Journal of Interdisciplinary History, LI:4 (Spring, 2021), 565–594.

Tirthankar Roy

Water, Climate, and Economy in India from 1880 to the Present

This article explores the interaction between water, environmental change, and economic change in India since the end of the nineteenth century. A struggle to mitigate poverty and inequality in access to water, a condition that the tropical-monsoon climate made almost universal, delivered economic growth and demographic transition in colonial India (1858–1947) and postcolonial India. At the same time, ensuring the fair distribution of a vital resource like water led to its overexploitation. The "tragedy of the commons" notion that Hardin advanced is not an accurate representation of this syndrome (see below).[1]

In the tropics, extreme heat dries up surface water quickly, making mobilization of water for cultivation, industrial use, and consumption costly. The heat and the oceans also produce a powerful hydrologic cycle, which makes agriculture possible but raises the risk of famines and floods. Economic shocks in South Asia were—and still are, to no small extent—environmental in origin. The climate caused drought if the monsoon was too weak and caused storm surges and floods if the monsoon was too strong. In the late nineteenth century, a succession of bad monsoons raised prices, reduced consumption, raised debts, and brought down banks. In the worst cases, famines and epidemics erupted among people weakened by malnutrition. In 1876, 1896, and 1899, famines ravaged peninsular India, killing millions. Droughts returned roughly once in seven years, always

Tirthankar Roy is Professor of Economic History at the London School of Economics and Political Science. He is the author of *The Crafts and Capitalism: Handloom Weaving Industry in Colonial India* (New York, 2020); with Leigh Gardner, *The Economic History of Colonialism* (Bristol, 2020); "The Rise of the West and Other Stories," *Journal of World History*, XXX (2019), 280–290.

The author thanks Bharat Punjabi, Jamie Daubenspeck, P.S. Vijayshankar, Sumit Guha, and two referees for their comments and suggestions on earlier drafts of the article, and Gareth Austin, Kaoru Sugihara, and Kenneth Pomeranz for helpful discussions.

 https://doi.org/10.1162/jinh_a_01628

1 Garrett Hardin, "The Tragedy of the Commons," *Science,* CLXII (1968), 1223–1248.

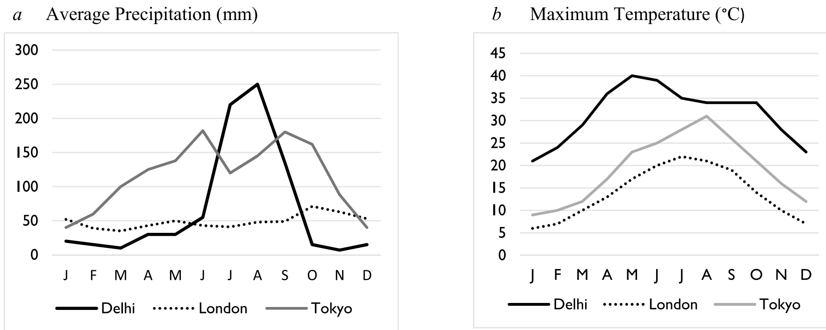
reducing consumption and sometimes causing severe stress to public finance, the balance of payments, and vulnerable communities.

The great famines of the nineteenth century began a deep-seated process of change. Famines disappeared in the region after 1900, even though severe weather shocks persisted, droughts became less destructive, and food production increased dramatically. After the great influenza epidemic of 1918, the population growth rate, which remained at a near-zero average for forty years, started rising steadily. What kind of intervention had eased the environmental constraints on economic progress? The common feature was increased water security, that is, greater per capita access to water and the availability of more potable water for communities that had earlier suffered deprivation. Although public works were an essential factor behind the change, the state was a limited agent. Popular politics, market forces, law, and the knowledge gained in famine operations played significant roles. Greater security enabled reclamation of marginal lands, intensive agriculture, urbanization, and disease control.

Gaining security at a time when renewable water was extremely scarce, and river morphology extremely unstable, could not have come without negative consequences. Colonial India heavily depended on the state-led technological solution of impounding excess flow in rivers via dams and reservoirs. In the twentieth century, the model came under so much criticism for its environmental and political costs that it was effectively abandoned. As it became unpopular, users switched to groundwater, which changed the nature of the problem from insecurity to depletion.

"India is in the grip of acute water scarcity," wrote a BBC news report in 2019. Academic work on the crisis and possible solutions to it tend to focus on the present. Most scientists and economists today would see ecological stress as an example of unrestricted greed leading to the degradation of the commons. Understanding the economic history of this crisis permits a more informed perspective on the problem. Given that a set of human actions has mitigated the climatic constraint on demographic and economic change since 1880, the questions are what exactly were these actions, why did they appear in the late nineteenth century, and what were their costs? The famine-relief policy instituted at that time defined the "water famine" as a seasonal condition, introducing the concept of the public trust in water. The story of India's problem with water security and access involves myriad

Fig. 1 Climate Data for Delhi, London, and Tokyo (Recent Years)



political movements addressing socially sanctioned forms of deprivation, various forms of public intervention, and ongoing water stress.

THE TROPICAL-MONSOON CLIMATE AND THE WATER PROBLEM A useful reference point is the köppen-geiger map of the world, which, using two dimensions—temperature and seasonality of precipitation—describes much of South Asia (along with coastal West Africa and a part of Southeast Asia) as areas of "tropical monsoon." Tropical monsoon is a combination of above-average temperature and seasonal concentration of rainfall. Figure 1a/b illustrates the South Asian situation, comparing three climatic profiles, "temperate," "temperate monsoon," and "tropical monsoon." The two temperate-zone places are London and Tokyo. Delhi is the tropical-monsoon city. In an average year, the maximum temperature in Delhi is about twice as high as that in London for every month of the year, exceeding 36 degrees celsius from mid-April to the end of June. In an average year, rainfall in Delhi, which depends on the monsoon winds, is confined to three months; the rest of the year is drier relative to the temperate zone. The monthly average rainfall in London varies from approximately 40 to 70 mm. The monthly average rainfall in Delhi varies from 10 to 250 mm. In Delhi, 75 percent of the rains occur during the third quarter of the year; in London, quarterly rainfall ranges between 21 and 31 percent. The seasonal concentration of moisture is a monsoon characteristic, but not all monsoons are alike. Delhi and Tokyo both have monsoons; Delhi experiences aridity, whereas Tokyo does not.[2]

2 For the köppen-geiger map, see http://koeppen-geiger.vu-wien.ac.at/present.htm (accessed May 21, 2020); for the WATCH (Water and Global Change) data sets, http://www

What is aridity? The heat in the tropical region dries up surface water. The average evaporation rate is a function of (among other variables) available surface water and the heat of the sun. During summer in the Himalayas or the Arctic, the rate reaches extremely high levels. In the deserts, the rate is extremely low throughout the year. Any region with a high rate in one season and a low one in another would have plenty of surface water in some months and lose it in certain other months. In most parts of India, the rate reaches 60 to 100 mm per month from June to September when the monsoon rain occurs in combination with high heat. As surface water dries up, the rate falls extremely quickly. The rate of evaporation (0 to 20 mm) that prevails from April to June in nearly all of India except the Bengal delta and the southernmost regions of the peninsular, like Kerala, tends toward the range that characterizes the great deserts of the northern hemisphere.[3]

Seasonality, Agriculture, and Poverty The tropical monsoon has always constrained economic growth. Because of the quick evaporation of surface water, agriculture and survival required procuring water over long distances, mining it from below ground, or relying on the seasonally variable common sources. The first two options were ordinarily expensive, and all three were uncertain; excessive heat reduced the infiltration and seepage that sustained non-surface sources. Furthermore, seasonality shortened the working year. The one short season of economic activity in the tropical-monsoon region typically did not occur in the rainier months but early in the winter, when the rain-fed crops came into the market—the busy season when wages and interest rates were at their peak. In the slack season, with surplus labor and idle capital, wages and interest rates plummeted. All agricultural societies experience seasonality. The tropical-monsoon regions experienced extreme degrees of it.[4]

.waterandclimatechange.eu/evaporation/average-monthly-1985-1999 (accessed October 19, 2019). Even though elements of the tropical-monsoon conditions exist in other geographies, not all tropical regions and all monsoon regions are similar. South Asia and northeast Asia are not comparable; nor are the countries of South Asia with those in the African Sahel. The Sahel has a monsoon like India's, but it is weaker. The Sahel's mean annual rainfall is 100 to 300 mm; India's is 300 to 650 mm. Both areas face a high seasonal cost of accessing water, but South Asia has greater ground- and surface-water resources.

