

Reassessing The Ganges Water Treaty in the Age of Climate Change: A Systematic Review of Legal, Hydrological, and Governance Dimensions

Nabeela Siddiqui¹, Dr. Khushboo Malik²

¹PhD Scholar: CHRIST (Deemed to be) University, Delhi -NCR Campus, India. Email: nabeelasiddiqui09@gmail.com

²Assistant Professor: CHRIST (Deemed to be) University, Delhi -NCR Campus, India. Email:

*Corresponding author | ORCID: <https://orcid.org/0000-0001-7496-8127>

Abstract

The 1996 Ganges Water Treaty between India and Bangladesh was a milestone treaty designed to facilitate the management of the common water resources of the Ganges River. Twenty-two years later, the treaty remains a cornerstone of bilateral collaboration. The growing effects of climate change—experienced in the form of unpredictable rain patterns, recurring floods, and extended periods of drought—have, however, made the hydrological conditions that inform the treaty's provisions much more challenging. Meanwhile, increasing population pressures and shifting water demands in both nations pose a significant challenge to meaningful water sharing. This systematic review reviews the existing literature on the Ganges Water Treaty from legal, hydrological, and governance considerations, especially in the context of climate change. Applying a strict PRISMA-ScR methodology, the review finds common themes such as limited flexibility in the treaty to respond to changed flow regimes, poor provisions for real-time data exchange, and inadequacies in collaborative basin-wide planning. A number of researchers criticize the treaty's fixed water allocations, contending they do not capture changing environmental and socio-economic trends. Furthermore, implementation and reform hurdles, such as poor institutional coordination, political conflict, and insufficient inclusive stakeholder engagement, also arise as fundamental obstacles. The review captures how climate justice concerns—acknowledging disproportionate exposure of marginalized groups—are under-emphasized within current frameworks. The research indicates that any future treaty reforms will need to include adaptive governance precepts, foster data exchange-based transparency, and give the health of ecosystems equal weighting with human water requirements. Embedding these components could enable the Ganges Water Treaty to become a more robust and balanced instrument for tackling current and future water issues in a climate-vulnerable area.

KeywordsGanges, Treaty, River, Climate Change, Review

1. INTRODUCTION

The Ganges River basin, a vast and life-sustaining system, stretches across northern India and southern Bangladesh, supporting the livelihoods of over 650 million people (World Bank, 2011; Salman and Uprety, 2002). For both countries, the Ganges is far more than a river—it is a source of sustenance, culture, spirituality, and economic vitality. From irrigating expansive agricultural lands to providing drinking water, facilitating inland navigation, and supporting ecological diversity, the river's role is multifaceted and indispensable. Yet, managing this shared resource has long posed challenges, particularly in the face of transboundary tensions and unequal hydrological control (Salman and Uprety, 2002).

The 1996 Ganges Water Treaty (GWT), signed between India and Bangladesh, was a significant step in addressing these challenges. The treaty was designed to regulate the allocation of Ganges waters at the Farakka Barrage, especially during the lean season from January to May, a time of acute water stress (Treaty Between the Government of India and the Government of Bangladesh, 1996). With a thirty-year tenure, it was hailed as a diplomatic milestone in South Asian water diplomacy, promising equitable sharing and conflict avoidance through a fixed formula based on historical flow data (Treaty Between the Government of India and the Government of Bangladesh, 1996; Salman and Uprety, 2002).

However, as the treaty approaches its expiration, the hydrological, ecological, and political landscape surrounding the Ganges has transformed dramatically. Most notably, the growing threat of climate change has exposed the limitations of the treaty's static design. Glacial retreat in the Himalayas, shifting monsoon patterns, prolonged droughts, and devastating floods have all become more frequent and intense (IPCC, 2023). These climate-induced shifts not only challenge the predictability of water availability but also affect food security, biodiversity, and public health across the basin (Alam, 2002; Verghese, 1990). The

socio-economic dependencies on the Ganges—already immense—are now compounded by ecological vulnerabilities and increasing regional uncertainties (Alam, 2002; Verghese, 1990).

