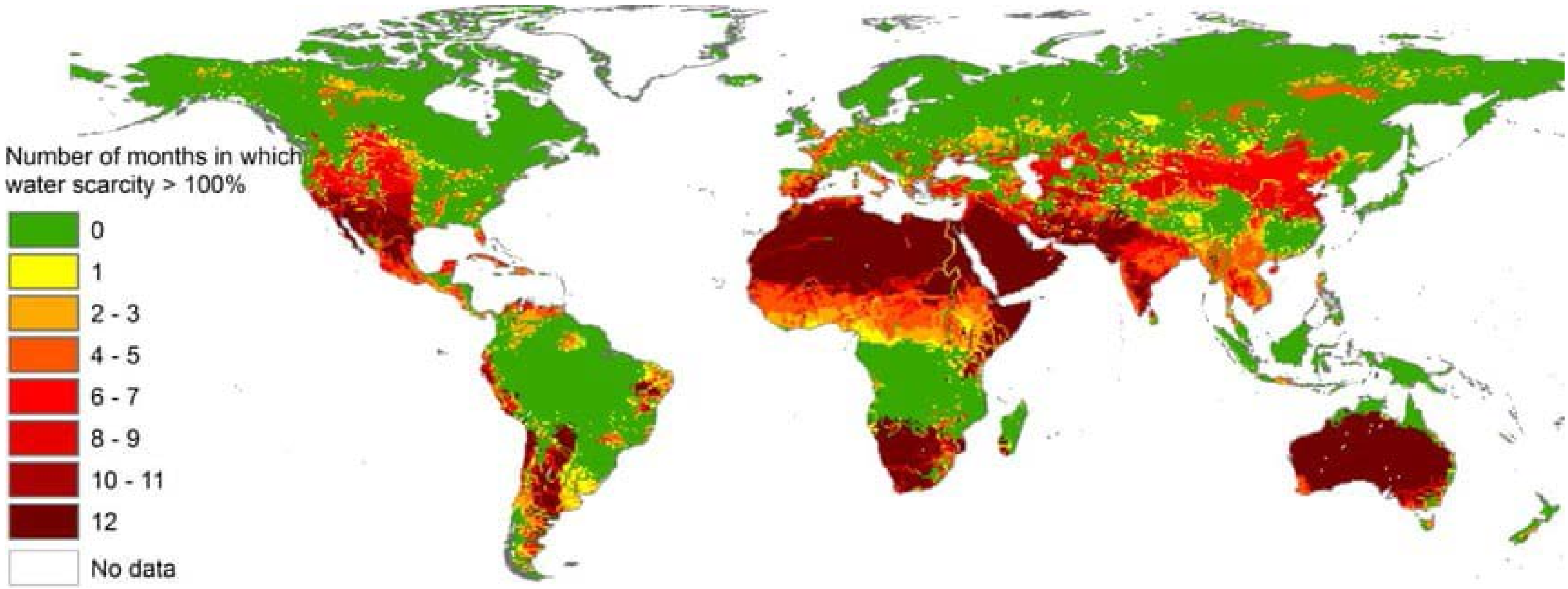

Figure 1. World Map showing the regions facing water scarcity. The orange and red areas show countries where water scarcity lasts at least two months or more. Darkest red areas have year-round scarcity >100% (Carrington, 2016).