3 Evaporation is caused not only by the heat of the sun but also by the transpiration from plants. However, the evaporation data cited herein do not account for transpiration.

4 For an economic-historical treatment of seasonality, see Roy, "Monsoon and the Market for Money in Late Colonial India," *Enterprise and Society*, XVII (2016), 324–357.

In the past, seasonality caused poverty by making intensive agriculture expensive and enforcing unemployment for months. In the absence of artificial irrigation, the monsoon rains made sowing relatively easy in most parts of India. The usual practice in the nineteenth century was to have two plantings in the monsoon, of which one was a major grain. In some regions, a weak winter monsoon enabled a second and minor crop. The ability to grow any of the major grains in winter, or some of the profitable year-round crops like sugar cane, depended on irrigation that required either impounding rain and river flows or digging for water underground. Private capital was generally insufficient to achieve both forms of recycling, especially in southern India where the crust was made of hard rock.

Recent national-income estimates for periods before 1850 confirm that India was a considerably poorer place than Western Europe before the Industrial Revolution began. These studies do not explain why India was impoverished for centuries. A plausible explanation is the low agricultural yield and under-employment of resources attributable to the environment. Moreover, the risk to life was considerable in this climate. In the nineteenth century, whenever two successive monsoons failed or the southwest monsoon and the northeast monsoon failed in the same year, famines were the inevitable outcome.[5]

What mitigating actions could those living in the countryside take to reduce poverty and the likelihood of famine? Migration with transhumance was one option, but that strategy carried costs. For most of the agricultural population, whose only asset was a plot of land fixed in space, other mitigation strategies were necessary. The most secure form was to create access to controllable and reliable sources of water that would be available throughout the year and enable intensive and profitable cultivation—a deep well on a large aquifer, for example, as opposed to seasonally variable sources like streams and ponds. In 1850s India, such fixed pools were usually privately or communally owned. The best supply sources were privately owned masonry wells. As the *Imperial Gazetteer* of 1909 noted, "The main opening for individual enterprise lies in the construction of wells." In southern India, artificial lakes and tanks provided a measure of security, but tanks were expensive to build and maintain,

5 Stephen Broadberry, Johann Custodis, and Bishnupriya Gupta, "India and the Great Divergence: An Anglo-Indian Comparison of GDP per capita, 1600–1871," *Explorations in Economic History*, LV (2015), 58–75.

Table 1 Annual Water Use, 1885–2015—Total and per Head

	AGRICULTURAL USE, BILLION CUBIC METER (BCM)	CONSUMPTION AND INDUSTRIAL USE, BCM	TOTAL WATER USE, BCM	POPULATION (MILLION, UNDIVIDED INDIA UNTIL 1938)	PER CAPITA WATER USE (CUBIC METER)
1885	43	6	50	260	192
1938	125	9	134	380	352
1968	309	15	324	535	606
1988	460	40	500	830	602
2015	876	124	1,000	1,310	763

NOTES The sources make a distinction between irrigation or agricultural use, and "domestic and industrial" or "consumption and industrial" use, which is, in theory, water for drinking in both rural and urban areas and water for industrial use. The first year for which reliable estimates for these two classes of use are available was 1968. Two assumptions allow us to stretch the estimate backward—that agricultural use rose at the same rate as the quantity of irrigated land and that the 1968 average "consumption and industrial" use had remained unchanged since 1885. Realistically, because the irrigation canals also delivered more drinking water, the earlier figures for consumption underestimate the increase.

SOURCES G. N. Kathpalia and N. S. Varadan, "Need for a National Water Policy," *Symposium on Integrated Development of Surface and Sub-surface Water Resources* (New Delhi, 1971), I, 49–66; Asian development Research Institute, "India's Water Facts," available at https://www.adriindia.org/adri/india_water_facts (accessed April 25, 2020); http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed April 25, 2020).

tended not to support equal access, and sustained reduced capacity after successive dry seasons.[6]

The New Access to Water The significant improvement in access to water in India from 1885 onward has led to a massive change in population and food production. During the last 130 years, per capita water use has increased three times (Table 1), population six times, and total water use more than twenty times. Food-grain production increased from 15 to 20 million tons in 1885 to 50 million in 1950 and more than 250 million in 2015.

The technology of water extraction, state intervention, and laws of access all changed after India gained independence from British rule in 1947. Nonetheless, the trajectory of rising use was colonial in origin. This achievement came at a cost, however, as expected for a region with limited renewable water stock. Usable stock as a proportion of renewable source fell (Table 2). The World Bank

6 *Imperial Gazetteer of India* (London, 1909), III, 92. A tank in South India is a human-made reservoir, sometimes embanked.

Table 2 Renewable Water Resource (Cubic Meters per Head)

	INDIA	UNITED KINGDOM	UNITED STATES	JAPAN	EXPLOITABLE WATER RESOURCE AVAILABLE (%)
1968	2,778	2,577	12,618	3,744 (1973)	70
1988	1,764	2,591	10,946	3,431	54
2015	1,116	2,191	8,685	3,373	8

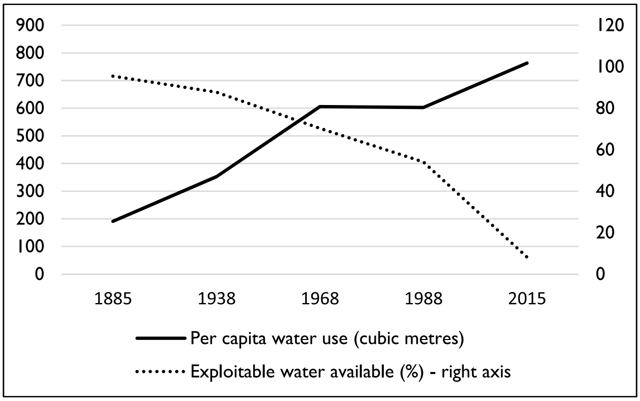
NOTES Exploitable resource = total renewable resource (surface water + groundwater – overlap) – environmental flow requirement for sustainability of the aquatic system. The figure for India is 1,089 BCM during the year (2015), held constant for all times. Usable resource is (1 – use/resource).
SOURCE http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed April 25, 2020).

measures water stress as the withdrawal of fresh water as a percentage of renewable supply. In 2016, levels of stress ranged from 42 percent in India to 105 percent in Pakistan; the levels were considerably lower in the United Kingdom (10), the United States (22), Japan (28), and China (30). The close across-country correlation between average temperature, latitude, and stress, suggests that the stress pattern is mainly climatic and geological in origin. Given that much renewable water remains still untapped, this situation may not seem tragic. But the marginal cost of using the resource is high and rising in South Asia.[7]

How do we know that it is high? First, not all the available water should be exploited; the proportion of use to exploitable resource has fallen at a progressively steeper rate in the late twentieth century. Second, the proportion of groundwater extraction seems to have increased (the data are not complete), and groundwater extraction is usually more expensive than the use of surface water. Already, the extraction of renewable sources generates higher costs (deeper bore wells) and poorer quality (brackish water and contaminated aquifers) than in the past. Third, hydro-politics has grown more contentious as these changes accrued. Hence, the history that this article traces in Figure 2 looks like a cross (Figure 2). Access increased in the long run, though stress also increased, because geography limited the "degrees of freedom" to sustain

7 For the World Bank, see https://data.worldbank.org/indicator/ER.H2O.FWST.ZS (accessed October 19, 2019); World Resources Institute, https://www.wri.org/resources/charts-graphs/water stress-country (accessed October 15, 2019).

Fig. 2 The Water Cross



continually increasing per capita entitlement. Most societies in the last century are probably amenable to such a cross, but the steep slope of the stress curve in India is unusual and worrying.

Previous Studies of India's Environmental History Is the argument of this article truly new? In specific contexts, environmental historians and economic historians of India have made a connection between the environment and the economy. Yet, to this point in time, no body of writings has asked the question that this article answers: How did human environmental intervention create conditions for economic growth and population transition? Until now, no historical scholarship, either on the economy or on the ecology in India, has taken note of what this article terms "the water cross."

