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Transboundary Water Sharing in the Ganges River Basin: Influence of India's Farakka Barrage on Agricultural Water Security in Bangladesh

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ABSTRACT

The construction and management of the Farakka Barrage, a low dam on the Ganges River to divert water, has been a point of social and political tension for over five decades. The barrage was designed to improve the navigability of the Hooghly River and Kolkata Port, but it has resulted in water availability and salinity concerns along the main branch of the Ganges River in downstream Bangladesh. This thesis explores how the Farakka Barrage exacerbates existing water scarcity problems (resulting chiefly from climate change, population growth and irrigated land expansion) in the dry season and how that scarcity impacts agricultural production in southwest Bangladesh. This review seeks to synthesize and relate literature at the international negotiation scale with the lived experience of farmers along the Ganges. Despite the challenges in relating these two different scales, it is important to identify relationships and patterns between international decisions and local experiences for decisionmakers to consider in the future. The timing of this review is particularly relevant given that the current Ganges Water Sharing Treaty is due to expire in 2026 after 30 years of implementation. This review finds that 1) management of the Ganges is determined by high-level politics and institutional factors within the two countries more than internationally recognized transboundary principles, 2) the river basin is heavily influenced by complex anthropogenic and environmental factors that are often oversimplified, 3) both experts and the public have continued to express discontent with the management of the Farakka Barrage throughout history and 4) there are opportunities for greater stakeholder engagement in the renegotiation of a Ganges water sharing agreement in 2026.

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This honors thesis would not be possible without the guidance of several mentors. I would first like to thank Dr. Christopher Scott for his continuous support, encouragement and advice throughout this entire learning process. His guidance helped me identify a topic I am passionate about and understand how this thesis can serve as a step toward pursuing my future goals. Support from Dr. Scott was made possible by the Maurice K. Goddard Chair Endowment at Penn State and USDA NIFA project PEN0 4816-7003839. I would also like to thank Dr. Robert Shannon for his gracious support as my honors advisor for the past four years. He helped me make the most of my experience at Penn State and find my niche within environmental resource management. I would also like to thank Dr. Tammy Shannon for her endless enthusiasm and confidence as I have pursued educational opportunities in environmental governance and diplomacy. Finally, I am sincerely grateful for the encouragement of my parents and friends throughout this thesis process.

Introduction

Nearly every nation in the world faces transboundary water management challenges ranging from the international to the local scale. Approximately 300 rivers and 100 lakes extend beyond a single nation's jurisdiction, posing challenges to coordinated and cohesive resource management (Salman, 2007). Riparian states often face quantity and quality problems with their waterways, but each river basin has its own unique factors that make management negotiations and decisions difficult. This thesis focuses on the transboundary Ganges River basin, particularly at the Farakka Barrage, as a prime example of how geographic position and political power can shape water use across a basin. The concepts and consequences it describes are applicable to dozens of other waterways across the globe and should serve as both an informative case study and a call for improved sharing strategies on the Ganges.

This review paints an integrated picture of the politics and ideas around Ganges water sharing and how they impact agriculture by exploring three research questions: What political dynamics influenced the development of the Farakka Barrage and the Ganges Water Sharing Treaty? How have the hydrological effects of the barrage impacted agriculture patterns in downstream Bangladesh? How has the public responded to these changes?

To answer these questions, one needs to consider the unique historical, political, economic, ecological and climatic dimensions of the Ganges River basin. While this thesis cannot address all the significant events and trends related to Ganges water sharing, it highlights some of the most important factors shaping management of the Ganges today. These factors include the cultural and religious significance of the Ganges, rapidly growing reliance on its flow

for human use, India's position as an upstream user of the Ganges, political dynamics between India and Bangladesh, rising temperatures and extreme precipitation patterns, intrusion of salinity and shifts in farmer behavior. With the linkages between those factors in mind, one can begin to understand the complex role the Farakka Barrage plays in how Ganges water is used for agriculture in Bangladesh.

This thesis is divided into three chapters. The first chapter provides broad context around the Ganges River basin and the people who rely on it. It then offers an overview of transboundary water management in the global legal context and in South Asia. The second chapter focuses on the development history of the Farakka Barrage, its inconsistent management over the decades and how the Ganges Water Sharing Treaty governs it today. The third chapter explains the impacts of the barrage on downstream agriculture, primarily through quantity concerns and increased salinity, and relates impacts to public response. The conclusion identifies challenges needing additional attention in the literature and further research.

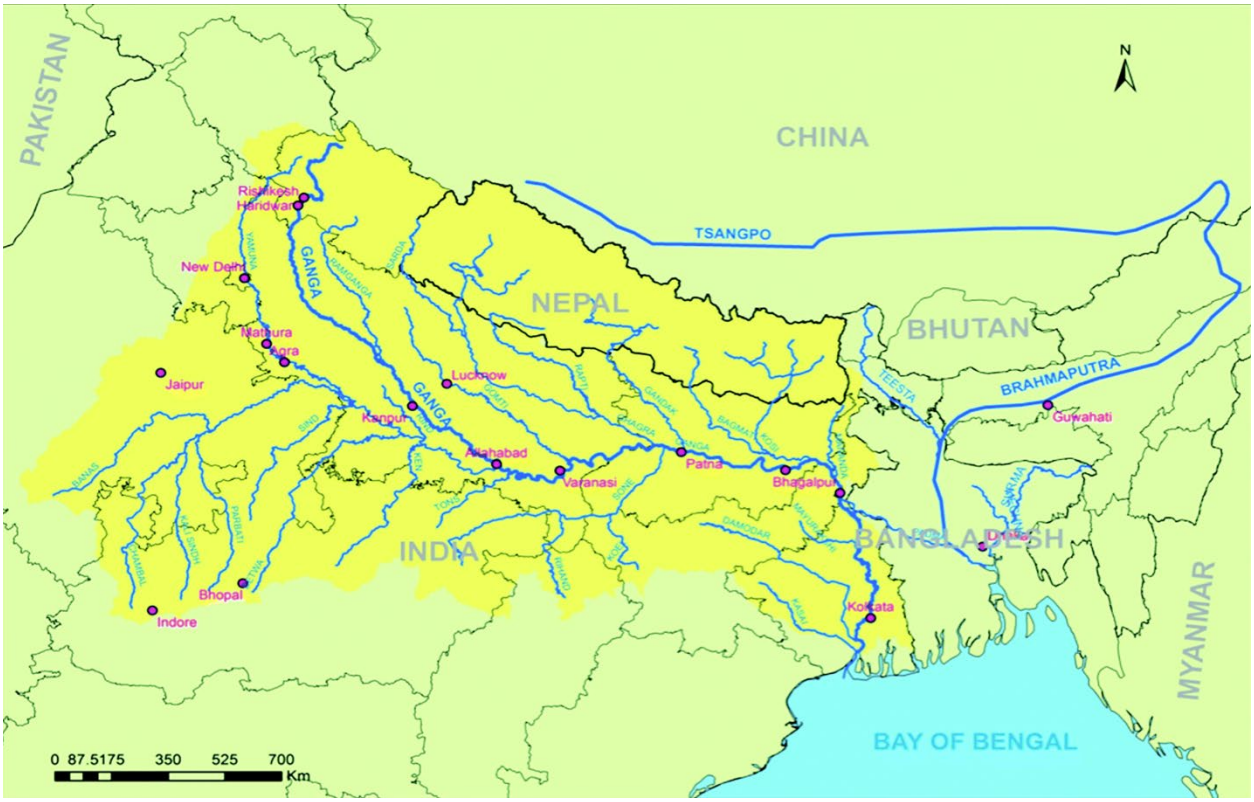
Chapter 1

Water Sharing between India and Bangladesh

Overview of the Ganges Basin

The Ganges River basin spans 2,500 kilometers and is the most populated river basin in the world (*The National Ganga River Basin Project*, n.d.). In 2018, there were nearly 650 million people living within the basin–twice the population of the United States–and accounting for about 10% of the world population (Mukherjee et al., 2018). The river's headwaters stem from glacier melt in the Himalayas, where it is called the Bhagirathi River, and then joins with the Alaknanda River to form the Ganges (Ganga in Sanskrit and modern South Asian languages). The river is fed by several more tributaries from China, Nepal and India as it flows in a southeastern direction. As depicted in Figure 1, the Hooghly River branches off of the Ganges toward Kolkata and the main Ganges branch continues into Bangladesh. It combines with the Brahmaputra and the Meghna and reaches the Bay of Bengal as the second largest river in the world by discharge. The mouth of the Ganges is home to the largest mangrove forest in the world, called the Sundarbans (Murshed et al., 2019). The richly biodiverse mangrove forest is 10,000 square kilometers and spans across Bangladesh and India, providing a source for fishing, timber harvesting and tourism (Murshed et al., 2019).