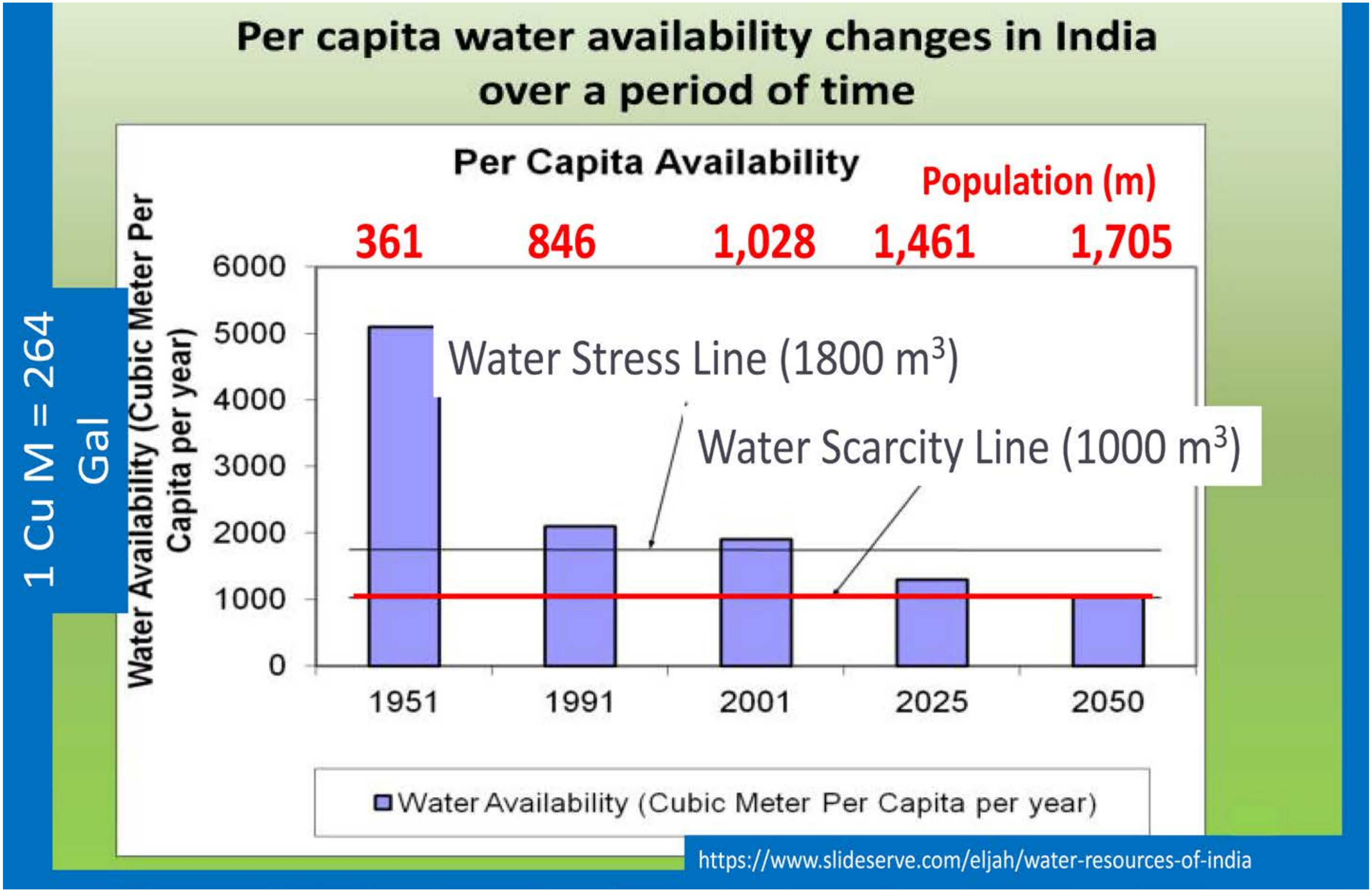

Figure 2. As the population of India has almost quadrupled in last 75 years, the water availability per capita has been cut by more than two-thirds. This has caused High to Extremely High water stress in more than half of the country (Josue, 2008, ASTM, 2015).