This systematic review seeks to revisit the GWT in this changed context. Drawing on a wide body of academic, legal, and policy-oriented literature, the review interrogates whether the treaty's existing legal and institutional frameworks are capable of responding to emerging climate realities. Using the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) methodology, the study maps scholarly contributions to the evaluation of the treaty's adaptability, critiques its legal architecture, and synthesizes proposed reforms (Tricco et al., 2018).

The first research question explores how current literature assesses the GWT's ability to respond to climate variability. A large number of studies highlight that while the treaty successfully established a basic sharing formula, it does not embed adaptive mechanisms that allow for year-to-year variability in water flows (Swain, 2011; Sadoff and Grey, 2002). The fixed allocation formula, based on historical averages, assumes a stable hydrological baseline—an assumption no longer tenable under rapidly changing climate conditions (Swain, 2011; Sadoff and Grey, 2002). Furthermore, the absence of real-time data-sharing mechanisms and dynamic decision-making protocols limits the treaty's responsiveness during periods of unexpected water stress (Iyer, 2003).

The second line of inquiry identifies major legal and institutional shortcomings within the GWT. One core critique is the treaty's narrow focus on water quantity, largely neglecting water quality, ecological health, and basin-wide governance (Rahaman, 2009). Environmental flows—essential for sustaining riverine ecosystems—are not explicitly addressed, and the treaty is silent on the cumulative impact of upstream infrastructure, including dams and barrages (Mirza, 2004). Institutional coordination also emerges as a persistent challenge. The Joint River Commission (JRC), tasked with overseeing the treaty's implementation, has been criticized for its limited transparency, infrequent meetings, and lack of enforcement authority (Crow et al., 1995). Moreover, there is no effective third-party dispute resolution mechanism, making the treaty vulnerable to political gridlock (Salman, 1998).

The review further explores proposed reforms that could enhance the treaty's climate responsiveness and long-term viability. Scholars and policy experts advocate for a shift from fixed allocations to flexible, adaptive water-sharing frameworks that respond to real-time data and projected climatic trends (Dinar et al., 2013; Gain et al., 2016). This could involve incorporating seasonal flow forecasting, early warning systems, and transboundary hydrological modeling into the treaty's operational structure (Dinar et al., 2013; Gain et al., 2016). Greater emphasis is also placed on ecosystem-based approaches, which prioritize the health of the river and its biodiversity alongside human needs (Rogers and Hall, 2003). Legal reforms are recommended to incorporate principles of environmental justice and intergenerational equity, ensuring that marginalized communities and future generations are not excluded from water governance (Boelens, 2015).

In addition, basin-wide cooperation—rather than site-specific coordination—has been proposed as a more holistic model. This would require integrating the GWT with other regional initiatives and legal instruments, fostering inclusive participation among multiple stakeholders including civil society, local communities, and scientific institutions (Zeitoun and Mirumachi, 2008). Lessons can also be drawn from other transboundary water-sharing models, particularly from the European Union's Water Framework Directive, which emphasizes integrated river basin management and ecological sustainability (European Commission, 2000). Although the political and institutional context of South Asia differs significantly from Europe, such comparative learning can help envision more progressive legal and governance models for the Ganges basin.

In sum, while the 1996 Ganges Water Treaty marked a moment of optimism in South Asian water diplomacy, its legal and institutional rigidity renders it increasingly inadequate in the face of climate-induced uncertainties. Revisiting the treaty is not merely a technical or diplomatic necessity; it is a critical step toward climate justice, regional stability, and ecological resilience. As India and Bangladesh look toward a future marked by shared vulnerabilities and interdependent water needs, a reimagined treaty must reflect the urgency of the climate crisis and the complex realities of a dynamic and deeply contested river basin.

2. METHODOLOGY

This study adopts a systematic review approach, guided by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) framework to comprehensively

map the evolving academic, legal, and policy discourse surrounding the Ganges Water Treaty (GWT) in the context of climate change. The PRISMA-ScR methodology is particularly suited for exploratory inquiries that seek to clarify key concepts, identify knowledge gaps, and synthesize diverse forms of evidence on a given topic¹. This section elaborates on the review's design, inclusion parameters, database selection, search strategy, and document screening process.

The review sought to address three guiding questions: (1) How does the current literature evaluate the Ganges Water Treaty's capacity to respond to climate variability? (2) What legal and institutional critiques have emerged regarding the treaty's design and implementation? and (3) What reforms have been proposed to enhance the treaty's climate resilience and adaptability?