Figure 1: Map of the Ganges River Basin



Source: Whitehead, P. G., Sarkar, S., Jin, L., Futter, M. N., Caesar, J., Barbour, E., Butterfield, D., Sinha, R., Nicholls, R., Hutton, C., & Leckie, H. D. (2015). Dynamic modeling of the Ganga river system: impacts of future climate and socio-economic change on flows and nitrogen fluxes in India and Bangladesh. *Environmental Science: Processes & Impacts*, *17*(6), 1082–1097. https://doi.org/10.1039/C4EM00616J

This ever-changing river system has supported human civilization in South Asia for thousands of years. The ancient kingdoms of Magadha, Gupta and later the Mughals were built on fertile lands along the river, and cities have continued to thrive in this region throughout history (Kumar, 2017). The religions of Hinduism, Buddhism, Jainism and Sikhism also formed in this region, solidifying the Ganges' cultural and spiritual importance (Kumar, 2017). In Hinduism, the Ganges River is seen as the incarnation of the Goddess Ganga and a symbol of purity (Kumar, 2017). Those who bathe in the Ganges are forgiven for their sins, and those who die along the Ganges reach heaven (Kumar, 2017). Due to this belief, cremation services have

been built along the river, and it is common for people to immerse ashes that float down it (Kumar, 2017).

People in the Ganges basin today continue to rely on it as an invaluable source of water. Over one third of India's surface water comes from the Ganges (*The National Ganga River Basin Project*, n.d.). About 90% of that surface water is used for agricultural irrigation and the rest is used for drinking water, power generation, ecologic function and navigation (Mukherjee et al., 2018).

While people rely on water from the Ganges for everyday needs, there are significant changes in its water depth throughout the year. The river basin experiences the South Asian Monsoon from June to October every year, and that short period accounts for more than 80% of the river's annual flow (Khan, 2014). Flooding is a major concern during this time, which is a stark contrast to the dry season when India and Bangladesh face severe water shortages. This paper focuses on water sharing during the dry season.

In addition to quantity challenges in the Ganges, there are also serious quality concerns. The dense population along the river has caused major pollution that inhibits its usability. The World Bank estimates that 3 billion liters of sewage enter the river each day from Indian cities, as well as industrial discharge (*The National Ganga River Basin Project*, n.d.). Additionally, arsenic levels in much of the groundwater of the Ganges River basin are not safe for human consumption. About 26 million people in India and 53 million people in Bangladesh have elevated arsenic levels in their drinking water, which can lead to poisoning and cancer (Chakraborty et al., 2020). The arsenic problem is caused by a combination of geologic, biochemical and other natural and anthropogenic factors, and it has been exacerbated by people's

growing consumption of groundwater as surface water become less available (Chakraborty et al., 2020).

These are just some of the key factors that make the Ganges River basin such a highly complex river system and so difficult to wholistically manage.

Frameworks and Guidelines for Transboundary Water Management

The frequency of political and social flashpoints over transboundary issues has led to an expansion of guidance for governments and stakeholders hoping to resolve conflict. This section will describe some of the key principles and agreements guiding transboundary water management in the world today.

Multiple principles regarding transboundary management have circulated among decision makers in recent centuries. One example is territorial sovereignty, which means waterways should be under the jurisdiction of the state they are in (Salman, 2007). Nation states can use the water any way they want if the waterway is within the state's borders. This concept is referred to as the Harmon Doctrine, named after a former attorney general of the United States who applied it to the shared US-Mexico Rio Grande/Río Bravo. It has earned a lot of criticism from experts and international organizations that promote cooperation and peace (Salman, 2007). In contrast to territorial sovereignty is the idea of territorial integrity. Territorial integrity protects the rights of downstream states by saying that upstream states should not interfere with the natural flow of the river (Salman, 2007). A third principle considers all the states along a transboundary river as a collective body and says that management decisions can either be made by shared agreement or based on proportional share of the river (Salman, 2007).

There are several more conflicting principles around transboundary water management, and each of them have their own drawbacks. In the modern day, we seek to minimize these drawbacks by negotiating and combining different principles in our decision making. For example, today's transboundary decisions typically utilize limited territorial sovereignty, which respects the rights of states to use the water in their territory but also acknowledges the need to maintain the river's functionality for other riparian states to use (Salman, 2007). This concept has influenced the development of three formal guidelines for transboundary water management in the past century: the Helsinki Rules, the UN Watercourses Convention and the Berlin Rules.

One of the most influential organizations shaping transboundary water governance is the International Law Association. The association is made up of lawyers from around the world who adopt rules and resolutions to clarify and build on international law (Salman, 2007).

In 1966, the International Law Association met in Helsinki and developed one of the most widely used set of rules to guide international water management, called the Helsinki Rules on the Uses of the Waters of International Rivers (Salman, 2007). The Helsinki Rules are not actually legally binding, but they are based on widely accepted principles of transboundary management and are recognized by decision makers globally (Salman, 2007).

The primary declaration of the rules is that riparian states are entitled to a reasonable and equitable share of the benefits of the river (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). It says that this share can be determined by considering factors like geography, hydrology, climate, dependent populations, economic needs and more (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). The rules also say that riparian states cannot cause additional water pollution to the river if it harms other riparian states, and that riparian states should work to abate existing harmful pollution (*The Helsinki Rules on the*

Uses of the Waters of International Rivers, 1966). If a riparian state does cause pollution, it must stop the action causing the pollution and compensate any other riparian states that have been harmed. When it comes to navigation, the Helsinki Rules say that any riparian state has the right to navigation on the full extent of the river (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). If one state undergoes a construction project that will affect the navigability of the river, other riparian states have a right to request consultation, potentially leading to negotiation (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966).

The Helsinki Rules also include a chapter on settling conflict between states. It maintains that conflict should be resolved peacefully and in a way that upholds international peace, security and justice (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). It recommends that states share data regarding the activities and uses of water within its territory with the other riparian states (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). It also advises that states should give notice to the other riparian states if they plan to conduct any sort of construction that will affect the waterway, and that those other states can share their feedback (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966).

When a water use conflict arises, the rules say that the problem should be passed to a joint agency that can study the basin, make recommendations for most efficient use by the states and submit the corresponding reports to all states involved (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966). If a joint agency is not able to sufficiently mediate the problem, the Helsinki rules suggest bringing in an international organization or third state to

mediate the conflict (*The Helsinki Rules on the Uses of the Waters of International Rivers*, 1966).

International transboundary water law was further developed in 1997 when the United Nations Watercourses Convention was adopted (Salman, 2007). The convention held many similarities to the Helsinki Rules; it again called for river management to be reasonable and equitable for riparian states and listed factors to consider for each river basin (Salman, 2007). It also attempted to strike a compromise between the upper riparian states that wanted a right to reasonable use and the lower riparian states that wanted no harm done to the rivers. The convention says that states must eliminate any significant harm done to the river, keeping in mind that they still have a right to utilize it (Salman, 2007). Despite this seeming compromise, the convention is commonly perceived as favoring upper riparian states' rights to the rivers over the no harm principle (Salman, 2007). Similarly to the Helsinki Rules, the convention also requires states to form joint commissions for river management and to share information with each other (Salman, 2007). It also includes another section that addresses ecological preservation of rivers with guidance on pollution, new species, preservation and more (Salman, 2007).

The UN Watercourses Convention entered into force in 2014, but several major countries abstained from signing, including India and Bangladesh (Mahmud, 2014). Bangladesh had been a proponent of the convention throughout its development, but the country did not take steps to ratify it (Mahmud, 2014).

The third set of rules influencing today's transboundary water conflict is the Berlin Rules on Water Resources, which were approved by the International Law Association in 2004 (Salman, 2007). The Berlin Rules are much more thorough than the Helsinki Rules and UN Water Convention, offering guidance that applies to both national and international rivers. The

Berlin Rules add that people impacted by water management decisions should be included in the decision-making process and that humans have a right to sufficient, affordable water (Salman, 2007). It has an extensive environmental chapter that outlines things like environmental assessment obligations (Salman, 2007). When it comes to the reasonable and equitable share versus the no harm debate, the Berlin Rules differ from the Helsinki Rules and the UN Watercourses Convention by focusing on riparian states' obligation to reasonably manage the water instead of emphasizing their right to use it. This alternative wording presents utilization and no harm as equal principles; however, it sometimes poses even more confusion when put into practice (Salman, 2007).

Transboundary Management in the Ganges Context

Now that the important principles, rules and conventions guiding transboundary water management around the world have been discussed, they need to be better understood in the context of the Ganges River. The unique politics and geography of India and Bangladesh make Ganges management more complex than just following a list of guidelines.