Global environmental history has, by and large, overlooked the tropical-monsoon condition in relation to economic change. The *Oxford Handbook of Environmental History* does not mention the word *monsoon*. Davis and Egan's *The Arid Lands* admirably questions many Europeanist preconceptions about tropical lands but does not engage with the combination of aridity and monsoon that produces seasonality in South Asia. Amrith's *Unruly Waters* connects the control of rivers with secure livelihoods in South Asia, but, unlike this article, it does not seek to explain the modern economic history of the region. The substantial Indianist scholarship about environmental history, part of it covering water, is rich and insightful about imperialism, but it scarcely engages in an economic history that can explain changes in India's production conditions and demographic transition.[8]

Development economics in the early postwar years was interested in natural-resource endowments but rarely discussed water. In the 1980s, an offshoot of this field coined the phrase *monsoon Asia*, to show why some monsoon regions facing seasonal unemployment needed to prioritize labor-absorbing activities. Because this Japanocentric concept of *monsoon Asia* did not deal with aridity, it did not apply well to the tropical monsoon areas (see Figure 1). By underestimating aridity, the concept of *monsoon Asia* imposed an artificial uniformity over a diverse geographical area.[9]

The literature about sustainability is also of limited relevance. The formative contributions to the field—from Hardin and Ostrom—turned the attention of scholars to the common-property-resource problem. The tragedy of the commons as generally understood in ecology and economic theory occurs when the heavy exploitation of a common resource leads to an adverse outcome. The implication is that some old rules of exploitation that could provide good results—what Hardin called "social arrangements that produce responsibility"—fell by the wayside, requiring new cooperative rules to be designed. The "tragedy" perspective spawned important works on water. The resource problem discussed in this article, however, is not necessarily an overuse problem but a complex condition involving a scarcity of renewable sources, seasonal famine, and social inequality. The

8 Andrew C. Isenberg (ed.), *The Oxford Handbook of Environmental History* (New York, 2017). Several essays in Paul G. Harris and Graeme Lang (eds.), *Routledge Handbook of Environment and Society in Asia* (New York, 2014), recognize water access, water stress, seasonality, and their institutional challenges but do not offer a coherent model of economic history. Constance Lever-Tracy (ed.), *Routledge Handbook of Climate Change and Society* (New York, 2010), is less informative about monsoon seasonality and is similarly preoccupied with the present. Sam White, Christian Pfister, and Franz Mauelshagen (eds.), *The Palgrave Handbook of Climate History* (New York, 2018) has excellent chapters about South Asia but barely addresses the impact of climate on water and society. See also Diana K. Davis and Michael Egan, *The Arid Lands: History, Power, Knowledge* (Cambridge Mass., 2016); Sunil Amrith, *Unruly Waters: How Mountain Rivers and Monsoons Have Shaped South Asia's History* (New York, 2018). For surveys, see Mahesh Rangarajan, "Environment and Ecology Under British Rule," in Douglas Peers and Nandini Gooptu (eds.), *India and the British Empire* (New York, 2012), 212–230; "Introduction," in Richard Grove, Vinita Damodaran, and Satpal Sangwan (eds.), *Nature and the Orient* (New York, 2000), 1–26. David Gilmartin, "Water and Waste: Nature, Productivity and Colonialism in the Indus Basin," *Economic and Political Weekly*, 38 (2003), 5057–5065; Rohan D'Souza, "Water in British India: The Making of a 'Colonial Hydrology,'" *History Compass,* IV (2006), 621–628.

9 Harry T. Oshima, *Economic Growth in Monsoon Asia: A Comparative Study* (Tokyo, 1987).

commons came under pressure because of a successful response to poverty, risk, and inequality—hardly a tragedy.[10]

WATER AND FAMINE IN THE DECCAN In the last quarter of the nineteenth century, the Deccan—the plateau that forms the central part of the peninsular region in South Asia—underwent three famines. The epicenter of the first one (1876/7) was in the southern districts, then called Madras-Deccan and now the southwestern region of Andhra Pradesh in India. The other two, 1896/7 and 1898/9, occurred on the northwestern side of the plateau, the area then known as Bombay-Deccan. Though hardly the only famines to have occurred in this region, these famines are distinguished by the large volume of documentation that they elicited in the attempt to generate a theory of dry land famines. The theory that eventually emerged was that famines were a feature of the tropical-monsoon climate and that preventive actions could include canal irrigation to increase food production and rail transport to enable cheaper and faster distribution of food when the monsoon failed. What followed this action plan is something of a puzzle.

The years of the Deccan famines saw unusual climatic conditions caused by the El Niño Southern Oscillation phenomenon. Even though famines disappeared from the Deccan after 1900, weather shocks of similar severity repeated after 1900 in at least four years. "Yet the potential dangers were largely dealt with." What had happened to make this transformation possible? Economic historians suggest that some aspects of the famine mitigation policy—especially the development of the railways as food carriers—helped to contain the demographic effects of the droughts. But this account is incomplete because it ignores water. As shown below, the documentation made a distinction between a famine of food and one of water. Railways could potentially solve the famine of food. In the case of water, irrigation became something of a preventive measure, but only in the less-deprived deltas and the Indo-Gangetic Basin, not so much in the Deccan, though famines did disappear there after 1900.[11]

10 The cited text is from Hardin, "Tragedy of the Commons,"1243–1248.

11 Tim Dyson, *Population History of India* (New York, 2018), 158; Michelle B. McAlpin, *Subject to Famine: Food Crisis and Economic Change in Western India, 1860–1920* (Princeton, 1983); Robin Burgess and Dave Donaldson, "Can Openness Mitigate the Effects of Weather Shocks? Evidence from India's Famine Era," *American Economic Review*, C (2010), 449–453; Martin Ravallion, "Trade and Stabilisation: Another Look at British India's Controversial Foodgrain Exports," *Explorations in Economic History*, XXIV (1987), 354–370.

In fact, famine documents revealed a growing awareness that, given the geography, the solution to the Deccan's problem demanded a different model from the official riparian policy. It required reliance on subsoil water, access to which was restricted by law, and by caste status. Water security in this region required a well, ordinarily an expensive asset. The famine relief led to the construction, and occasionally the sequestration, of wells. How extensive these actions were and the legacies that they produced will need more research. Famine historiography has overlooked, or at least underestimated, this aspect of the relief process. The water-specific actions likely contributed to the disappearance of famines; at the very least, they introduced the concept of the public trust in underground resources, a radical idea for the time.[12]

What made water such an issue in the Deccan? A full answer to the question combines climate with geology. The larger part of the plateau in its northwestern side, the so-called Traps, was formed of late Mesozoic volcanic eruptions 60 to 65 million years ago. The southern and eastern side of the Deccan uplands formed parts of the Gondwana continent that drifted away from Africa and collided with the Eurasian plate about 40 to 55 million years ago, creating the Himalayan mountains. Because of their different geological origins, the soil and rock types vary between these zones. Both regions, however, have hard-rock formations. The pattern of precipitation also imparts a uniformity to both regions. The rain-bearing clouds of the southwest monsoon lose a lot of their moisture when crossing the Western Ghat mountains. The hotter air of the plateau creates a convectional process that causes storms and cools the air, but seasonal rainfall is less than one-third that on the windward side of the mountains.

Although the Deccan received smaller quantities of annual monsoon rainfall than did eastern or coastal India, it was not the driest part of India. Furthermore, since the mountain range has few gaps along its north–south expanse for nearly 1,000 miles, much of the rainwater flows down the eastern slope into the plateau and forms the so-called Ghat-fed rivers. Godavari and Krishna, and the two tributaries of the Krishna, Bhima, and Tungabhadra Rivers, carry most of this flow. Between them, the Godavari and Krishna drainage area covers more than two-thirds of the plateau.

12 The Famine Commission of 1898 described the scale of construction of wells, which was large, but the enterprise suffered from a high incidence of failed construction. India, *Report of the Indian Famine Commission 1898* (Simla, 1898), 185–186.

Nonetheless, "the Deccan rivers cannot be depended upon as a perennial source of supply." Whereas in northern India, the rivers receive snow melt, the Deccan rivers do not. Therefore, the flow level varies enormously between seasons. On an October day in 1903, more than 1 million cubic feet flowed per second near Vijayawada town, which is about 70 miles inland from the mouth of the Krishna River. In the summer months at the turn of the nineteenth century, the level reduced to 100 cusecs. During the dry season of 1899, the mighty Krishna and Godavari were "reduced to a series of shallow pools." For eight months in a year, the rivers did not carry much water to sustain either intensive agriculture or a large population.[13]

Tanks and Wells Other than in the deltas, cultivation and survival were dependent on tanks and wells instead of the rivers. Wells were not easy to build. The aquifers in the Deccan trap occur in fissures between layers of hard rock. Some of these fissures formed from successive volcanic eruptions. In the alluvial Gangetic Basin, subsoil water can be found nearly everywhere. In the Deccan trap, the presence of subsoil water depends on the position of a fissure. Having to dig through basaltic rock made well construction expensive and risky: "[T]here [was] by no means a certainty of meeting water. The Deccan . . . is full of wells which have been dug and been failures . . . . [T]he percentage of failures among wells [cannot] be less than forty per cent." Besides, successive dry seasons could reduce water in tanks and wells to dangerously low levels. Hence, subsoil water was crucial to meet seasonal shortages in the region.[14]

The value of the wells had become common knowledge in famine operations since the 1876–1878 episode. Yet, the civil administration in most provinces did not collect or record data about the quantity and depth of subsoil water. The only data set available came from the logbooks of the Great Indian Peninsular Railway that registered levels in the wells from which the locomotives drew water. At the onset of the 1898 famine, the local officers who studied these data concluded that a period of relative dryness had caused almost "total disappearance of a huge volume of subterranean water all over the Deccan, on which it was formerly possible to draw in a year of drought." Soon, more specific reports were available from other

13 *The Economic Life of Hyderabad* (Hyderabad, 1937), 117; *Report on the Famine of the Bombay Presidency* (Bombay, 1903), 8.