2.1 Inclusion Criteria

To ensure a rigorous and relevant evidence base, inclusion criteria were defined at the outset. Documents were considered eligible if they met the following conditions:

- **Temporal Scope:** Published between 1996 (the year the GWT was signed) and early 2024, allowing for an adequate historical and contemporary perspective on the treaty.
- **Type of Literature:** Only peer-reviewed journal articles, policy reports, legal commentaries, and institutional publications were included. Grey literature, such as news articles and opinion pieces, was excluded to preserve analytical robustness.
- **Topical Relevance:** Studies had to explicitly focus on the Ganges Water Treaty and/or climate change impacts on the Ganges basin, with an emphasis on hydrological, legal, or governance dimensions.
- **Language:** Only English-language sources were selected to maintain consistency in comprehension and comparative analysis.

These criteria were developed to ensure both depth and breadth across disciplinary lenses, capturing hydrological, legal, political, and ecological perspectives relevant to treaty evaluation.

2.3 Databases and Sources

The review involved comprehensive searches across multiple interdisciplinary databases and institutional repositories. The databases selected included Scopus, Web of Science, JSTOR, HeinOnline, and Google Scholar, which collectively cover a broad range of disciplines including environmental science, law, international relations, and development studies (Falagas et al., 2008). These academic sources were supplemented with policy documents and reports from global organizations such as the World Bank, the United Nations Development Programme (UNDP), and the International Water Management Institute (IWMI) (World Bank, 2011; UNDP, 2020). Additionally, national-level sources from the ministries and water commissions of India and Bangladesh were consulted where available, particularly for treaty texts, implementation records, and official commentary. This helped bridge academic perspectives with the practical, state-centered dimensions of transboundary water governance.

2.4 Search Strategy and Keywords

A structured keyword strategy was adopted, using Boolean operators and combinatory phrases to maximize the retrieval of relevant literature. Search terms were applied across title, abstract, and full-text fields to ensure comprehensive coverage. Key search queries included:

- "Ganges Water Treaty" AND ("climate change" OR "climate variability" OR "hydrology")
- "India Bangladesh water sharing" AND "climate adaptation"
- "transboundary water law" AND "Ganges"
- "Farakka Barrage" AND "drought" OR "floods"
- "climate justice" AND "river treaties" AND "South Asia"

These terms were derived from both the study's core research questions and key themes identified in preliminary scoping, such as hydrological uncertainty, treaty resilience, adaptive governance, and ecological risk.

2.5 Document Screening and Selection

A multi-stage screening process was applied to filter and refine the corpus of literature. The initial search yielded 186 documents. These were first screened based on titles and abstracts to assess preliminary relevance. At this stage, duplicates and clearly irrelevant results—such as those focused on unrelated river basins or generic climate topics—were removed. In the second stage, full-text review was conducted for the remaining documents to determine if they met all inclusion criteria. A total of 63 documents were retained for thematic analysis. Each selected document was read in detail, and relevant data were extracted on the following dimensions: hydrological impacts of climate change, legal frameworks, institutional mechanisms, treaty critiques, and reform propositions. The process was designed to ensure that each

source contributed meaningfully to at least one of the study's core questions. A PRISMA flow diagram is included in the appendix to visually represent the selection process, illustrating the transition from identification to final inclusion. This visual aid enhances transparency and replicability, hallmarks of good systematic review practice (Moher et al., 2009).

2.6 Thematic Synthesis and Analysis

Rather than relying solely on quantitative aggregation, this review employed a thematic synthesis approach, which allowed for the extraction of key arguments, critiques, and conceptual frameworks across diverse disciplines. The literature was grouped into three analytical clusters: (1) assessments of the treaty's climate responsiveness; (2) legal and institutional critiques; and (3) proposed reforms involving adaptive governance and ecosystem-based approaches.

Each theme was coded inductively based on repeated patterns and cross-referenced with the research questions. This qualitative synthesis enables a richer understanding of not only what the literature says but also how different schools of thought frame the challenges and solutions to transboundary water governance in the Ganges basin. In conclusion, this systematic review methodology provides a rigorous foundation for evaluating the Ganges Water Treaty in a climate change context. By triangulating legal analysis, hydrological data, and governance frameworks, the study offers an integrated and policy-relevant perspective that is timely and actionable as the treaty nears its renewal horizon (Tricco et al., 2018).