When considering the Ganges, one can quickly see that India has the upstream advantage. About 80% of the river flows within India before it crosses the border into Bangladesh (*The Ganges: India's Sacred River*, n.d.). Being the upstream riparian state automatically gives a country more influence over river use because it can build hydraulic infrastructure to meet its use needs before the water ever crosses a border (Zeitoun & Warner, 2006). Whatever flow level and quality of water is left over is what the downstream state receives, and it may not be the amount

or quality that the downstream state is hoping for (Zeitoun & Warner, 2006). Therefore, geography alone gives India an advantage over Bangladesh in Ganges River management.

While geography plays a big role in transboundary river management, political power can be even stronger. Countries that have more resources and influence can use their position to put pressure on those they are negotiating with and achieve more favorable outcomes (Zeitoun & Warner, 2006). Downstream countries that rely heavily on a river need enough political power to compete against the geographic advantage if they want to achieve a desirable use agreement (Zeitoun & Warner, 2006).

In the case of the Ganges, India certainly has more political power than Bangladesh. Two factors that give it more influence in South Asia are its high population and GDP level. As of 2022, India had a population of over 1,417,170,000 people, which is nearly 74% of the population of South Asia overall (*Population Total- South Asia*, n.d.). The next most populous country is Pakistan with 235,824,860 people, and then Bangladesh with only 171,186,370 people (*Population Total- South Asia*, n.d.)— still, half the population of the United States in a territory the size of Georgia. This drastic population difference is perceived to give India more legitimacy when deciding how to utilize resources in the region. In addition to having more people, India produces a significantly higher GDP in total and per-capita terms than its neighbors (*GDP- South Asia*, n.d.). As of 2022, India had a GDP of $3.4 trillion, nearly 78% of the total GDP of the region (*GDP- South Asia*, n.d.). Its economic influence is one of its most powerful tools on the international negotiation stage. India used 2.7% of that GDP to pursue rapid military expansion over the past few years (Kumar, 2023). India has the third highest level of military spending in the world, surpassed only by the United States and China (Kumar, 2023).

This growing influence impacts regional and global perceptions of modern-day India. Throughout the literature on Ganges water sharing, India's growing attempts and ability to sway policy decisions in South Asia are frequently noted, and the country is sometimes referred to as a regional hegemon.

One way that India utilizes its power in water sharing negotiations is by only engaging in bilateral talks and agreements with other riparian states (Hassan, 2019). For example, India has declined requests for basin-wide Ganges management strategies and has instead formed separate agreements with Nepal and Bangladesh (Hassan, 2019). By only engaging with one neighbor at a time, India can maintain an imbalance at the negotiation table so that it always has the greater political power (Zeitoun & Warner, 2006). If India were to engage in multilateral negotiations, the other parties would have the opportunity to work together to challenge India's desired outcome (Zeitoun & Warner, 2006). This bilateral insistence is a common strategy in international relations.

There is clearly a complex set of factors affecting the Ganges River and how it can be managed. This presence of compounding factors is not unique to the Ganges—transboundary waterways around the world face varied anthropogenic and environmental challenges that make them so complex. While no two river basins are the same, some of the challenges are similar between rivers and can be used as lessons for future transboundary management. To pursue this analogy, it is worth briefly examining other transboundary river cases, the Colorado and the Nile.

An example of another river that has a highly contentious water scarcity problem is the Colorado River in the United States and Mexico. Like India and Bangladesh, the states along the Colorado River have experienced rapid population growth and water demand over the past few decades (Rivera-Torres & Gerlak, 2021). The river is managed by the 1944 Water Treaty, which

divides water between the countries by volume based on hydrologic data from the time (Rivera-Torres & Gerlak, 2021). This concept is similar to the 1996 Ganges Water Sharing Treaty that divides the Ganges flow between India and Bangladesh based on historical (and now, largely inaccurate) hydrologic data. The 1996 Ganges Water Sharing Treaty is described in more detail in Chapter 2.

Another transboundary river that faces similar questions and challenges as the Ganges is the Nile River, and especially the Blue Nile, which runs through Ethiopia, Sudan and Egypt (Mbaku, 2020). Riparian states along the Nile are currently dealing with an infrastructure dispute regarding the Grand Ethiopian Renaissance Dam. Despite objections throughout the whole process, Ethiopia (the upstream state) built and began filling the reservoir (Mbaku, 2020). Ethiopia has said that the reservoir will not significantly impact Nile flow to Sudan and Egypt, but there is no formal water sharing agreement in place to ensure that (Mbaku, 2020). This contested construction of major infrastructure by an upstream state is similar to the construction of the Farakka Barrage along the Ganges River in India. In both situations, the downstream states have characterized the new infrastructure as an existential threat. The Farakka Barrage will be described in more detail throughout the rest of the review.

Chapter 2

The Farakka Barrage and Associated Water Agreements

Building the Barrage

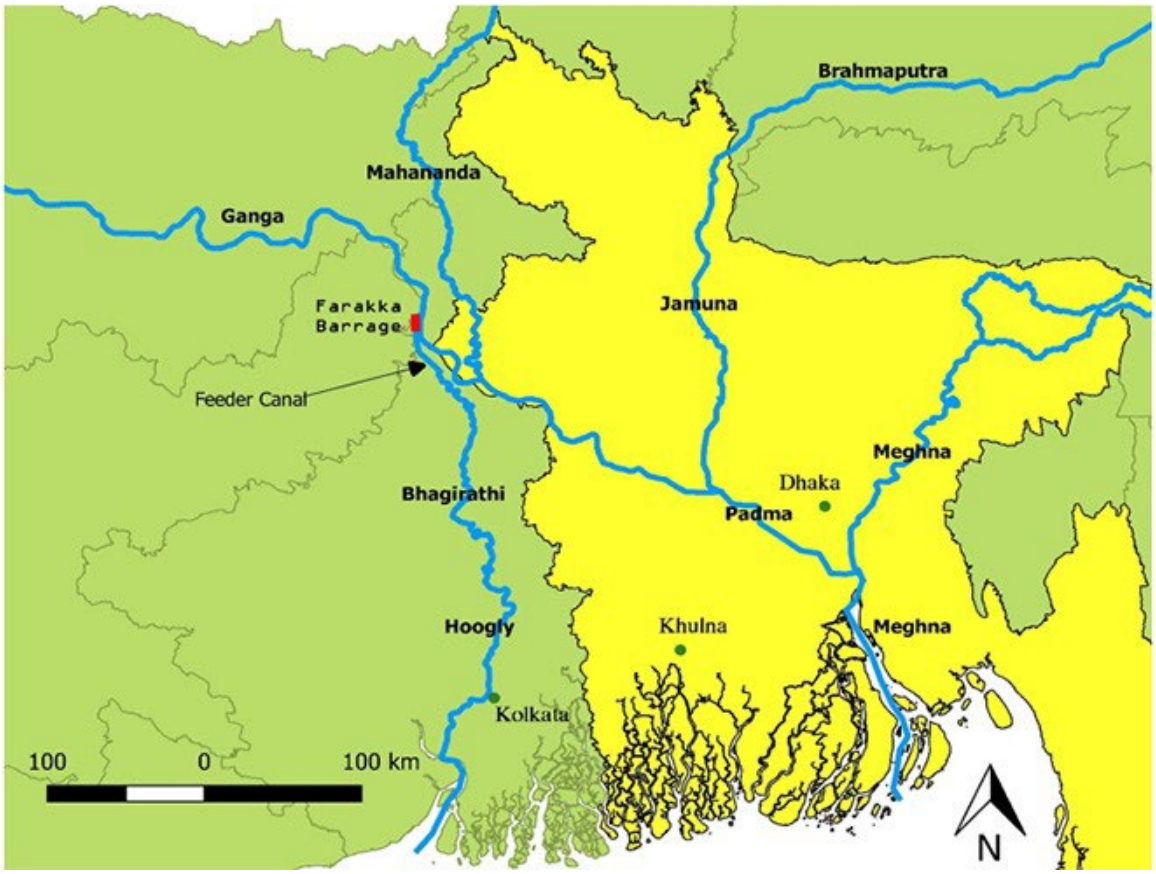
The concept of a barrage at Farakka was the result of decades of discussion about how to improve navigation of the Hooghly River. For centuries, the Hooghly was an important trade route for merchants trying to reach Bengal and sell goods in exchange for rice and textiles (Ivermee, 2017). Trade continued to flourish for centuries, and eventually Kolkata was established along the Hooghly in the late 1600s (Ivermee, 2017). The city relied on the river not only for transport, but also for food, drinking water, health and hygiene (Ivermee, 2017). The Hooghly allowed Kolkata to rapidly grow into the bustling urban center it is today. However, this rapid growth was not without setbacks. Surveys on river depth in the 1800s showed that parts of the river were becoming dangerously shallow for transport (Ivermee, 2017). The river was accumulating about 4 million tonnes of silt from the ocean every year, and it raised concerns about the future of this economically vital region (Singh, 2018).