14 Harold H. Mann, *Well Waters from the Trap Area of Western India* (Poona, 1915), 3.

regions, with the same message: "[T]he level of the sub-soil water has never been so low within living memory . . . [in all] districts of the Deccan and Karnatak." In Sholapur district, tanks still had some water in them, but the little that remained was preserved for drinking, not for cultivation. "In many places, do what one may, no water is to be got." The same story repeated in many small towns in the Bombay-Deccan and the army bases. "The rain we have just had has been all absorbed by the parched surface soil and has not replenished the spring."[15]

Local officials understood that subsoil water was the crucial warning sign, though the administration did not back up their hunch with a monitoring system. Between 1876 and 1899, the administrative correspondence created the phrase "water famine," which filtered into the growing media discourse about famines in western India. Importing food from outside the region could technically end a famine of food, but a water famine had no solution. "The shortage of drinking water is one of the most grievous effects of a drought, that is naturally more dreaded than a failure of food crops and is also more difficult to be combated than the scarcity of grain."[16]

State relief was often too little and too late, though it introduced two new tactics regarding groundwater—the requisition of private wells and steps to improve the quality of well water. Private rights were an obstacle to famine response not only because the law protected them but also because they were biased by caste. The governor of Bombay observed that the "humble castes" had suffered the most from the calamity in 1876–1878. During the 1899 famine, again, local officials found that "as to the 'caste' of those died, by far the great majority are 'Hindus of low caste.'" Famine mortality derived largely from unequal rights of access to the best wells. Members of the depressed castes relied

15 *Papers Regarding the Famine and the Relief Operations in India during 1900–1902* (London, 1902), 263, 176.

16 Water security entered the discourse of famine response in western India before 1876, but only randomly. Water eventually occupied a central place in the framework of relief that emerged in the last quarter of the century. For a discussion of the water initiatives in early nineteenth-century famines, see George Adamson, "'The Most Horrible of Evils': Social Responses to Drought and Famine in the Bombay Presidency, 1782–1857," in Greg Bankoff and Joseph Christensen (eds.), *Natural Hazards and Peoples in the Indian Ocean World* (Basingstoke, 2016), 79-104. The 1899 famine "was a famine of water as well as of food," according to the *Report of the Indian Famine Commission, 1901* (Calcutta, 1901), 61. Anon., "The Famine in India: Nasik District," *Times of India,* 20 Feb. 1900; *Report of Famine Operations in the Baroda State 1911–12* (Bombay, 1913), 22.

on the commons, exposing themselves and their animals to disease, whereas the secure sources were guarded closely by the village elite. By the 1899 famine, this pattern was so well-known that the Bombay Famine Code had instructed the medical officers on duty "to watch the state of the water-supply, especially that allotted to the low-caste people."[17]

In an uncoordinated way, the relief effort involved creating an increase in the only form of asset that could potentially mitigate a drought. The relief-camp operation usually started with a search for a secure water source or the digging of a well. In regions with less of a water problem, the camps gave work and food only to workers who brought their water for the day. That option did not exist in the Deccan. On a few occasions, the camps also requisitioned private wells, overriding legally secure private rights. Although the British Indian state was ordinarily reluctant to revoke caste privileges, during the 1899 famine, the relief authorities often did so. They dug a great many wells with relief money to ensure that whenever possible, "low caste people were . . . given separate wells." In 1896/7, famine relief included a policy "to deepen wells when necessary and advisable; and . . . to sink new wells in districts where they may be necessary, to prevent migration of cattle and people."[18]

Water, Disease, and Sanitation Work on wells acquired another important motivation when the safety of water, rather than the mere quantity of it, became a concern between 1876 and 1900. In 1876, food and the railways were considered to be sufficient for an effective famine policy. By 1900, the accent in the official reports had shifted to disease after cholera was found to have taken more lives than

17 The governor of Bombay, cited in Sivaram H. Chiplonkar (ed.), *Quarterly Journal of the Poona Sarvajanik Society* (Poona, 1878), 7. *Papers Regarding the Famine and the Relief Operations in India,* 238. Referring to a 1951 epidemiological study of cholera in Madras Presidency, David Arnold wrote, "Even in non-famine times, social discrimination against low-caste and Untouchable labourers often obliged them to drink from readily contaminated water sources" ("Cholera and Colonialism in British India," *Past & Present*, 113 [1986], 1 126). *Famine Relief Code: Bombay Presidency* (Poona, 1927), 59.

18 *Appendix to the Report of the Indian Famine Commission, 1898, being Minutes of Evidence, etc.* (London, 1898), I (Bengal), 112; *Report on the Famine in the Bombay Presidency*: "Orders were also issued granting certain concessions to owners of private wells who allowed the public to draw water for domestic consumption, and wherever people of low caste were to be supplied from these wells, Government undertook the expenditure of providing special water carriers" (42); *Report of the Indian Famine Commission, 1901*, 62; *Report of the Famine in the Bombay Presidency in 1896–1897* (Bombay, 1898), xcix; *Papers Regarding the Famine and the Relief Operations in India*, 262.

Table 3 Occurrence of Words Every 100 Pages in Three Famine Commission Reports

	1880	1898	1901
Irrigation	126	69	18
Railway	23	19	3
Cholera	2	8	18

starvation, making not only secure but also safe water a private good (Table 3). Sanitary engineers appeared in the major provinces around 1860, though not much money or power attached to the position. During the 1876 famine, the Sanitary Department's work "[fell] far short" of needs. The provincial governments had too few funds to shore up their work. Moreover, "the risk of interfering with prejudice . . . frequently [stood] in the way of improvement." Nonetheless, the famine of 1876 defined the role of this office more sharply than ever before. In 1896 and again in 1899, the Bombay Sanitary Department officers were disinfecting wells on an unprecedented scale.

The reports stated that the mortality in the dry land famine was attributable to caste prejudice because access to secure water favored the higher castes. Within a few years after the last of the great dry land famines, a movement formed to challenge these traditional biases.[19]

RELIGION, CASTE, AND EQUAL RIGHTS TO WATER Contemporary commentators on the movement for secure, clean water treated these biases as the legacy of an ancient set of entitlements. Anthropological history sometimes involves the claim that some features of the caste system were reframed during colonial times. Be that as it may, the question still arises, What, if anything, did colonial India inherit from the distant past?[20]

In 1936, Ambedkar, the leading spokesperson for the depressed castes, maintained that the "annihilation of caste" would be difficult to achieve without radical methods, because caste and sacredness were interdependent concepts. The link between them implied a norm that sharing water with others caused pollution and loss of

19 Arnold, "Cholera and Colonialism," discusses the "synchronization" of famine and cholera in the late nineteenth century; *Report of the Indian Famine Commission. Part I. Famine Relief* (London, 1880), 108.