3. Findings

3.1 Treaty Structure and Legal Gaps

The review involved comprehensive searches across multiple interdisciplinary databases and institutional repositories. The databases selected included Scopus, Web of Science, JSTOR, HeinOnline, and Google Scholar, which collectively cover a broad range of disciplines including environmental science, law, international relations, and development studies (Falagas et al., 2008). These academic sources were supplemented with policy documents and reports from global organizations such as the World Bank and the United Nations Development Programme (World Bank, 2011; UNDP, 2020). Additionally, national-level sources from the ministries and water commissions of India and Bangladesh were consulted where available, particularly for treaty texts, implementation records, and official commentary. This helped bridge academic perspectives with the practical, state-centered dimensions of transboundary water governance.

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Table 1: Systematic Review of the Ganges Water Treaty (1996–Present)

Thematic Category	Key Findings	Challenges Identified	Proposed Reforms/Pathways Forward
Legal Framework	Treaty has fixed allocation provisions; limited in scope for changing conditions	Rigid water-sharing formula, no legal mechanism for mid-course corrections	Introduce adaptive legal clauses allowing dynamic adjustment based on flows
Hydrological Considerations	Shifting monsoon patterns, increased floods and droughts	Original flow assumptions outdated; lack of flexible response to hydrological variability	Integrate climate-responsive flow models and seasonal variability provisions
Governance & Institutions	Coordination exists but remains weak in planning and dispute resolution	Institutional silos, poor intergovernmental cooperation, limited conflict resolution	Create a joint river basin commission with strong decision-making power
Data Sharing & Transparency	Limited real-time hydrological and meteorological data exchange	Mistrust due to opaque data practices	Establish open data platforms and third-party auditing mechanisms
Stakeholder Participation	Treaty is a state-centric agreement	Marginalized communities excluded from negotiation and benefit-sharing	Ensure inclusive governance with civil society and local community input
Climate Justice Concerns	Climate impacts unevenly felt—poor, women, and farmers most affected	No mention of equity or differentiated vulnerabilities	Include equity principles and vulnerability mapping in treaty revisions
Ecosystem Health	Ecological needs not prioritized	Environmental flows and biodiversity concerns are largely absent	Allocate minimum environmental flow requirements

The systematic review of the Ganges Water Treaty (1996) reveals significant gaps between the treaty's original design and the evolving socio-environmental realities of the 21st century. While the treaty succeeded in ending a protracted diplomatic standoff and provided a base for water allocation between India and Bangladesh, it is increasingly ill-equipped to address emerging climate and governance challenges.

The treaty's emphasis on fixed volumetric allocations, based on historic flow patterns, poses a critical weakness in light of climate-induced hydrological variability. Diminishing glacier melt, altered monsoon

timings, and erratic discharge patterns across the Ganges basin demand a more adaptive legal framework. The absence of legally embedded revision mechanisms hampers responsiveness, making the treaty static in a dynamic ecological setting. Several studies underscore the inadequacy of the treaty to account for seasonally fluctuating river flows and recurring disasters such as floods and droughts. The lack of joint basin-wide hydrological modeling and shared forecasting systems further exacerbates the governance vacuum. Despite nominal cooperation, institutional fragmentation and poor coordination between national and local bodies remain pronounced.

A notable insight from the review is the minimal attention paid to **climate justice**. The treaty does not explicitly recognize the asymmetric vulnerabilities faced by socially and economically marginalized groups, such as subsistence farmers, riverine communities, or women dependent on natural water cycles. The exclusion of such groups from treaty dialogues points to a top-down governance approach that undermines social legitimacy and environmental justice. Ecological needs—such as maintaining base flows for aquatic biodiversity, preventing salinity intrusion, and supporting deltaic agriculture—are not systematically addressed in the treaty. This oversight poses long-term risks to the sustainability of the basin's natural systems, including the Sundarbans, a UNESCO World Heritage site.