Starting in the 1910s, India sought the advice of engineers from around the world about how to address this navigability problem (Singh, 2018). Notable consultants included William Willcocks and T.M. Oag, among others (Singh, 2018). However, the plan for the full barrage that became a reality was suggested by Dr. Walter Henson in 1957 based on a report from the Kolkata Port's Hydraulic Study Department (Singh, 2018).

Luckily for Henson, Farakka had already been identified as a valuable area for water resource management and was within India's border (Ranjan, 2021). Indian control of the area

stems back to the 1947 partitioning when Britain delineated a border between India and Pakistan to be respected once granted independence (Ranjan, 2021). The partitioning job was led by Sir Cyril Radcliffe who was tasked with dividing Hindu regions into India and Muslim regions into Pakistan (Ranjan, 2021). However, this task was tangled when it came to the site of the now Farakka Barrage. After so many years of discussion about the Hooghly, the Farakka area was recognized as being strategically important for water management. It sits in the district of Murshidabad, which is primarily made up of Muslims (Ranjan, 2021). Despite Murshidabad's Islamic roots, India expressed strong desire to keep Murshidabad within its borders, and in exchange was willing to give the Hindu majority district of Khulna to Pakistan (Ranjan, 2021). This partition was made and ended up serving as an inflection point in Ganges water management. The public did not respond positively to this exchange and demanded that the cities be redrawn into the countries with their religious majority, but the protests were not successful, and the cities remained as drawn (Ranjan, 2021).

Figure 2: Map of the Farakka Barrage and Feeder Canal



Source: Farakka Barrage. (n.d.). *INSIGHTSIAS*. Retrieved March 28, 2024, from https://www.insightsonindia.com/international-relations/india-and-its-neighborhood/india-bangladesh-relations/teesta-river-issue/farakka-barrage/

Once the idea of the barrage gained traction among decision makers, it was only a matter of time before construction started in the spot indicated in Figure 2. The decision to begin building the barrage was made despite the protest of Pakistan, which repeatedly expressed concerns about downstream water scarcity resulting from the barrage (Singh, 2018). India assured Pakistan that the barrage would not negatively affect its irrigation and that it would primarily redirect water during the monsoon season when the flow is too high in Pakistan (Singh, 2018). Pakistani officials were not reassured, and there were several unsuccessful attempts by Pakistani and Indian officials to meet and find agreement on the issue (Singh, 2018). The

disagreement continued to grow to the extent that the foreign minister of Pakistan accused India of foregoing international law and practice in its construction of the barrage (Singh, 2018). Pakistan attempted to internationalize the issue by raising it at the International Water for Peace Conference in Washington D.C. in 1967 and at the Afro-Asian Legal Consultative Committee meeting in Bangkok in 1968, but India refused to allow a neutral third party or technical experts to broker an agreement (Singh, 2018).

Construction of the barrage began in 1961 and was completed in 1975, four years after Bangladesh became independent from Pakistan (*Farakka Barrage Project*, 2023). The structure is 2.25 kilometers long and has 24 sluice gates and 85 spillway gates (*Farakka Barrage Project*, 2023). There is a road and a railway across the top of the barrage. The feeder canal that carries water from the Ganges to the Hooghly is upstream of the barrage, as indicated in Figure 2, and is 38.38 kilometers long (*Farakka Barrage Project*, 2023). The barrage itself is located 17 kilometers upstream from India's border with Bangladesh (Hassan, 2019). The barrage has diverted water into the feeder canal every year since construction.

Formal Agreements Prior to 1996

The independence of Bangladesh and its new relationship with India ushered in a wave of optimism that the Farakka Barrage could be mutually beneficial. Since the construction of the barrage, the countries have made multiple attempts to manage the Ganges in a fair, coordinated way.

In 1972, the countries agreed to form the Joint River Commission, which was made up of experts from both countries. The commission would conduct hydrological surveys, study

embankments potential, conduct economic feasibility studies and carry out other tasks necessary to best manage the barrage. This independent commission coincides with the recommendations of the Helsinki Rules, UN Watercourses Convention and Berlin Rules described in Chapter 1.

The initial bilateral agreement was formalized in 1977 and was seen as a significant step toward improving Indo-Bangladeshi relations (Kawser, 2016). The 1977 agreement decided how water would be shared between the two countries at Farakka during the dry period, from January to May (Kawser, 2016). The amount of water that each country was allocated was calculated from the 75 percent availability of water at Farakka between 1948 and 1973 (Rahaman, 2006). Note that this calculation did not consider climate change or additional upstream water diversions after 1973. The allocations were divided into periods of ten days with set allocation requirements. The calendar from the 1977 agreement document with each ten-day period can be seen in Table 1. The average ratio of Bangladesh's allocation of the Ganges to India's allocation was 60 percent to 40 percent (Rahaman, 2006). If the actual river flow at Farakka was higher or lower than the predicted flow for a specific 10-day period, the water was divided based on the ratio for that period (Rahaman, 2006). Another important part of the agreement was the 80 percent guarantee clause, which stated that if the actual flow at Farakka was so low that Bangladesh would receive less than 80 percent of its allocated quantity, the allocation would be adjusted so that it receives no less than 80 percent (Rahaman, 2006).

Table 1: Division of water at Farakka mandated by the 1977 Water Sharing Agreement

SCHEDULE

[Vide Article II(i)]

Sharing of waters at Farakka between the 1st January and the 31st May every year.

1	2	3	4
Period	Flows reaching Farraka (based on 75% availability from observed data (1948-73).	Withdrawal by India at Farraka	Release to Bangladesh
	Cusecs	Cusecs	Cusecs
January 1-10	98,500	40,000	58,500
11-20	89,750	38,500	51,250
21-31	82,500	35,000	47,500
February 1-10	79,250	33,000	46,250
11-20	74,000	31,500	42,500
21-28/29	70,000	30,750	39,250
March 1-10	65,250	26,750	38,500
11-20	63,500	25,500	38,000
21-30	61,000	25,000	36,000
April 1-10	59,000	24,000	35,000
11-20	55,500	20,750	34,750
21-30	55,000	20,500	34,500
May 1-10	56,500	21,500	35,000
11-20	59,250	24,000	35,250
21-31	65,500	26,750	38,750

Source: *Bangladesh-India: Agreement on Sharing of the Ganges' Waters.* (1977). Government of Bangladesh.

The agreement also established a Joint Committee to implement its terms and record the water flows at Farakka and at the Hardinge Bridge, which is inside the Bangladesh border (*Bangladesh-India: Agreement on Sharing of the Ganges' Waters*, 1977). Both the Indian and Bangladesh governments nominated representatives to serve on the Joint Committee, and all the data they collected was to be shared with both governments (*Bangladesh-India: Agreement on Sharing of the Ganges' Waters*, 1977).

Soon after the agreement was put into action, the government of West Bengal expressed frustration with it, saying that India's allocation of the water was not enough to maintain the

Kolkata Port (Kawser, 2016). Given that Kolkata Port navigation was the primary reason for the construction of the barrage, this grievance brought into question the success of this $208 million project (Kawser, 2016).

In addition to greater water demands for Hooghly and Kolkata Port navigability, water demand for agriculture continued to rise. The Green Revolution in the 1960s initiated a boom in food production as farmers adopted new agricultural technologies—like high yielding variety seeds, fertilizers, pesticides and more (Crow, 1985). Greater production led to greater water demand, particularly in the Indian states of Punjab, Haryana and western Uttar Pradesh (which contains more than half the length of the Ganges River) (Crow, 1985). As farmers began to accumulate wealth and economic importance in India, they gained significant political leverage (Crow, 1985). Elected officials who wanted to stay in office needed to appease these powerful farmers and keep reliable irrigation water as a top national priority.

By the time the agreement's 1982 expiration began to approach, the feeling of optimism and enthusiasm for Indo-Bangladeshi cooperation had begun to dwindle (Crow, 1985). Both countries were experiencing the realities of an unstable water supply for an ever-growing population. The pressure and efforts to create a future agreement culminated in a two-day official state visit in October, just one month before the agreement expired (Crow, 1985).

When Lt. Gen. Hussein Mohammed Ershad, the military President of Bangladesh, visited Indira Gandhi, the Prime Minister of India in 1982, it was the first time that the leaders of the two countries had met directly in eight years (Claiborne, 1982). Each was accompanied by senior officials, including the Indian Minister of Irrigation and the Bangladeshi Minister of Agriculture. While government accounts of the visit and negotiations described them as "warm and friendly," the result was the willful expiration of the 1977 agreement and a less formal Memorandum of

Understanding in its place (*Joint Communiqué Issued at the End of the Visit of Bangladesh President Hussain Muhammad Ershad to India*, 1982).