20 Nicholas B. Dirks, *Castes of Mind: Colonialism and the Making of Modern India* (Princeton, 2001).

caste. Interpretations of scripture and activist writings about caste as a lived experience suggest that this moral rule was an inheritance rather than a colonial invention. Summing up a millennium of injunctions about caste, Kane said, "In most of the works on the castes in India a few features are pointed out as the characteristics of the caste system." One of them concerns who could (or could not) take water from whom. The underlying idea was that water was not a shareable good, and rights depended on caste. Classical Hindu writings on statecraft and social conduct are explicit that such rights entail segregation according to ritual status.[21]

Dumont's later proposal that India was a civilization based on "a single true principle, namely the opposition of the pure and the impure," confirmed what the classical scholars had said about the origin of the rights. The nature of that right was not proprietary in the modern sense but moral, with a two-sided claim. The Brahmin had a right to use a village well, and the untouchable had a religious duty *not* to use the same well. The two-sided right would appear to many people, including many untouchables and government officers, to be in keeping with religious faith, which made the famine authorities take extra caution when overriding it. Ambedkar's declaration that "[t]he Untouchable does not want water. What he wants is *the right* to draw water from a common well" implicates a moral imperative.[22]

By and large, the historiography of access to natural resources in India tends to be preoccupied with legal property rights rather than cultural norms. A popular reading of Indian famines claims that "in most of India water had always been a communally managed common resource." According to such readings, sharing and cooperation were the ancient norms, and inequality and exclusion were the colonial inventions—a questionable claim. Colonial

21 Bhimrao R. Ambedkar, *Annihilation of Caste* (Bombay, 1936); Pandurang V. Kane, *History of the Dharmashastra* (Pune, 1930–1962), II, Part 1, 23; Kautilya's *Arthashastra* (trans. R. Shamahastri), https://csboa.com/eBooks/Arthashastra_of_Chanakya_-_English.pdf): "A reservoir of water belonging to Chándálas is serviceable only to Chándálas, but not to others" (35). See also Deepa Joshi and Ben Fawcett, "Water, Hindu Mythology and an Unequal Social Order in India," paper presented at the second conference of the International Water History Association, Bergen, 2011.
22 Louis Dumont, *Homo Hierarchicus: The Caste System and Its Implications* (Chicago, 1970), 43; Leif Wener, "The Nature of Rights," *Philosophy and Public Affairs*, XXXIII (2005), 223–252, repr. in Brian H. Bix and Horacio Spector (eds.), *Rights: Concepts and Contexts* (Aldershot, 2012), 213–242; Ambedkar, "Gandhi and His Fast" (1932), *Writings and Speeches* (New Delhi, 1989), V, 329–395 (emphasis added).

reforms recognized property rights but left the right to the commons undefined. Precisely because the state did not frame these rights in detail, the right to the commons remained embedded in cultural practice. Did culture advocate inclusion, as the citation says, or exclusion, as the classical scholars would say? Shah rejects the notion of inclusion: "Indian peasant society was highly unequal even before the British came in. One source of this stratification is the caste system, which also blocked the entry of large sections of Indian rural society into landownership." What is true of land should be true of water as well; both of them were scarce resources.[23]

Whether ancient or not, the moral command was under attack during the protest movements that emerged in the interwar period. Two court judgments bookend the most significant phase of that movement. In 1914, the *Times of India* reported a court case in which Hiraman Dhondi Mochi, a leather worker and an untouchable, concealed his caste identity to draw water from a sacred lake affiliated with a temple near Bombay, whereupon the temple sued him for defiling the water. Insult to religion being an offense under penal law, the magistrate ordered a prison sentence. On appeal, the case was settled in Mochi's favor. The appellate court made a distinction between drawing water and intentional disrespect to religion, observing that if the two acts conflated, all rivers would be inaccessible to most Indians.[24]

Whether an effect of the judgment or the expansion of local governance, the next ten years witnessed groups in many villages of western India trying to take control of pools that the upper castes held sacred. These cases ordinarily ended not with violence or with a protracted legal battle but with some form of arbitration. In a 1924 incident at the central-Maharashtra town of Lonar, a "band of 500 untouchables" failed to ""pollute" the sacred stream" because the "Deputy Commissioner . . . threatened the depressed classes with instantaneous arrests in case they repeated their attempts." A 1931

23 Mike Davis, *Late Victorian Holocausts: El Niño Famines and the Making of the Third World* (New York, 2001), 331; Mihir Shah, "The Rule of Water: Statecraft, Ecology and Collective Action in South India by David Mosse," *Conservation and Society*, II (2004), 201–204; *idem*., "Structures of Power in Indian Society: A Response," *Economic and Political Weekly*, 43 (2008), 78–83. For a critique of the myth of an "eco-golden-age" of water access in rural India, see Shri Krishan, "Water Harvesting Traditions and the Social Milieu in India: A Second Look," *Economic and Political Weekly*, 46 (2011), 87–95.

24 Anon., "Appellate Side: Defilement of Well Water," *Times of India,* 28 July 1914.

movement to open access to a well failed because of a dispute among the depressed caste groups. Caste set a moving target. "Within the ranks of 'untouchables' are grades of untouchability, and where this is the case the higher grades will not drink from the wells of the lower grades."[25]

Another type of outcome was a result of outside arbitration, which became more frequent in western India after Mohandas K. Gandhi and Ambedkar both tried to usher the depressed castes into the political mainstream, with different arguments. In 1931, a political activist persuaded the upper castes in a Karnatak village to open access to the deprived castes, whom he convinced to refrain from eating meat and drinking alcohol. Ambedkar's *Annihilation of Caste* documented many more cases of local protest. Newspapers in the cities had also documented and discussed numerous instances wherein privately secure water became a target. The most organized movement was in the small town of Mahad, 100 miles south of Bombay, where a group led by Ambedkar in 1927 tried to gain the right to draw water from a tank. Despite its lack of success in court that year, it helped Ambedkar eventually to become the most influential campaigner for caste equality in Indian politics. In 1931, a judge in the local court decreed that the Mahad tank was a public property open to all. The judgment gave prestige to the movement and further elevated Ambedkar's status.[26]

Western India was the center of this political activity. In South India, the non-Brahmin movement in provincial politics adopted the cause, with less publicity. In North India, caste difference entailed new rules for sharing, but water was not a scarce resource there. Conflicts emerged when religious reformers challenged these rules.

Provincial and princely state legislatures followed the incidents and court judgments closely. The princely state of Baroda passed a law that would deprive any organization practicing discrimination of government grants based on caste. After the Bombay Legislative Council passed a resolution in 1923 that government grants would

25 Anon., "Caste Warfare," *Times of* India, 16 Aug. 1924; Anon., "Water, Water!" *ibid.*, 25 April 1925.

26 Anon., "Untouchables Use Water from Common Pond," *Times of India*, 21 Nov. 1931. For descriptions of the Mahad incident and its legacy, see Gail Omvedt, *Dalit Visions: The Anti-caste Movement and the Construction of an Indian Identity* (Hyderabad, 2006), 44; Anupama Rao, *The Caste Question: Dalits and the Politics of Modern India* (Berkeley, 2009). Anon., "Untouchables Win: Mahad Tank Declared Public Property," *Times of India*, 22 Jan. 1931.

not be available for wells or land containing a pool unless all castes had equal access, groups of people forced their entry into tanks situated on government land.[27]

Between the judgments of 1914 and 1931, case law established the important principle that a source belonging to a public body (a temple or otherwise) was a public good. Together these incidents made the struggle for equality a political issue. When an elected legislature assumed control of the provincial governments during the interwar period, the issue of water equality came to the fore. According to Rao, with reference to Mahad, "The events of 1927 marked a significant departure in Dalit politics and inaugurated urban-centered regional associational forms." Rao deemed this departure the transformation of untouchables into Dalits, or genuine political subjects. The year after the Mahad judgment, Gandhi's All India Anti-Untouchability League formed. The figure of Ambedkar loomed large in any discussion of equality, not least because of the caste reservation of electoral seats that he had helped to achieve, despite Gandhi's opposition.[28]

What exactly did the movement achieve with regard to the access to, and safety of, water? In 1932, participants in a seminar on equality held in Bombay observed that "there had been a remarkable change in the spirit of the people . . . in the cities"; but "fear and . . . oppression" still prevailed in more rural areas. In the cities, where water was more readily available, piped water had effectively ended the predominance of private rights, whereas in the countryside, where water was scarce, the progress of public works was not enough to end the dominance of private rights.[29]

After independence in 1947, the democratic state turned its attention to the battle in the villages. In the peninsular states and in Gujarat,

27 For examples of the non-Brahmin movement in South India, see Adapa Satyanarayana, "Nation, Caste, and the Past: Articulation of Dalitbahujan Identity, Consciousness and Ideology," *Proceedings of the Indian History Congress*, LXV (2004), 416–467; for a north Indian conflict involving the Arya Samaj, Kenneth W. Jones, "Ham Hindu Nahin: Arya-Sikh Relations, 1877–1905," *Journal of Asian Studies*, XXXII (1973), 457–475.