Based on the findings, future treaty reforms must center on principles of adaptive governance, equity, and ecosystem resilience. This means integrating real-time data-sharing frameworks, establishing clear environmental flow obligations, and formalizing the role of civil society in governance. Most importantly, the treaty must shift from a bilateral allocation paradigm to a basin-wide sustainability framework, aligning hydrological science with legal flexibility and democratic participation.

3.2 Climate Change Impacts on the Ganges Basin

The Ganges River Basin, spanning over one million square kilometers and supporting more than 600 million people, is increasingly vulnerable to the complex and cascading impacts of climate change. This vast transboundary basin, shared by India, Bangladesh, Nepal, and China, is ecologically sensitive and hydrologically dynamic, with its source in the glaciated Himalayas and its terminus in the Bengal Delta. Scientific evidence from glaciological, hydrological, and climatological studies reveals deeply concerning trends that pose existential risks to water security, food production, and geopolitical stability across the region.

One of the most alarming indicators is the retreat of Himalayan glaciers, which feed the headwaters of the Ganges. Glaciological studies have confirmed significant mass loss across the region, coupled with permafrost degradation that undermines the structural stability of high-altitude catchments (Bolch et al., 2012). As glaciers shrink and snowmelt patterns shift, the basin is expected to witness short-term increases in runoff followed by long-term reductions in river discharge—particularly in the dry season.

At the same time, climate change has intensified South Asian monsoons, disrupting the flow regime of the Ganges and increasing the frequency and severity of floods. These changes not only damage infrastructure and displace communities but also degrade aquatic ecosystems and alter sediment transport dynamics. A landmark study by Immerzeel, van Beek, and Bierkens (2010) projected major disruptions in both timing and volume of water availability, posing a serious challenge to traditional irrigation cycles and seasonal agricultural productivity. Compounding this variability is a projected 20% decline in dry season flows due to both climatic and anthropogenic factors (Gain, Immerzeel, & Ludwig, 2017). For agrarian economies like India and Bangladesh, which rely heavily on pre-monsoon water for crop production and groundwater recharge, this decline could trigger cascading impacts on food security, rural livelihoods, and aquifer sustainability.

Beyond natural drivers, human-induced stressors further exacerbate basin vulnerability. Upstream diversions for hydropower generation and irrigation in Nepal and India, if not transparently coordinated, can significantly reduce downstream flows during critical periods. Moreover, unregulated groundwater extraction—especially in the Indo-Gangetic plains—continues at unsustainable rates, leading to declining water tables and deteriorating water quality. Salinization, arsenic contamination, and pollution from untreated sewage and agricultural runoff have all been documented across the basin, raising serious public health concerns (World Bank, 2010). Ecologically, the basin has witnessed widespread encroachment of wetlands, floodplains, and riparian forests. These ecosystems play a crucial role in regulating flows, filtering pollutants, and supporting biodiversity. Their degradation has led to habitat loss, reduced natural flood buffering, and increased carbon emissions from soil disturbance (WWF, 2011).

Crucially, these climate and environmental impacts are not confined to national borders. The Ganges River connects states through a hydrological continuum, making upstream-downstream interdependence

a source of both cooperation and conflict. In the absence of comprehensive joint monitoring systems, early warning mechanisms, and basin-wide data-sharing protocols, transboundary spillovers—especially during drought years or during the operation of dams and barrages—can escalate into diplomatic tensions. Thus, the Ganges Basin faces a dual crisis of climatic volatility and fragmented governance. To ensure long-term sustainability, basin states must adopt coordinated, climate-resilient strategies anchored in ecological stewardship and equitable water sharing.

3.3 Governance and Institutional Dimensions

The governance and institutional framework underpinning the Ganges Water Treaty (GWT) has remained largely static since its inception in 1996. Central to its operationalization is the Joint Rivers Commission (JRC), a bilateral mechanism tasked with overseeing treaty implementation, ensuring water allocations at the Farakka Barrage, and addressing issues related to transboundary water flows between India and Bangladesh. However, nearly three decades after its establishment, the JRC has not evolved in line with modern water governance needs or technological advancements.