Much of the disagreement in the renewal talks centered around the sovereignty of the Bangladesh and Nepal governments. To increase the water flow of the Ganges to better meet India and Bangladesh's needs, the Indian government proposed diverting water from the Brahmaputra River into the Ganges by building another barrage and canal (Crow, 1985). The barrage would have been built within India's territory, giving the country greater control of yet another crucial Bangladeshi waterway. Given the existing conflict over water distribution at Farakka, the Bangladesh government was not keen on handing more resource control to India (Crow, 1985).

Bangladesh in turn proposed that joint action be taken to increase dry season flow in the upstream waters of the Nepalese Himalayas (Crow, 1985). It proposed building over a dozen reservoirs in Nepal to manage the river's flow throughout the year (Crow, 1985). However, the Indian government would not agree to share any resulting increase in flow with Bangladesh and refused to engage in any formal agreement between all three countries (Crow, 1985).

Note that this negotiation process took place between government officials and there is no evidence of farmers being formally engaged in the process. The Berlin Rules, which state that those affected by a water management decision should be included in the decision-making process, were not drafted until decades later.

Without establishing a formal treaty, Bangladesh and India signed a 1982 Memorandum of Understanding (MOU) recognizing that there is limited water in the dry season and that both countries will have to compromise their optimal water allocation (Kawser, 2016). The Joint River Commission was tasked with conducting economic and technical studies over the next 18

months to inform decision makers of how to optimize this limiting situation (Kawser, 2016). The most significant difference between the initial 1977 agreement and the 1982 MOU is that the MOU lacked the 80 percent guarantee clause per insistence of India (Crow, 1985).

It has been noted that the Bangladesh negotiation team had initially expected the guarantee clause to remain in the agreement (Crow, 1985). However, Bangladesh demonstrated a willingness to share the burden of water scarcity with India and the decision to drop the clause was made in a meeting between heads of state during the state visit (Crow, 1985).

The 1982 MOU was in effect until 1984, and then a second MOU was signed in 1985. The 1985 MOU had the same terms as the 1982 MOU but also initiated a yearlong joint study of the available water in both countries to inform an improved allocation plan (*Annual Report 1985-86*, n.d.).

The detailed politics of administration changes is outside the scope of this paper, but the lack of a formal treaty in this period is frequently attributed in the literature to the continued absence of friendly governments (Kawser, 2016).

The 1985 MOU expired in 1988 and there was not another agreement to take its place (Kawser, 2016). India continued to divert water at Farakka to try to maintain Kolkata Port despite the objections of the Bangladesh government (Kawser, 2016). The two countries agreed to relaunch the Join River Commission in 1990, but there was not another formal agreement for sharing of the Ganges until 1996 (Kawser, 2016).

Ganges Water Sharing Treaty of 1996

When considering how a treaty was formed after so many years of disagreement, it is important to have a sense of the political context that led up to the agreement. 1996 was a year of political turmoil in Bangladesh. The party that was in power, the Bangladesh Nationalist Party, was accused of interfering with free and fair elections which launched a wave of protests, election boycotts and an attempted coup (Kochanek, 1997). After months of chaos, the Awami League, which was established before Bangladeshi independence and had ruled from 1973-75, returned to power (Kochanek, 1997).

The Awami League (AL) was seen as a much more pro-Indian government than the Bangladesh Nationalist Party. To curtail concerns that the AL was too pro-India, the AL leader promised to demand a fair share of Ganges flow during the 1996 campaigns (Kochanek, 1997). Still, warmer feelings between the new Bangladesh government and India paved the way for another formal sharing agreement for the Ganges.

In an interview for this research, a senior Bangladeshi water expert reaffirmed the significance of this government change to the development of the treaty, saying, “This is process highly political. Changes in political leadership in the country made negotiations both sweet and sour until the new government came in 1996, which was known to be friendly toward India.”

The final Ganges Water Sharing Treaty identified and laid out terms for three water-sharing scenarios in the low-flow season between January and May. Table 2 shows each scenario as it is organized in the treaty document. The first scenario occurs if there are more than 75,000 cusecs of available water flow when the river reaches Farakka. Note that 1 cubic foot per second (cusec) of flow is sufficient for approximately 35 acres of rice land under direct irrigation, so the 75,000 cusecs can irrigate approximately 2.5 million acres of rice. When there is more than

75,000 cusecs of water, India is to divert 40,000 cusecs into the Hooghly, and the rest of the flow moves onward to Bangladesh (*Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*, 1996). In the second scenario, water flow at Farakka is between 70,000 and 75,000 cusecs. In this case, Bangladesh receives 35,000 cusecs of water and the rest is diverted to the Hooghly (*Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*, 1996). Finally, if the flow at Farakka decreases to 70,000 cusecs or below, India and Bangladesh share the water 50-50 (*Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*, 1996). The 1996 treaty also guarantees that both India and Bangladesh receive 35,000 cusecs in alternating ten-day periods (*Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*, 1996). For example, if the flow drops to 65,000 cusecs in one ten-day period, Bangladesh may get 35,000 cusecs and India gets 30,000 cusecs. If the flow was once again 65,000 cusecs in the next ten-day period, India would get 35,000 cusecs and Bangladesh would get 30,000 cusecs of water.

The treaty also includes text specifying that India cannot divert water from the Ganges downstream of Farakka unless it is less than 200 cusecs and for a reasonable use. (*Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*, 1996).

Table 2: Water sharing requirements of the 1996 Ganges Water Sharing Treaty

Availability at Farakka	Share of India	Share of Bangladesh
70,000 cusecs or less	50%	50%
70,000 cusecs-75,000 cusecs	Balance of flow	35,000 cusec
75,000 cusecs or more	40,000 cusecs	Balance of flow

Subject to the condition that India and Bangladesh each shall receive guaranteed 35,000 cusecs of water in alternate three 10-day periods during the period March 11 to May 10.

Source: *Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic Of India on Sharing of the Ganga/Ganges Waters at Farakka*. (1996). Government of the Republic of India and the Government of the People's Republic of Bangladesh.

It is important to note that while the political dynamics behind the Treaty negotiations are frequently discussed in the literature, there is a lack of attention to whether any civil society agricultural groups or individuals were involved.

In an interview for this research, a senior Bangladeshi water expert said that there are lots of non-governmental organizations raising concerns about farmers' rights and the Farakka Barrage in Bangladesh, but "unfortunately these organizations were not in capacity to take part in the negotiations." He said that today there is a new, growing emphasis on participatory water management practices that involve stakeholders, but he "cannot tell you that these [organizations] are deep-rooted, functional bodies" in the political system.

Also note that the Berlin Rules, which call for those affected by management decisions to be engaged in the decision-making process, were not written or recognized until years after the 1996 Treaty negotiations.

In addition to concerns over lack of stakeholder engagement, the 1996 Ganges Water Sharing Treaty has faced extensive criticism regarding its implementation. Several academic studies and interviews for this research have revealed a common sentiment that the treaty's terms have not been followed. There have also been criticisms of the division plan itself and the data it is based on. The following chapter details these concerns and their impacts on farmers in Bangladesh.

Chapter 3

Impact on Downstream Agriculture and Farmers

Hydrology Changes

The Ganges is an extremely complex river system, so the sudden changes in water flow from the barrage at Farakka had varying effects on downstream hydrology. Not only have different regions experienced different impacts, but those impacts vary throughout the year. This subsection serves as an overview of the implementation of the Ganges Water Sharing Treaty and resulting hydrologic changes in southwest Bangladesh.

The academic literature includes several studies that measure the success of water sharing at Farakka and whether the terms of the treaty are being upheld.