28 Rao, *Caste Question*.

29 Anon., "The Depressed Classes: Progress in Western India," *Times of India*, 24 Nov. 1932. As Mansukh G. Bhagat, "The Untouchable Classes of Maharashtra," *Journal of the University of Bombay*, IV (1935), 130–174, noted a few years after Mahad, "Nowhere have I found a common well used by the touchables [*Sic.*] and the untouchables, although from time to time, the Government might have issued orders, that all the public wells should be thrown open to all" (163).

where periodic aridity and caste-based inequality were common, the state governments devoted part of their budget to the construction of wells for depressed caste people. Political and administrative conflicts beset these actions; the creation of separate wells for the lower castes seemed to perpetuate discrimination. The proliferation of agencies to achieve multiple goals—security, equality, and sanitation—made progress slow and maintenance chaotic. Not surprisingly, reports of inequality and discrimination persisted in surveys of access. Nevertheless, the movement had killed the force of the moral rule regarding purity. At the end of the twentieth century, the field of ritual purity had narrowed, applying more to temple access than to water. "Untouchability is not experienced in normal times[; only] when water is scarce, [do] the [oppressed castes] experience difficulty and discrimination in taking water."[30]

The state was only indirectly an agent of change in the struggle for equality, but it played a direct role in carrying out public works with taxpayers' money. Water was probably the most important field of public investment and expenditure in colonial India. The scale of the investment, however, was highly uneven and geographically conditioned.

PUBLIC WORKS: DAMS, CANALS, AND MULTIPURPOSE PROJECTS In the nineteenth century, officers and engineers believed that a state-led technological response would solve the problem, impounding excess flow in rivers via dams and reservoirs. This strategy seemed obvious in a monsoon climate with a vast "wastage" of rainwater available to meet the needs of eager farmers. In the southern deltas during the 1840s, new canals encouraged rice cultivation, trade, and business at local ports. In today's western Uttar Pradesh (UP) and the Haryana states, the construction of a network of canals (later called Ganges and Jumna) in the nineteenth century partly entailed the revival of dormant channels created by the Indo-Islamic states that had ruled

30 Ishwarlal P. Desai, *Water Facilities for the Untouchables in Rural Gujarat: A Report* (New Delhi, 1973); Sukhadeo Thorat, "Oppression and Denial: Dalit Discrimination in the 1990s," *Economic and Political Weekly*, XXXVII (2002), 572–578. For the persistence of water discrimination, see Hannah Johns, "Stigmatization of Dalits in Access to Water and Sanitation in India," submitted to the National Campaign on Dalit Human Rights (New Delhi, c. 2012); Sanjiv J. Phansalkar, "Water, Equity and Development," *International Journal of Rural Management*, III (2007), 1–25. A. M. Shah, "Purity, Impurity, Untouchability: Then and Now," *Sociological Bulletin*, LVI (2007), 355–368.

the region from the fourteenth century. By contrast to South India or the Ganges–Jumna area, Punjab and Sind pursued the creation of canals from perennial rivers on a much larger scale. Between 1870 and 1920, engineers tapped the five rivers of Punjab, turning a vast extent of interfluvial tracts into arable land.[31]

During the interwar period, the impounding model changed. The new canal systems followed the American model of the "multipurpose" project to create a reservoir, a hydro-electric power generation plant, and irrigation canals. For at least forty years after India's independence, this paradigm of hydraulic engineering prevailed. The immediate impetus to expand the Punjabi canal system came from an emergency caused by the Partition of India—the need to resettle peasant migrants in both India and Pakistan. Moreover, by 1940, the Punjabi canals had become incapable of meeting the demands of the four-million hectares of irrigated land that they served. After the Partition, India and Pakistan, which shared the canal system, had limited options for its expansion. India built the Bhakhra Dam Project, first proposed in 1919, to impound the Sutlej River. Pakistan was keen to build reservoirs in the upper valleys, which included Kashmir. After the initial boost in India, massive investment on the upland rivers in southern and eastern India ensued. By 1990, Indian rivers had more than 2,000 dams, most of them appearing on the Deccan rivers after 1947.[32]

A similar trajectory unfolded in the cities, where the impounding idea had immense support. Geographically, the port cities suffered from neither a water shortage nor the exigencies of seasonality. In the past, the seaboard, which was far more dependent on services and manufacturing than on agriculture, usually received more average rainfall, thanks to the vagaries of the monsoon wind. Precisely because life was more secure there, cities like Bombay, Calcutta, and Madras

31 The river-water recycling models differed between Punjab, Sindh, the southern deltas, and the Ganges-Jumna tract. For a recent work on a major project in the Punjab state, see Zahid Ali Khalid, "State, Society and Environment in the Ex-State of Bahawalpur: A Case Study of the Sutlej Valley Project, 1921–1947," unpub. Ph.D. diss. (Univ. of Sussex, 2017); for Sindh, David Gilmartin, *Blood and Water: The Indus River Basin in Modern History* (Berkeley, 2015).

32 For the emergence of the American model and a case study, see Aditya Ramesh, "Water Technocracy: Dams, Experts, and Development in South India," unpub. Ph.D. diss. (School of Oriental and African Studies, Univ. of London, 2018). R. MacLagan Gorrie, "Soil and Water Conservation in the Punjab," *Geographical Review*, XXVIII (1938), 20–31.

received many migrants. Their high population growth created local shortages as well as sanitation crises from time to time.

Until well into the nineteenth century, most cities were not too dissimilar from the countryside. Supplies came from ponds, lakes, and wells. According to a report about Pune (Poona) of 1872, "The poor low caste people have . . . to wait at a little distance from the wells until some person of caste gives them, either for money or out of charity, a small quantity of water. There are very few wells in the city which are accessible to any but persons of caste." The mention of payment by "money" suggests that markets emerged in the cities during shortages, and even though all markets tended to exclude the poor, markets could overcome caste distinctions. During the hot season in Bombay city, "we see water carts going about the town distributing scanty supplies here and there." Conditions were not different in Madras province, as economists' surveys of immigrant localities in the interwar period discovered.[33]

The engineering corps of the army and the urban administration had advocates of gravity schemes, as well as skeptics who doubted how receptive Indian city dwellers would be to the idea of piped water served via a faucet that they would have to pay a tax to access. This resistance notwithstanding, towns developed gravity systems and pipes, with the help of the growing economic and political power of businesspersons, as well as a general moral concern about "filth," an issue that had originated in Britain and migrated to different parts of the Empire.[34]

Bombay, Calcutta, and Madras Bombay was a case in point. Despite its heavy rainfall, the scale of its migration placed a huge draft on water. From 1872 to 1881, the famine decade, Bombay's population increased by 20 percent, whereas the population of the Bombay Presidency (or Province) stayed unchanged. The city's population teemed with migrants fleeing the dry regions. In the next decade, Bombay's population fell 6 percent because of plague and cholera epidemics. The medical experts attributed the outbreaks to overcrowding, poor

33 Anon., "Great Scarcity of Water at Poona," *Times of India*, 4 June 1872; Thomas Blaney, letter, "Our Inefficient Water-Supply," *ibid.*, 5 May 1884; D. Arulanandam Pillai, "Problems Relating to Paraiyas in the Tanjore District," *Papers Read at the Third Annual Conference of the Indian Economic Association Held in the Senate House, Madras, 1919–1920* (Madras, 1920), 88.

34 John Broich, "Engineering the Empire: British Water Supply Systems and Colonial Societies, 1850–1900," *Journal of British Studies*, XLVI (2007), 346–365.

sanitation, and poor water quality, though their relief plans often made matters worse. The scientific response to the problem, which had already seen some success, was to tap or dam the numerous seasonal streams in the watershed. Sanitary reformers campaigned for technology that would pipe water from the lakes into the city's storage tanks, and the administration set up the infrastructure. A key element in the initiative was to involve the city's wealthy Indian merchants in public activities. The city now had an executive authority of its own, and water was its first field of action. Notwithstanding the corruption scandals around municipal finances and strong resistance to paying the tax, the supply conditions changed.[35]

Calcutta's mid-nineteenth-century history with water was similar, though the source of its piped water was different. In 1870, a central system processed water from the Hooghly River—storing it in settling tanks, filtering and restoring it in covered wells, and supplying it to homes via pipes. Systems like Calcutta's appeared in northern towns in the late nineteenth century wherever rivers were available. Bombay's "impounding reservoir" system had a counterpart in the Deccan cities, especially Hyderabad, where artificial lakes trapped rainwater for use in the drier seasons. Pune relied on a combination of tanks and rivers. Much of the public supply came from reservoirs in the Katraj Valley and the Kharakwasla Lake (which was built by damming the Mutha River) via aqueducts.

The economics of building and sustaining these systems varied. The cost was relatively high in southern India. Take Madras, for example. The weaker monsoon and higher average annual temperature there than in Bombay and Calcutta rendered surface and underground water subject to sharper fluctuations. Madras harnessed the Adyar and Coovam Rivers, but the channels received enough water only during the monsoon. Moreover, such waterworks were an expensive proposition for a city with relatively low business income.