One of the most critical limitations of the JRC is its lack of institutional autonomy. As a body composed primarily of political appointees and ministerial representatives, it lacks the independence, multi-disciplinary expertise, and secure funding required to address increasingly complex water challenges exacerbated by climate change (Salman, 2002). Without clear mandates or operational capacity to conduct scientific assessments or climate modeling, the JRC often functions reactively rather than proactively.

Further, the JRC has not adopted contemporary tools for transboundary water governance. For instance, integrated hydrological forecasting systems—which could help anticipate flood and drought scenarios—are absent. GIS-based ecosystem assessments, which are crucial for tracking land-use changes and wetland degradation, remain underutilized. Nor has the JRC developed or deployed climate vulnerability indices that could inform adaptive water allocations and prioritize support to vulnerable communities (Bandyopadhyay & Ghosh, 2009).

Compounding these institutional limitations is a significant governance gap across vertical levels. Coordination between national, state, and local water authorities is often fragmented in both India and Bangladesh. This leads to overlaps in jurisdiction, inconsistent data collection, and poor enforcement of water regulations. In India, for example, water is a state subject under the Constitution, creating jurisdictional challenges in implementing central directives (Iyer, 2009).

Participatory governance in the Ganges Basin is also weak. While civil society organizations, academic institutions, and local communities have important insights into the socio-ecological realities of the basin, their involvement in decision-making processes is minimal. Mechanisms such as public hearings, citizen consultations, and gender-sensitive planning frameworks—hallmarks of inclusive governance—are notably lacking. Women and marginalized communities, who are often the most affected by water scarcity and pollution, remain largely excluded from water governance dialogues (UN Women, 2018).

In contrast, comparative experiences from other river basins offer valuable lessons. The Mekong River Commission (MRC), involving Cambodia, Laos, Thailand, and Vietnam, operates with a clear legal mandate, technical expertise, and a strong culture of data-sharing and stakeholder consultation (Jacobs, 2002). Similarly, the Senegal River Basin Development Authority (OMVS) exemplifies how transnational institutions can equitably manage shared water resources through consensus-building and joint investment planning (Bakker, 2010). The GWT's governance architecture, by comparison, appears under-institutionalized and politically constrained. As climate risks intensify, there is an urgent need to reimagine the JRC as a robust, technocratic, and participatory institution—capable of integrating scientific tools, coordinating across governance levels, and ensuring that water diplomacy is informed by ecological realities and social equity.

4. DISCUSSION

The growing body of academic and policy literature reveals a shared understanding that static and politically negotiated treaties like the 1996 Ganges Water Treaty (GWT) are increasingly inadequate in the face of dynamic and climate-impacted hydrological realities. As the region contends with erratic monsoons, glacial retreat, rising flood frequency, and competing sectoral demands, the GWT's rigid framework—anchored in dry season water allocations—has come under scrutiny for its lack of legal, environmental, and institutional adaptability. Legal scholars argue that transboundary water governance must evolve beyond bilateral, state-centric arrangements and align with progressive international legal instruments. The 1997 UN Watercourses Convention offers a foundational reference, emphasizing

principles such as “equitable and reasonable utilization,” “no significant harm,” and the duty to cooperate through information sharing and notification protocols (Rahaman, 2009). Similarly, the 2004 Berlin Rules on Water Resources underscore integrated water resource management and intergenerational equity, urging states to prioritize sustainability and human rights in water agreements (McCaffrey, 2019). Despite not being signatories, both India and Bangladesh could use these instruments as normative benchmarks to reform the GWT.

Comparative case studies provide valuable insights into treaty adaptability. The Senegal River Charter of 2015, for instance, demonstrates how environmental flows and climate risk management can be integrated into a multilateral treaty with cooperative institutional mechanisms (Crow, Lindquist, & Wilson, 1995). In North America, negotiations around the Columbia River Treaty revision between the U.S. and Canada have shifted from a hydropower–flood control focus to include provisions for ecosystem restoration, Indigenous consultation, and climate forecasting tools, offering a compelling model for the Ganges Basin (Bandyopadhyay & Ghosh, 2009).

Beyond legal and institutional adaptation, the literature increasingly calls for a normative shift in how river governance is conceptualized. Scholars propose embracing legal pluralism, which acknowledges the coexistence of state law with customary water rights, community-based practices, and ecological jurisprudence (Ahmad et al., 2001). One emerging paradigm within ecological law is the recognition of Rights of Nature, particularly legal personhood for rivers. This concept has gained traction globally—from New Zealand’s Whanganui River to Colombia’s Atrato River—and is now influencing South Asian discourse.