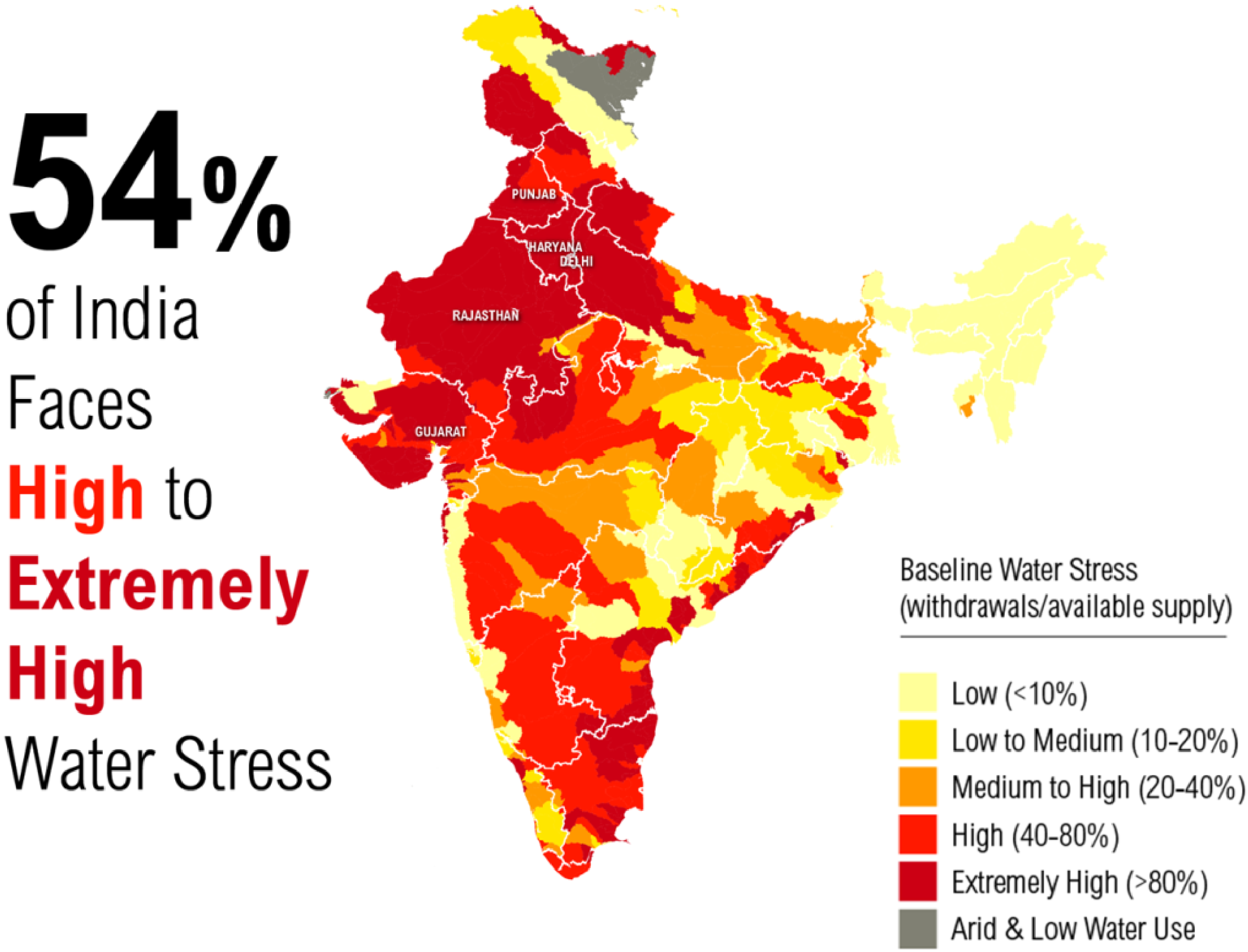

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Figure 3. Map showing the areas in India facing "High" to "Extremely High" Water stress. In the darkest red areas (Extremely High) the withdrawal to available supply is >80% (ASTM, 2015).