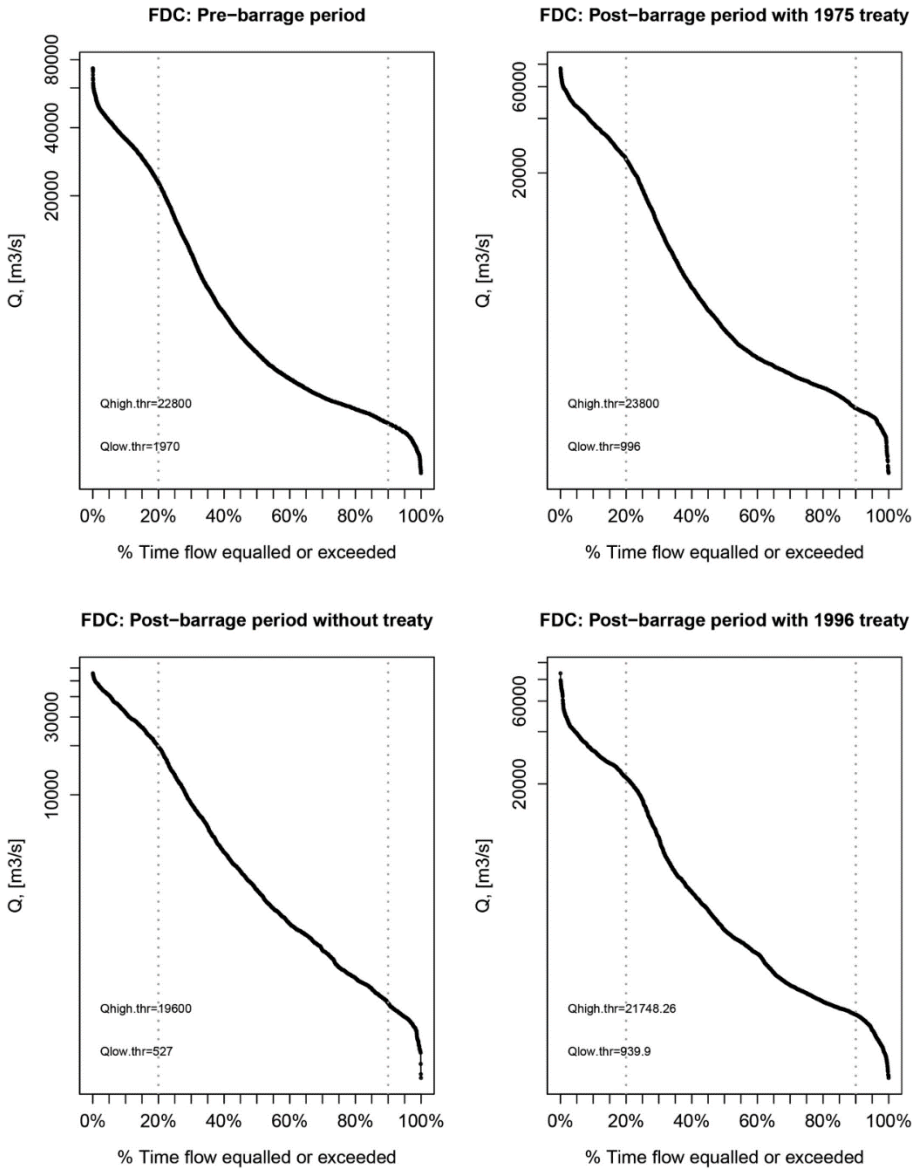
One 2019 study measured the dry season water flow at the Hardinge Bridge, a bridge across the Ganges that is shortly inside the Bangladesh border (Rahman et al., 2019). The study lasted from 1997, when the treaty was first implemented, until 2016 (Rahman et al., 2019). The researchers divided the ten-day periods over five years into 60 separate events that could show change over time. They measured what percentage of time the water flow at Hardinge Bridge did not meet the minimum requirements of Bangladesh's allocation. They found that the agreed upon allocation was not met 31% of the time overall, nor was it met for 65% of the critical dry periods (Rahman et al., 2019).

Another study compares how the actual post-barrage flow during dry season has compared to the expected flow mandated in the treaty from 1997-2016 (Thomas, 2017). The author describes some of the data used in the study as "previously unpublished" and called one piece a "restricted" study from the Bangladesh government (Thomas, 2017). The author used the

data to determine that there has not been a significant decline in water that arrives in Farakka from upstream (Thomas, 2017). It then says that India only withholds more than its water allocation 20% of the time, more often allocating Bangladesh more water than mandated (Thomas, 2017). However, the author notes that the timing of this withholding is key to assessing the success of the treaty and its downstream consequences (Thomas, 2017). The study finds that Bangladesh does not receive its minimum allocation 55% of the time during the critical periods when Bangladesh is most strained for water (Thomas, 2017). Therefore, India generally follows the terms of the treaty, but it does so strategically so that it benefits during the critical dry season. This study also notes that wet season flow into Bangladesh should not be negatively impacted by the barrage (such as causing more floods) because it is not a holding structure, and without it all the flow would go into Bangladesh anyway (Thomas, 2017).

A third study took a different approach to studying water quantity downstream at Farakka. The data was collected at SW90, a discharge station along the Ganges inside the Bangladesh border (Murshed et al., 2019). Instead of looking at water allocation after the 1996 treaty, it includes data from 1976 when the barrage began operating through 2015. As depicted through flow-duration curves in Figure 2, the results showed that from 1976-1989, the period when the 1977 Water Sharing Agreement and MOUs were signed, the flow at SW90 was 49% less than it was before the construction of the barrage (Murshed et al., 2019). From 1990-1996, when there was not an agreement governing flow at Farakka and India was unilaterally withdrawing water, the flow at SW90 was 73% lower than pre-barrage flow (Murshed et al., 2019). Finally, from 1997-2015, the flow was 52% lower than it was pre-barrage (Murshed et al., 2019). The in-depth study also looked at multiple variables related to climate variability, salinity changes, population and land use trends.

Figure 3: Flow-duration Curves under Different Management



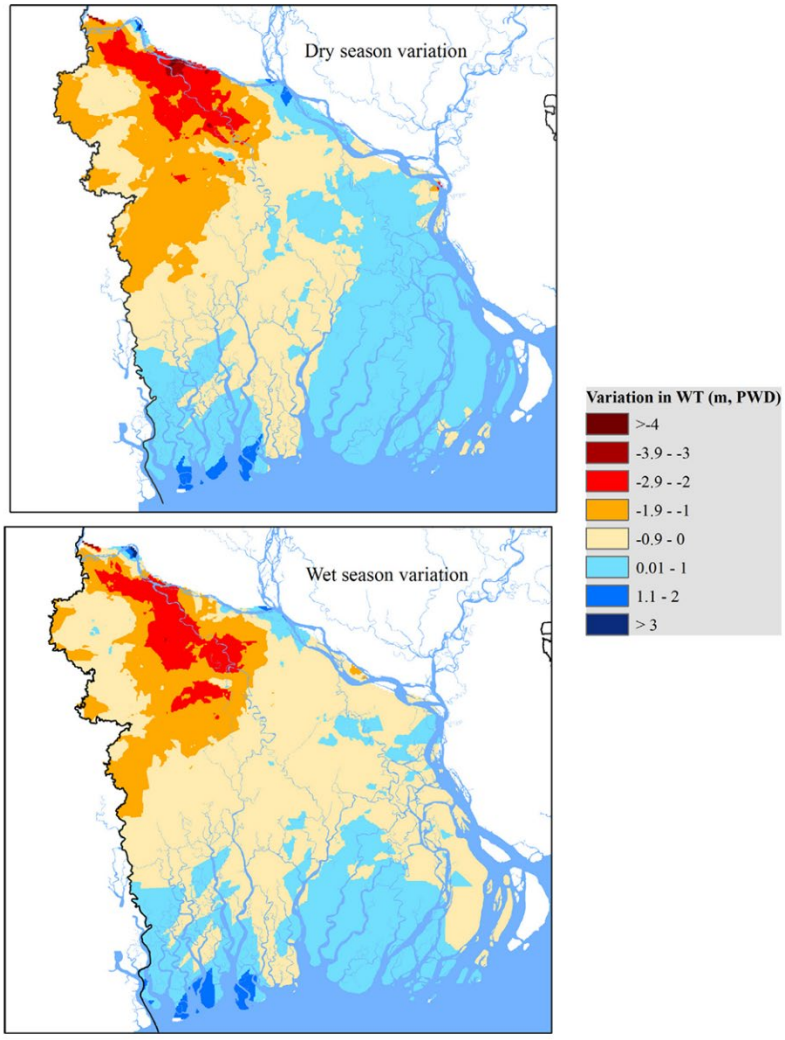
Source: Murshed, S. B., Rahman, R., & Kaluarachchi, J. (2019). Changes in Hydrology of the Ganges Delta of Bangladesh and Corresponding Impacts on Water Resources. *Journal of the American Water Resources Association,* 55(4). https://doi.org/10.1111/1752-1688.12775

The decline in available freshwater in the Ganges post-barrage has different effects in different regions of Bangladesh. When the river first fully enters the country, along and below the districts of Kushtia and Rajbari, the biggest hydrologic impact is the decrease in available surface water and the corresponding lowering of the water table (Murshed & Kaluarachchi,

2018). Figure 4 below shows how the average depth of the water table below sea level has changed from 1967-1980 to 2006-2015 (Murshed & Kaluarachchi, 2018). As indicated by the red highlight, the upstream portion of the Ganges in Bangladesh faces the greatest decrease in water level (Murshed & Kaluarachchi, 2018).