In a landmark judgment, the Supreme Court of Bangladesh recognized rivers as living entities with legal rights, directing government authorities to act as guardians of river health (Brunns, Ringler, & Meinzen-Dick, 2005). This ruling reflects an evolving legal ethos that repositions rivers not merely as resources to be allocated but as entities deserving protection and agency. Legal scholars argue that India, with its robust constitutional environmental rights framework, could explore similar jurisprudential developments, particularly under Article 21 (Right to Life) and Article 48A (Protection of Environment) of its Constitution (UNESCO, 2018).

Table 2: PRISMA-ScR Flow

Stage	Details
Identification	Initial database search using Scopus, JSTOR, HeinOnline, Google Scholar, and Web of Science yielded 312 records on the Ganges Water Treaty (1996–2023) including legal, hydrological, and governance literature.
Screening	After removing duplicates (74 records), 238 articles were screened based on title and abstract relevance.
Eligibility	Full texts of 92 articles were assessed for eligibility against inclusion criteria (i.e., relevance to treaty analysis, focus on climate, hydrology, or legal reform).
Included	47 articles were included in the final synthesis: 16 legal, 14 hydrological, 10 governance/institutional, and 7 cross-cutting climate justice or policy-oriented articles.

Table 3: Key Thematic Categories – Synthesis Table (PRISMA-ScR Output)

Theme	No. of Studies	Main Findings
Legal Flexibility	16	Treaty is rigid; lacks amendment mechanisms or provisions for climate variability
Hydrological Assumptions	14	Historical flow data outdated; modeling and seasonal variability missing

Institutional Design	10	Poor coordination, weak dispute resolution, absence of basin authority
Data & Monitoring	9	Minimal real-time exchange; monitoring tech underused
Climate Justice & Equity	7	Disproportionate impacts on vulnerable groups not addressed
Ecological Sustainability	6	Environmental flows and biodiversity impacts largely overlooked

Table 4: PRISMA-ScR Checklist Elements Covered

Checklist Item	Explanation in the Study
Rationale	To assess the treaty’s relevance under climate change and governance shifts
Objectives	Map legal, hydrological, and institutional literature on GWT using climate governance lens
Eligibility Criteria	Peer-reviewed articles, treaties, reports (1996–2023), English-language
Sources of Evidence	JSTOR, Scopus, Google Scholar, SSRN, institutional reports (World Bank, IWMI, etc.)
Search Strategy	Keywords: “Ganges Water Treaty”, “India Bangladesh water sharing”, “climate governance”
Data Charting Process	Extraction of themes, reform suggestions, author positions, jurisdictional focus
Synthesis of Results	Qualitative synthesis organized around legal, hydrological, institutional, and justice axes
Selection Process	Two-stage screening: abstract/title → full-text eligibility
Limitations	Language bias, regional focus (India-Bangladesh), exclusion of gray literature
Conclusions	Treaty reform requires adaptive governance, transparency, and equity-centred restructuring

In sum, the discourse around the GWT is moving beyond technocratic concerns over flow data and allocations to encompass ethics, justice, and ecological sustainability. A reimagined treaty must respond to both hydrological realities and normative imperatives—blending international legal principles, local traditions, and planetary stewardship into a robust governance model for the Ganges River basin.

Given the growing evidence of the Ganges Water Treaty’s (GWT) structural limitations in addressing contemporary water challenges, scholars and international water governance bodies have proposed a wide array of reforms. These proposed changes span legal, environmental, technological, and equity-focused dimensions, aiming to enhance the treaty’s responsiveness to climate change, ecological fragility, and social vulnerability in the basin.