Yet, the very existence of a public authority funded by the taxpayers' money managed to turn water into a quasi-public good. Piped water initiated a revolution because it weakened water as a marker of poverty. This is not to imply that poverty and inequality disappeared. As migration outstripped the capacity of the system,

35 Mariam Dossal, "Henry Conybeare and the Politics of Centralised Water Supply in Mid-nineteenth Century Bombay," *Indian Economic and Social History Review*, XXV (1988), 79–96; Sapana Doshi, "Imperial Water, Urban Crisis: A Political Ecology of Colonial State Formation in Bombay, 1850–1890," *Review (Fernand Braudel Center)*, XXXVII (2014), 173–218.

poorer migrants could access a smaller quantity of piped water. In the colonial era, pipes reached European homes first. Nonetheless, piped water gave the cities some security from water famine. Recent surveys of standards of living find that most families living in the cities have access to "some form of communal running water supply." Such measures of urban living standards, combined with the proportion of the urban oppressed caste population, provide an indication of the extent to which inequality in access to water has changed since the early twentieth century. In 1901, this joint proportion was considerably lower than in 2001.[36]

India's urbanization rate was relatively low in the four decades after independence, before it began to accelerate sharply. By the end of the twentieth century, growing population and water usage in the cities had seriously stressed the capacity of the public system. India's economic boom was an urban phenomenon. Certain cities, like Bangalore or Madras, emerged as hubs of global service export and magnets to a skilled and educated workforce. As the density of population in the inner areas increased, and apartment blocks ate up space, the old-style homestead wells disappeared. But municipal supply continually fell behind demand. In apartments as well as homesteads, bore wells (or artesian wells) increasingly produced the supply. Municipal piped water mainly served the poorer residents of the city.

Although the bore well was well known as a tool from the early twentieth century, no one could have foreseen the enormous demand that agricultural and urban consumption would make on groundwater in the new millennium. This subject, which is central to the stress issue, needs historical contextualization.[37]

WATER STRESS Water stress—a growing imbalance between use and stock, causing shortages as well as conflicts—stemmed from the

36 Nicolas Martin, "Rural Elites and the Limits of Scheduled Caste Assertiveness in Rural Malwa, Punjab," *Economic and Political Weekly*, L (2015), 37–44. In 1901, 11% of the Indian population was urban. In 2001, 28% was urban, 20% of the "scheduled caste" population was urban. India, *Handbook of Social Welfare Statistics* (New Delhi, 2016). The corresponding percentage for water access in 1901 is unavailable. Assuming that the proportion rose at the same rate as the average urban percentage, the 1901 figure for the oppressed castes would be 8%. However, given the historically well-established weaker access of the oppressed castes to education and capital—measures of which ordinarily rose with the percentage of the urban population—the percentage of access to water in 1901 for the oppressed classes would have been even smaller.

37 Anthony Acciavatti, "Re-imagining the Indian Underground: A Biography of the Tubewell," in Anne Rademacher and Kalyanakrishnan Sivaramakrishnan (eds.), *Places of Nature in Ecologies of Urbanism* (Hong Kong, 2017), 206–237.

unsustainability of the impounding paradigm in the late twentieth century. Concern about rising stress started in the second decade of the twentieth century when the study of economics and agronomy emerged. Some contributors to this field believed that the river projects were changing local geographies for the worse. Colonial preoccupation with rivers sometimes led to a neglect of traditional resource-management systems like tanks. The criticisms, however, did not seriously challenge the prevailing model of irrigation; post-independence India inherited and based projects on that principle. A resolve to end poverty had made the developmental agenda overlook potential costs of irrigation projects; "overriding priority was mostly placed on the first-order effects of technology and economic growth." The 1970s Green Revolution further endorsed the investment in canals.[38]

From the 1970s onward, the costs were becoming too great to ignore. To many critics, the dams caused floods because of reservoirs that were overfull during monsoons, forcing engineers to release excess water on short notice. These floods degraded land by interfering with natural silt flows; disrupted aquatic life; destroyed forests; caused waterlogging, salination, and diseases; displaced people; and increased the risk of earthquakes. The protests reached their peak with the Narmada River project, which had been conceived in the 1950s and begun during the 1980s. When the project's extensive displacement and environmental consequences became apparent in the 1990s, a few Indian NGOs campaigned against it. Although it did not halt, it was possibly the last multipurpose river-basin project to materialize in India.[39]

Canal irrigation also came under attack, for encouraging waste at the head end and shortage at the tail end. Farmers adapted coping patterns to seasonal scarcity and devised their own rules to contain open conflicts on a local basis. The heavy losses of water in the conveyance from the source to points of use contributed to India's low levels of water productivity. Evaporation contributed to these losses, but management

38 Velayutham Saravanan, *Water and the Environmental History of Modern India* (London, 2020); Margaret R. Biswas and Asit K. Biswas, "Complementarity between Environment and Development Processes," *Environmental Conservation*, XI (1984), 35–44.

39 Satyajit K. Singh, "Evaluating Large Dams in India," *Economic and Political Weekly*, 25 (1990), 561–574. For a short historical account of the river projects and their controversies, see Michael H. Fisher, *An Environmental History of India: From Earliest Times to the Twenty-First Century* (New York, 2018). Robert H. Wade, "Muddy Waters: Inside the World Bank as It Struggled with the Narmada Projects," *Economic and Political Weekly*, 46 (2011), 44–65.

and engineering failure compounded the problem. Poorly lined canals caused considerable water to percolate underground.[40]

Water-Sharing Conflict A more important dispute involved the sharing of river flows between states within India and nation-states of South Asia. Three large economies in South Asia share water from the Indo-Gangetic Basin; two of them, India and Pakistan, rely on the five rivers of the Indus Basin for irrigation and power. All of these rivers originate inside India, and four of them flow inside Pakistan. The Indus Waters Treaty of 1960, which allowed Pakistan to exploit the western rivers more intensively while granting India rights to the eastern rivers, survived relatively trouble-free until 2002, when the countries exchanged threats. Indeed, hydro-political analysis has grown more alarmist, acknowledging that the prospect of war about water is not beyond imagination, especially because the terms of negotiation in international treaties reflect the economic weight of nations more than ecological considerations. Furthermore, climate change has shifted the geographical knowledge base on which some of the deals were drawn.[41]

In the Deccan region, where five states of India share three river basins of limited capacity and fluctuating levels of supply, interstate disputes about riparian flow typically involve two or more territorial units positioned on different reaches of a river. In 1956, an Interstate River Water Disputes Act created a framework for negotiations, inquiries, tribunals, and processes for appeal. The Act assumed control of the task that state-appointed tribunals had earlier performed, as in

40 Ashok K. Mitra, "Underutilisation Revisited: Surface Irrigation in Drought Prone Areas of Western Maharashtra," *Economic and Political Weekly*, 21 (1986), 752–756. For the problem of waste and shortage in the Krishna basin, the largest field of irrigation development in the Deccan Plateau, see Bret Wallach, "Irrigation Developments in the Krishna Basin since 1947," *Geographical Review*, LXXIV (1984), 127–144. Peter Mollinga, *On the Waterfront: Water Distribution, Technology and Agrarian Change in a South Indian Canal Irrigation System* (Hyderabad, 2003): "[T]he rules are resources that are called upon when needed" (181); Mitra, "Joint Management of Irrigation Systems in India: Relevance of Japanese Experience," *Economic and Political Weekly*, 27 (1992), A75–A82. For several examples of disputes about river water, see Madhav Gadgil and Ramachandra Guha, *Ecology and Equity: The Use and Abuse of Nature in Contemporary India* (New York, 1995), 76–81; Saravanan, *Water*.