It is important to note that within the region's water cycle, surface water is directly linked to groundwater and serves as an important part of its replenishment. During the Green Revolution, farmers in the region transitioned from traditional crops to high-yielding varieties (Thomas, 2017). For example, many rice farmers began using Boro rice, which grows during the dry season (Thomas, 2017). These high-yield crops are typically more resource intensive than traditional ones, so demand for irrigation water rose. Farmers began to transition from variable surface water supplies to seemingly reliable groundwater supplies for irrigation purposes (Thomas, 2017). The combination of the increased demand and dwindling surface water replenishment has continuously drained available groundwater and has even affected domestic water supply (Thomas, 2017).

Figure 4: Change in Mean Water Table Depth from 1967-80 to 2006-15



Source: Murshed, S. B., & Kaluarachchi, J. (2018). Scarcity of fresh water resources in the Ganges Delta of Bangladesh. *Water Security*, *4*, 8–18. https://doi.org/10.1016/j.wasec.2018.11.002

The problems associated with decreased water supply downstream of Farakka are further exacerbated by changing climate in the region. According to a 2019 study, average temperatures in the lower Ganges basin have been rising since the construction of the barrage (Murshed et al., 2019). Rising temperatures have led to increased evapotranspiration throughout the region, which can inhibit plant growth if available water is depleted (Murshed et al., 2019). The

combination of the anthropogenic decline of Ganges water flow and climatic warming has contributed to growing water insecurity in the region.

Farther down the Ganges and in the coastal districts along its distributaries, freshwater scarcity is due to salinity concerns more than quantity concerns. The Ganges River ends at the Ganges River Delta where the water flows into the Bay of Bengal. When there is high, steady water flow down the Ganges, the flow of freshwater flushes out into the bay and prevents much of the saltwater from creeping upstream (Murshed et al., 2019). However, in the drier months, the lower water levels do not have strong enough flow to hold the saltwater back. Seawater from the Bay of Bengal makes its way up the rivers and streams that distribute to it, increasing salinity farther inland. Saline water cannot be used for irrigation or domestic use, so populations along these affected areas increasingly rely on groundwater, which is also inexorably salinizing (Murshed et al., 2019).

This thesis primarily focuses on the dry season impacts of the Farakka Barrage, but one should note that there are water-related damages and disasters in the wet season as well. The sharp changes in water flow between dry season and wet season amplify riverbank erosion which can lead to loss of farmland, homes and other infrastructure adjacent to the river. Within the literature, there is also debate about whether the barrage has made monsoon season flooding better or worse. Whether or not the impacts or severity of flooding have changed, the number of dangerous floods has significantly decreased over the past century. From 1911-1920, before the barrage was constructed, there were seven dangerous flood events along the Ganges in Bangladesh (Murshed et al., 2019). There was only one dangerous flood from 2001-2010 and none from 2004-2014 (Murshed et al., 2019).

To respond to the wide-ranging consequences of the barrage, some researchers have recommended adjustments to the Ganges Water Sharing Treaty when it expires in 2026.

The Rahman et al. paper identifies four potential reasons that the water flow at the Hardinge Bridge falls below the agreed amount. First, it says that the treaty did not accurately incorporate upstream withdrawals and climate variability when projecting future flow. This inaccurate projection led to inequitable flow cut-off points in the treaty (Rahman et al., 2019). Second, it identifies that the implementation of the guaranteed flow created drastic changes in flow for both countries and decreased their available water in the most critical periods. It recommends removing this version of a guaranteed flow in a future treaty and managing low flow periods by percentage (Rahman et al., 2019). Third, the study identifies discrepancies between the flow allocated to Bangladesh at Farakka and the flow at the Hardinge Bridge. The data frequently showed lower flow at the Hardinge Bridge despite an additional tributary entering the Ganges after Farakka and a ban on additional Indian withdrawal (Rahman et al., 2019). The authors recommend additional study to determine the cause of this flow discrepancy. Finally, the study does recommend a guaranteed flow clause in extreme conditions when flow at Farakka falls below 50,000 cusecs (Rahman et al., 2019). This guarantee would serve as additional protection for Bangladesh and incentivize India to minimize Ganges withdrawals farther upstream (Rahman et al., 2019).

The Thomas study does not make such direct recommendations about how the treaty could be changed, but it raises important questions to consider in a renegotiation. It asks how cooperation will be defined in this situation, citing that India believes it is already cooperating and Bangladesh continues to ask for more (Thomas, 2017). It also identifies ways that reported compliance with the treaty may not be as accurate as it seems (Thomas, 2017). This paper offers

a new way to consider the success of the Ganges Water Sharing Treaty, paving the way for negotiations of the future.

The Murshed et al. study takes a different approach to future recommendations, focusing on providing detailed data patterns to inform future policy change. It does not directly list ways to improve the treaty, but it does warn that "this inconsistent pattern of available instream water is a forewarning to take immediate steps to deal with water scarcity" (Murshed et al., 2019).

While the 2019 study did not offer much detail on future treaty recommendations, lead author Dr. Sonia Murshed responded to the question in a verbal interview for this research. She suggested that 1) data sharing between the two countries be more open and transparent so that the success of the treaty can be assessed, 2) that the river be managed multilaterally and 3) that both Bangladesh and India sign and ratify the 1997 UN Watercourses Convention.

An environmental social scientist from Bangladesh also called for greater transparency and accountability with water sharing data in an interview for this research. He suggested that the next treaty seek the assistance of the international community or a neutral party to ensure a fair agreement.

Additionally, a senior Bangladeshi water expert expressed that a treaty should reflect the public sentiment about the issue. He also expressed a need to stop further diversion of water upstream of the barrage.

One of the biggest groups that will be affected by the terms of a future agreement are the farmers that rely on the Ganges for irrigation. The next section will discuss the impact the barrage has had so far on agriculture in Bangladesh.

Agricultural Production Changes

These widespread and severe hydrology changes along the Ganges River have impacted the way farmers operate, the success of crops and what they are growing. Agriculture is a major industry in Bangladesh—about 11.55 million hectares of land in the country are used for agricultural production (Mamun et al., 2021). The country is a top ten producer of 22 different crops and the third largest producer of rice in the world. Other major crops include lentils, onions, potatoes and tea ("Bangladesh among Top Ten Producers of 22 Agri Products," 2023). Because of rice's agricultural and consumption dominance in the country, this section will primarily focus on how rice production has changed.

There are three main types of rice in Bangladesh that are grown in different times of the year. Aus rice is grown from July to August, Aman rice is grown from December to January, and Boro rice is grown from March to May (Chakraborty, 2017). Note that Boro rice is grown and irrigated during the dry season, making water application easier to control without floods and cyclones to worry about (Mainuddin et al., 2020). Aman rice is cultivated on a larger portion of land than the other two varieties, but more Boro rice is produced overall (Chakraborty, 2017). This difference between amount of land and level of production is due to Boro rice's high-yield capacity. Boro rice can produce about 3.99 tons/ha but Aman and Aus rice can only produce 2.23 tons/ha and 2.38 tons/ha, respectively (Chakraborty, 2017). The combination of more irrigation control over Boro rice, its higher level of productivity, government incentives and other factors has made it an increasingly attractive crop to farmers over the past few decades.

Agricultural production in Bangladesh began booming in the mid-1960s. Worldwide changes in agricultural practices like systematic fertilizer usage, genetic improvements of crops and higher quality seeds made it possible for Bangladesh's rice production to grow from about

11 million tons in 1971 to about 36.6 million tons in 2020 (Al Mamun et al., 2021). This rapid growth has taken its toll on Bangladesh's resources. In the past 30 years, demand for irrigation water in southwest Bangladesh has risen by 498% and accounts for 94% of available freshwater (Murshed et al., 2019). Demand for irrigation water continues to grow, yet the supply remains limited by the barrage, climate change and the natural limits of the river.

Farmers feel the strain on available freshwater firsthand. Some have reported an inability to irrigate because groundwater levels have fallen below the depth of pumps or because irrigation canals are dry (Mirza & Hossain, 2004). Additionally, farmers near coastal Bangladesh have been hit hard by intruding salinity from the Bay of Bengal (Mirza & Hossain, 2004). It is difficult to quantify yield loss from the Farakka Barrage because of how many other complex factors impact river flow. However, we can look at how lower availability of fresh water and higher salinity affect farmers' livelihoods to understand its impact.

One of the major trends in southern Bangladesh is the conversion of crop farming to shrimp farming. Crop farming requires fresh water to irrigate plants, but shrimp farming uses saline water (Fatema & Miah, 2011). As salinity increases and moves inland, many farmers have decided to take advantage of it and transition to shrimp production (Fatema & Miah, 2011). The rise of shrimp farming has caused contention between the shrimp and crop farmers. When shrimp farmers pump saline water to their land, it leaves the soil severely dehydrated (Fatema & Miah, 2011). The use of shrimp feed and other chemicals needed for cultivation further damages the fertility of surrounding soil (Fatema & Miah, 2011). As shrimp farming spreads, it destroys the productivity of rice, wheat and vegetable farms throughout the region (Fatema & Miah, 2011). Lower productivity means lower income and drives more farmers to convert to shrimp farming, which then harms the soil even more for others, creating a dangerous feedback loop.