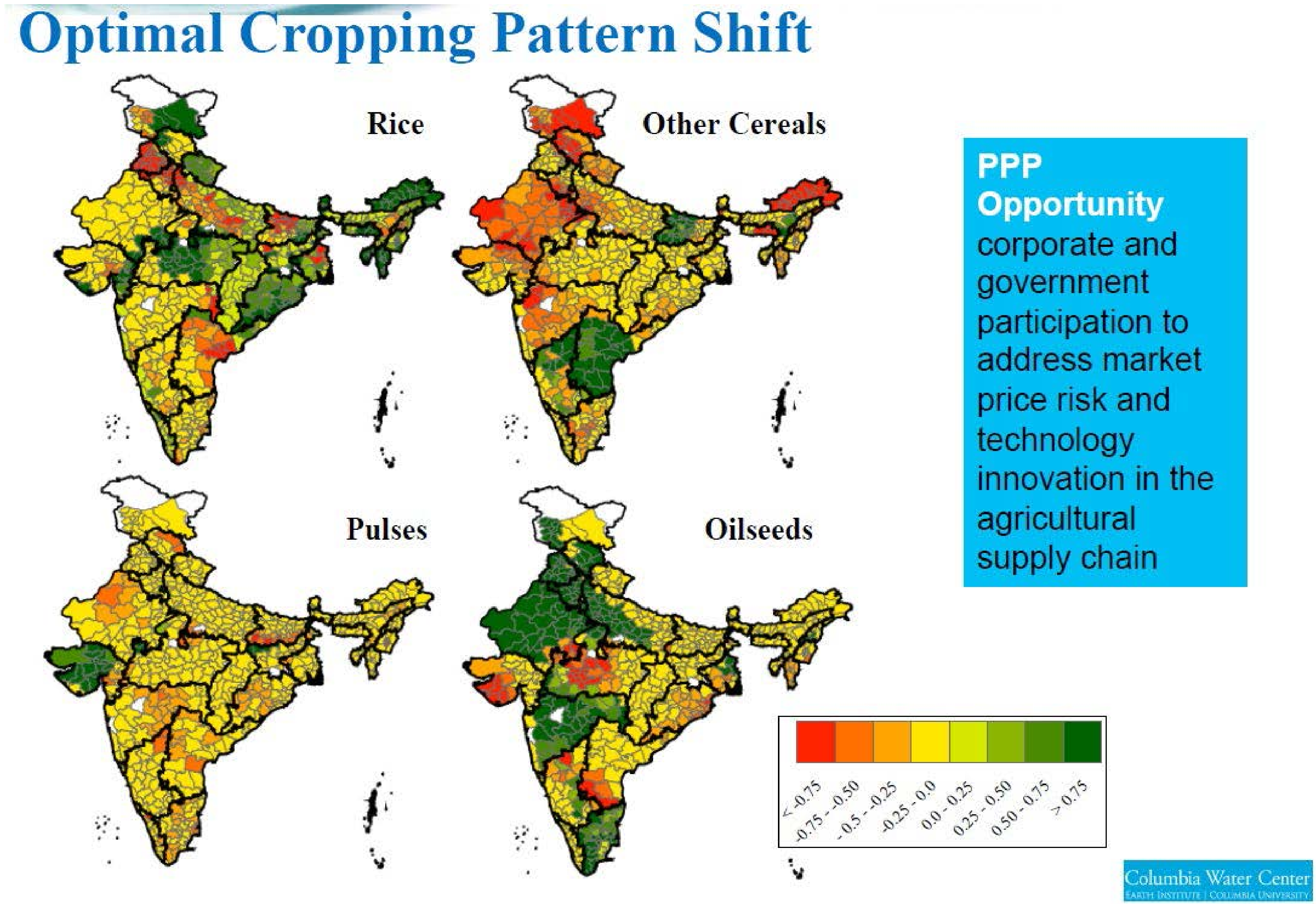

Figure 4. Maps showing district-level cropping patterns that would optimize water usage and would not jeopardize food security. However, this would require change in incentives to farmers to convince them to shift the crops planted without risking their economic gains (Devineni et al., 2013)