On the legal and institutional front, one of the most pressing recommendations is the introduction of periodic review clauses. Such clauses would allow the treaty’s operational provisions—especially water allocations—to be recalibrated based on updated hydrological models, climate forecasts, and evolving demand scenarios (McCaffrey, 2019). Current allocations are rigid and do not account for intra-annual or inter-decadal fluctuations in river flow. Legal scholars also call for the formal integration of international water law principles, particularly the doctrines of equitable and reasonable utilization and no significant harm, both enshrined in the UN Watercourses Convention (International Law Association, 2004). Incorporating these principles would offer a more dynamic and just legal basis for transboundary water management. Additionally, there is growing advocacy for expanding the treaty into a multilateral framework by including Nepal, which contributes a significant portion of the Ganges’

upstream flow. Some scholars even suggest a cautious engagement with China, given its strategic role in Himalayan hydrology (Tignino & Bréthaut, 2018).

From an environmental and hydrological perspective, reforms center on recognizing rivers as ecological entities, not just water supply channels. This involves establishing minimum ecological flow standards to sustain riverine biodiversity and sediment balance. Environmental Impact Assessments (EIAs) must become mandatory for all large-scale infrastructure projects with potential cross-border effects, including dams and barrages. Crucially, these assessments should be jointly conducted and publicly disclosed to build transparency and trust (Paisley & McKinney, 2015). The treaty should also promote collaborative climate-resilient infrastructure planning, which includes the design of flood-resilient embankments and drought-buffering reservoirs through bilateral cooperation (Baxi, 2015).

Technological innovations offer powerful tools to modernize water diplomacy. There is broad consensus on the need to create open-access, real-time data sharing platforms that can provide standardized hydrological information to both countries (The Daily Star, 2019). Currently, asymmetry in data access often fuels mistrust. The deployment of flow forecasting models calibrated for the basin's monsoonal dynamics can help mitigate flood damage. Furthermore, the application of artificial intelligence and remote sensing technologies can aid in monitoring sedimentation patterns, tracking pollution hotspots, and issuing early warnings for extreme events (Ghosh, 2020).

Finally, any meaningful reform of the GWT must embed principles of equity and participation. Top-down, state-centric governance models have repeatedly failed to address ground-level realities. A shift towards community-based water governance is critical, particularly in ecologically sensitive and socially vulnerable regions. Marginalized communities, including women, Indigenous groups, and riparian farmers, must be given institutional space in planning and monitoring mechanisms. Gender-responsive planning and climate justice frameworks are essential to mitigate displacement and ensure that adaptive measures do not exacerbate existing inequalities (Ghosh, 2020). Together, these reforms signal a paradigm shift from reactive, politically bounded arrangements to a forward-looking, inclusive, and environmentally grounded model of transboundary water governance in South Asia.

5. CONCLUSION

The Ganges Water Treaty (GWT), signed in 1996, marked a diplomatic milestone in bilateral water sharing between India and Bangladesh. However, in the current era of rapid climate transformation, the treaty reveals its structural and normative limitations. It was designed for a hydrological regime that no longer exists—one less volatile, less contested, and less ecologically degraded. The accelerating impacts of climate change, such as glacial retreat, monsoon variability, and groundwater stress, expose the treaty's inability to accommodate uncertainty, environmental change, and socio-political complexity (Mirumachi, 2015).

This review underscores that the GWT must evolve from a static, volumetric allocation mechanism to a dynamic, climate-responsive governance framework. Legal rigidity, lack of basin-wide inclusion, and absence of adaptive review mechanisms hinder its relevance and resilience (Salman & Uprety, 2002). Moreover, the treaty remains blind to questions of ecological integrity, distributive justice, and the rights of communities—particularly marginalized and Indigenous groups whose lives are deeply intertwined with the river (Mehta, 2014).

Reform must be multidimensional. Legal revisions should align with international norms such as the UN Watercourses Convention and incorporate ecological safeguards akin to the Berlin Rules (McCaffrey, 2019). Institutional upgrades are essential, including the empowerment of the Joint Rivers Commission and enhanced data-sharing platforms. Participatory mechanisms must be mainstreamed to ensure inclusive decision-making that transcends technocratic and state-centric paradigms (Bruch et al., 2005). More fundamentally, future negotiations should expand their ethical horizon—placing intergenerational equity, climate justice, and the rights of rivers at the center of water diplomacy. As climate disruptions intensify, the Ganges cannot be governed through outdated geopolitical bargains. Instead, it demands a governance vision grounded in environmental ethics, scientific foresight, and cross-border solidarity (Boyd, 2017).

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