The ever-growing environmental stress along the Ganges has also driven migration to urban centers (Ahmed, 2021). When farm output is not enough to support families, men have tended to move to cities for varied amounts of time to get additional jobs (Ahmed, 2021). Women are often left to tend to the farming operation despite their exclusion from many male-dominated agricultural resources and communities (Ahmed, 2021). If opportunities are better in the cities, entire families will sometimes move there, leaving their farming livelihood and lifestyle behind.

It is also important to note that because irrigation is such a major user of available freshwater, a common perception is that farmers are wasteful with irrigation. However, a 2020 study challenges that perception. It found that Bangladeshi farmers who rely on shallow tube wells are often prudent with their water usage, and the amount of water applied to crops is very close to the amount of water that the crops need (Mainuddin et al., 2020). Bangladeshi farmers are aware of their limited water supplies and are being cautious about how they use it in the dry season. In a different study that hosted discussions with farmer groups throughout Bangladesh, the top two issues that farmers identified were the need for more irrigation and increasing climate variability (Sala & Bocchi, 2014)—two issues that are shown in this review to be serious concerns. Accusations that the water scarcity problem in Bangladesh is caused by farmers' ignorance or carelessness about their irrigation practices are not supported.

Public Response

The Farakka Barrage has received public comment, support and criticism from both sides of the border since its conception.

The largest public demonstration against it took place only a year after it was completed, in 1976 (Kawser, 2016). The Bengali political figure and independence leader Maulana Abdul Hamid Khan Bhasani attempted to rally Bangladeshis against the barrage, saying that it would cause desertification in Bangladesh (Kawser, 2016). He organized a march from Rajshahi, Bangladesh to Farakka in a symbolic attempt to tear down the barrage (Kawser, 2016). Hundreds of thousands of people showed up to march and they made it to the Bangladesh-India border (Kawser, 2016). While the Bangladeshi government tried to indicate support for the march, it worked alongside India to ensure that there was no real damage to the barrage and no serious conflict erupted (Kawser, 2016). The protest became known as the Farakka Long March.

According to 2004 study, media coverage of the Farakka Barrage and the Farakka Long March seemed to miss the point of the march and failed to draw continued attention to civilian concerns about it (Naser et al., 2004). Coverage of the march focused on its political implications but did not have as much emphasis on the ecological concerns driving it. The author identifies the lack of accurate reporting as a result of uninformed journalists who either did not understand the complexity of the Ganges system or could not access enough data to analyze it (Naser et al., 2004). The paper also says that many of the environmental media's sources at the time were government officials, so the information they gathered could have been incomplete or misleading (Naser et al., 2004).

A robust news media is an essential part of maintaining an informed and engaged electorate, so this lack of coverage raises serious concerns about the public's knowledge of their own water management. Without being able to keep up with news and impacts of the Farakka Barrage, the public is limited in its ability to call for changes.

It is important to note that while the Naser paper calls for more comprehensive critique of the Farakka Barrage, there is also positive public sentiment toward the barrage. For example, Dr. Kausik Ghosh, a hydrology and sedimentology expert from India, positively expressed in an interview for this research that the barrage has helped mitigate downstream flooding by diverting some of the natural flow away from Bangladesh during the wet season. He noted that for an upstream country, it is easier to focus on the benefits of water sharing infrastructure, and for a downstream country, it is easier to blame that infrastructure for environmental problems.

In addition to insufficient media coverage of the barrage, some farmers face additional barriers to understanding barrage management. The last thing on the minds of farmers living in poverty is international advocacy, an environmental social scientist said in an interview for this research. Additionally, some farmer groups are particularly vulnerable to exclusion from important water resource information systems.

For example, those with large farming operations have more influence and capital to stay up to date and respond to environmental threats than small farming operations do. Small farmers have less access to community resources and are therefore more susceptible to crop and land damage (Ahmed, 2020). Female farmers are also disproportionately unsupported because they are often excluded from community social structures (Ahmed, 2020). Ahmed found that women are less likely to receive warnings about natural disasters because they have weaker relationships with extension agents (Ahmed, 2020). In some cultural and religious contexts, women cannot have solo interactions with men outside their family, further separating them from the local agricultural network (Ahmed, 2021). Religion can also play a role in farmers' level of influence and ability to utilize community resources. Muslims are the majority in the Ganges Delta and

Hindus are the minority (Ahmed, 2020). Hindus tend to make less money for their crops than Muslims do and are excluded from informative and supportive social networks (Ahmed, 2020).

These groups face multiple barriers to the resources that help farmers prepare for severe hydrology changes, so they end up experiencing the brunt of the negative impacts. The result is that the people who feel the impacts of the Farakka Barrage the most are the ones with the least political agency to do something about it.

Conclusion

This review considers the unique factors of the Ganges River Basin and how they have led to a water sharing agreement that harms downstream agriculture. After considering the issue from hydrological, political and cultural perspectives, it was found that 1) management of the Ganges is determined by high-level politics and institutional factors more than internationally recognized transboundary principles, 2) that the river basin is heavily influenced by complex anthropogenic and environmental factors that are often oversimplified, 3) both experts and the public have continued to express discontent with the management of the Farakka Barrage throughout history and 4) there are opportunities for greater stakeholder engagement in the renegotiation of a Ganges water sharing agreement in 2026.

As noted in the Frameworks and Guidelines for Transboundary Management section, the international community's recommendations for transboundary waterways include no significant harm to downstream riparian states, open information sharing and stakeholder engagement. It could be argued that the water quantity and salinity problems downstream of Farakka qualify as significant harm, and that data sharing between the two countries near Farakka is not transparent. Additionally, it was not found that civil society stakeholders from the agricultural sector were included in the decision-making process. Therefore, the current management of the Ganges does not align with internationally recognized principles.

The review also finds that there are a multitude of factors influencing Ganges water use for agriculture, so attribution of current water flow to a single piece of infrastructure would be an oversimplification. Climate change has been rapidly affecting precipitation and temperature in the basin, the expansion of irrigation has increased water demand almost five times over, the change in what types of crops farmers are growing has shifted resource strain, political

administrations have held different priorities and more. All of these factor affect the flow of the Ganges. The Farakka Barrage certainly contributes to it, but it cannot be labeled as the sole influence.

It can also be seen throughout the history of the barrage that its construction and management is misaligned with a large portion of the population's opinion. From the Farakka Long March in 1976 to today's frequent criticisms of the 1996 Ganges Water Sharing Treaty in academic literature, the people of India and Bangladesh have continued to express their concerns, doubts and new ideas about the way the barrage is managed.

Finally, there is an opportunity to improve future sharing of the Ganges with the expiration of the 1996 Ganges Water Sharing Treaty in 2026. While previous negotiations lacked formal, well-documented inclusion of farmers and agricultural stakeholders, this renegotiation should include farmers from both countries throughout the process. The Farakka Barrage impacts agriculture more than any other industry so it is essential that farmers' voices and experiences are heard. This stakeholder engagement would make a future agreement more closely aligned with today's prominent transboundary guidelines.

The literature on the Farakka Barrage is extensive—from its political origins to its ecological impacts to its role as one of the most widely known transboundary rivers in the world. Each piece of research offers its own insight into the river basin, and it takes dozens of studies to even begin building a wholistic perspective on Ganges water sharing. The literature on the Farakka Barrage stands out because a notable portion of it seems to clearly reflect the opinions of the authors. While opinionated articles raise some red flags, in this case they were referenced to paint a better picture of the varied perspectives on the barrage. One cannot understand the complexity of the barrage debate without understanding the claims and central facts of the people

disagreeing. While not a review of public opinion, this thesis attempts to introduce readers to the wide range of factors that inspire such varied (and sometimes heated) perspectives. It is the hope that readers will draw from this review that Ganges water sharing is far from a black and white issue.

Despite the intensive research on the Farakka Barrage and Ganges water sharing, there is a gap in the literature. The civil society stakeholders who influenced or were involved in the series of water sharing negotiations are seldom mentioned in prominent literature. There are studies that describe the government ministries and public individuals who were involved, but not the farmers organizations or civil agricultural leaders/practitioners whose efforts may have influenced the agreements. Farmers are one of the most highly impacted groups affected by the Farakka Barrage, so their participation in the water sharing process, whether formal, informal or nonexistent, should be evaluated. A future study on farmer engagement in Ganges water sharing could serve as a lesson for other governments hoping to engage with citizens on transboundary river issues.

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