41 Brahma Chellaney, *Water: Asia's New Battleground* (Washington, D.C., 2011); Paula Hanasz, "Power Flows: Hydro-hegemony and Water Conflicts in South Asia," *Security Challenges*, X (2014), 95–112; Daanish Mustafa, "Social Construction of Hydropolitics: The Geographical Scales of Water and Security in the Indus Basin," *Geographical Review*, XCVII (2007), 484–501. For the origin of the Treaty and its durability notwithstanding regional politics, see David Haines, *Rivers Divided: Indus Basin Waters in the Making of India and Pakistan* (New York, 2017). India's decision to build a barrage on the Ganges at the Bangladesh border (1973/4) caused much uneasiness between the two countries. The river-sharing arrangements between India and Nepal, and between India and Bhutan, were more peaceful.

the Kaveri River dispute. The history of agreements to share the Kaveri River dates back to the early twentieth-century treaties between the Mysore state and the Madras Presidency. A larger share of the water went to deltaic Tamil Nadu, where the waters sustained intensive cultivation in the Thanjavur rice belt, but a larger area of the basin fell in the Karnataka state. The agreements set limits on intra-territory usage, dam building, and reservoir capacity in the upper reaches of the river. From the 1970s onward, the Green Revolution, industrialization, and urban use increased the demand for water throughout the basin, making the tribunals' task of adjucating almost impossible to achieve. In 1995 and 2002, a weak monsoon reduced flow in the river and the reservoirs, compelling Karnataka to capture more water. The result was ongoing civil unrest in Tamil Nadu. Those engaged in the arbitration process appeared to believe that institutional solutions to such conflicts were possible. Yet, some of the longest-running disputes involved a sharp rise in usage that effectively defeated the judicial process. The tribunal discussed the capacity of the rivers, whereas agents who were not part of the process shaped demand.

Cities, Farms, Waste, and Depletion The surface-water model came under pressure from the cities during the 2000s: "A combination of institutional path dependence and a neoliberal restructuring" has "extended the ability of [the cities] to establish new forms of water entitlement in rural and peri-urban areas." Allocation to the cities routinely entailed stormy negotiations between the city and the farmers around it, which began in the ministries in charge of drinking water and irrigation but eventually wound up in politics. The river model had already died by that time. Wells were politically safer.

India's rice-based Green Revolution of the 1980s, which centered mainly on groundwater, met with success in food production but at an enormous environmental cost. Soil nutrients depleted in many cases, and water was mined recklessly. As farmers increasingly began to suffer, some states offered them cheap electricity, leading to huge rise in groundwater extraction. Outside agriculture, groundwater and capitalism became deeply interdependent. Wells provided 80 percent of urban and industrial water.[42]

42 Bharat Punjabi and Craig A. Johnson, "The Politics of Rural–Urban Water Conflict in India: Untapping the Power of Institutional Reform," *World Development*, CXX (2019), 182–192. For case studies about urban and peri-urban water systems in recent decades, see Vishal Narain and Anjal Prakash (eds.), *Water Security in Peri-urban South Asia: Adapting to Climate Change and Urbanization* (Delhi, 2016); for the shift toward privatization of water in the cities, Vandana Asthana, *Water Policy Processes in India: Discourses of Power and Resistance* (New York, 2009).

As private investment in wells assumed the responsibility of supplying farms, factories, and cities with water, depletion due to overuse of the aquifers became a new worry. Between 1995 and 2004, the proportion of the Indian population living in "unsafe" districts—those in which the aquifers no longer were able to recharge and sustain current levels of extraction—increased from 7 to 35 percent. In the northern districts that had led the earlier wheat-based Green Revolution, exploitation of groundwater in the 1990s far exceeded the capacity of the aquifers to respond. Pakistan faced the same problem on a larger scale. Elsewhere, the hydrogeological conditions influencing supply varied too much to make predictions on future supply a simple matter. The main issue, however, was not the matter of volume per se but the fact that the law implicitly viewed groundwater as a private good even though it came from a shared pool.[43]

Experts on depletion came in several categories. Economists usually explored market-based solutions to the problem. Geographers and political scientists observed that non-market processes, often called capture and appropriation, prevailed in many cases. Few such cases involved extralegal or coercive means. More often, political arm-twisting addressed them. In addition, experts in demand management from NGOs strongly advocated the use of water-saving technologies like drips and sprinklers. Every method to deal with shortage required certain preconditions, none of which works perfectly to contain demand in cities or restrain private investment. Indeed, as the marginal cost of extraction rose (as discussed above), no state could hope to subsidize it alone; private investment had to expand. In other words, there had to be a tradeoff between economic sustainability and ecological sustainability.[44]

Environmental Law and the Public Trust Before independence, the law left the private right to groundwater intact while weakening exclusionary rules on the commons. The Indian Easements Act of 1882 recognized customary rights to water, but custom was often disputed, iniquitous, or damaging. Beginning in the interwar period, courts and a few provincial legislatures sanctioned an eminent-domain rule, whereby the state could take control of a common source

43 P. S. Vijay Shankar, Himanshu Kulkarni, and Sunderrajan Krishnan, "India's Groundwater Challenge and the Way Forward," *Economic and Political Weekly*, 46 (2011), 37–45.

44 Mattia Celio, Christopher A. Scott, and Mark Giordano, "Urban-agricultural Water Appropriation: The Hyderabad, India Case," *Geographical Journal*, CLXXVI (2010), 39–57; A. Narayanamoorthy, "Drip and Sprinkler Irrigation in India: Benefits, Potential and Future Directions," *Agris* (2012), 254–266.

"in the public interest." More recently, activists have campaigned to strengthen the public trust as well as to end exclusive private rights in groundwater. Legally, a well is private property now; under a reformed legal system, a well would have the status of common property. Politics, however, has defended private investment and private property more fiercely since India's economic boom began.[45]

The public trust in environmental law can be applied in different ways. One of them is non-excludability. Because all water comes from common pools, "one does not own a property right in water in the same way he owns his watch or his shoes, but that he owns only usufruct—an interest that incorporates the needs of others." In India, the public trust argument has started to appear more often, though few significant cases have dealt with water. In 1997, a Supreme Court case affirmed that the state was the trustee for the water in the commons. The Water (Prevention and Control of Pollution) Act in India, passed in 1974 and long-dormant, became a rallying point for several hundred cases since 2000. In recent years, the court has heard cases that invoked this law and the constitutional right to personal liberty to demand "safe and clean" drinking water—the meaning of which varies between one department of government and another, as well as between the courtroom and the scientific community—free from the actions of polluting industries. A recent judgment involving the Ganges affirmed that rivers have the same right as a legal person, giving rise to administrative confusion over who is the trustee of that right since most rivers flow over several states.[46]

This article argues that actions that improved water security enabled economic and population growth in India, at the cost of ecological stress. A series of actions taken by the state, scientists, and society since 1880 weakened the chains that linked water insecurity, low yield, mass mortality, and caste-biased mortality. The story has two lessons for comparative development.

45 Videh Upadhyay, "The Ownership of Water in Indian Laws," in Ramaswamy R. Iyer (ed.), *Water and the Laws in India* (New Delhi, 2009), 134–148.

46 Joseph L. Sax, "The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention," *Michigan Law Review*, LXVIII (1970), 485; Jona Razzaque, "Application of Public Trust Doctrine in Indian Environmental Cases," *Journal of Environmental Law*, XIII (2001), 221-234; Philippe Cullet, *Water Law, Poverty, and Development: Water Sector Reforms in India* (New York, 2009); Aviram Sharma, "Drinking Water Quality in Indian Water Policies, Laws, and Courtrooms: Understanding the Intersections of Science and Law in Developing Countries," *Bulletin of Science, Technology and Society*, XXXVII (2017), 45–56.

The first concerns economic history, which tries to discover the preconditions of modern economic growth. Theories of growth have a standard structure. They explain the genesis of income growth with a variable that pertained to Western Europe, release from the burden of predatory states or overpopulation. Having established Europe's success story, the theories note the absence of this variable from the economically less-developed world. The contention herein is that the approach is flawed because Europe and this other world are geographically incommensurate. Because their initial conditions were different, they could arrive at economic growth only by solving different problems.

A climatically conditioned water supply was the obstacle to modern economic growth in India; human intervention helped to alleviate it. The thesis has broader implications. Much of the world is dry. Western Europe, Japan, and North America are fortunate exceptions. For the rest of the world, a society's ability to control water determined its ability to generate population and economic growth. European history can tell us little about how non-Western societies acquired that ability.

The second lesson concerns sustainability. In India, environmental stress was the price paid for welfare gains. Popular discourse, however, does not usually see it in that way. It remains trapped in a rhetoric lamenting the tragedy of the commons, in which stress occurs wherever private greed and weak property rights jointly lead to overuse of shared resources. The maxim that emerged from Hardin's framing is that "freedom in the commons brings ruins to all." On the contrary, freedom in the commons was a benefit tending toward growth and welfare, not tragedy. Vulnerable geography made the process costly to sustain. In a dry region, well-being and the environment are constantly in flux. Asking deprived individuals to consume less or cooperate more is not necessarily the best response to such a fluid situation. Science and capitalism—the mechanisms that work behind drip irrigation, to take one example—may well be a better solution.[47]

47 For Hardin's maxim, see "Extensions of 'The Tragedy of the Commons,'" *Science*, CCLXXX (1998), 682–683.