

Water demand and ecosystem nexus in the transboundary river basin: a zero-sum game

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Abstract The water demand in the upstream and downstream of a transboundary river basin varies based on the water use by the irrigation projects, dam, hydroelectricity, ecosystem, livelihood practices and household activities of the people. The study considered the case of Teesta river basin and estimates the water demand of upstream, downstream region as well as entire Teesta river basin shared by India and Bangladesh. The water productivity method exercised in the study demonstrates that 2648 and 1971 cumec water is required to fulfill the irrigation demand of command and irrigable areas, respectively, of entire Teesta basin throughout the year against 198, 1472, 793 cumec water discharge in dry, monsoon and lean season. Although there is a substantial water demand for the hydropower projects in the upstream, it is appeared that water required only by the upstream irrigation project is beyond the water supply capacity of the Trans-Himalayan river Teesta during dry and lean season. This may underpin the shortage of water in the lower riparian country, which fuels the zero-sum game in the river basin, where one player is affected by the intervention of the another player. The result from this analysis with *zero-sum game* perspective may be useful for reviewing transboundary water policies, basin management and development, sustainable water resource management and water sharing mechanism among countries in the transboundary river basin.

Keywords Blue peace · Ecosystem service · Transboundary water · Teesta river · Water conflict · Water resource economics · Zero-sum game

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1 Background

Water plays a determining role to support and generate different economic and livelihood activities for the communities across the river basins (Ahmed et al. 2001; WWF 2011). The river-dependent communities always depend on the river's water resources for fishing, agriculture, communication (boat etc.), fresh water (household use and irrigation), and livestock rearing (MEA 2005; Payne et al. 2003). Besides, infrastructure projects in the river basin induce water demand for the targeted communities within and outside the catchment area of rivers (Shah 2001; Upteri 1993). The upstream water diversion of the transboundary rivers shrinks the availability of water in the downstream region, which excludes the lower riparian people to meet their own demand for water (Arfanuzzaman and Ahmad 2015a; Wirsing and Jaspardo 2007; Meek and Meek 2009). Here, the water harvest done and associated benefit enjoyed by the population in the upstream may be equal to the amount of loss incurred by the water deprived downstream region. This results in the "zero net gain" at basin or sub-basin level, which is termed as a "zero-sum game" in terms of resource distribution and utilization. When water supply is fixed, at least to some extent, any increase in water allotment or consumption to one riparian implies a reduction of some other riparian's allocation. This is a typical precedent of a "zero-sum game," following from the "game" being perceived as, or based on, physical units of water. Further, "zero-sum game" is the opposite condition of win-win situations, where one player's gain is the other's loss (Binmore 2007). Consequently, larger socioeconomic gain in the river basin is missed if "zero-sum game" exists, which also incurs the water conflict among the riparian nations. Teesta is one of the key tributaries of mighty Brahmaputra–Jamuna river system with a total of 29 million people of India and Bangladesh who are directly rely on this river and its fresh water resource for their livelihood options. There are approximately 84 glaciers in the upstream of Teesta river basin, covering an area of 440.30 km² which are distributed in 10 sub-basins (Trivedi et al. 2013). This Himalayan sourced river originates in the North West Indian state of Sikkim and enters into Bangladesh flows through the Northern districts of Cooch Behar, Jalpaiguri, Darjeeling, Uttar Dinajpur, Dakshin Dinajpur and Malda in West Bengal. In Bangladesh, Teesta river passes through Lalmonirhat, Nilphamari, Rangpur, Kurigram and Gaibandha districts of North-western region.

Figure 1 illustrates the boundary and length of Teesta river basin in each riparian country. Out of 404 km, 270 km falls under Indian territory and rest of 154 km lies in Bangladeshi part. The distance from Gazaldoba to Dalia irrigation barrage is 105 km. These two barrages are constructed to supply the low-cost irrigation facility and foster the rural income through sustained food production in the regions. In dry and lean season, the withdrawal of irrigation water in the upstream often reduces the water availability in the downstream basin of Bangladesh. In addition, due to squeezed water supply from the upstream, irrigation demand and target is not fulfilled in the Bangladeshi barrage areas. As a result, the people of lower Teesta basin face the severe water crisis the dry season, where the predominant rice crop Boro is cultivated.

Arfanuzzaman and Ahmad (2015) disclosed that due to upstream induced irrigation water unavailability, the lower Teesta basin of Bangladesh missed above than 4.45 million metric tons of rice production during 2006–2007 to 2013–2014. The total rice production missed in the lower Teesta basin region during these periods is more than the country's total rice import during 2008/09–2013/14 fiscal years and nearly one quarter of the total Boro production in the 2012–13 fiscal year, which indicates the severe economic consequences of zero-sum game in the Teesta basin. Besides, a good number of dams and mega

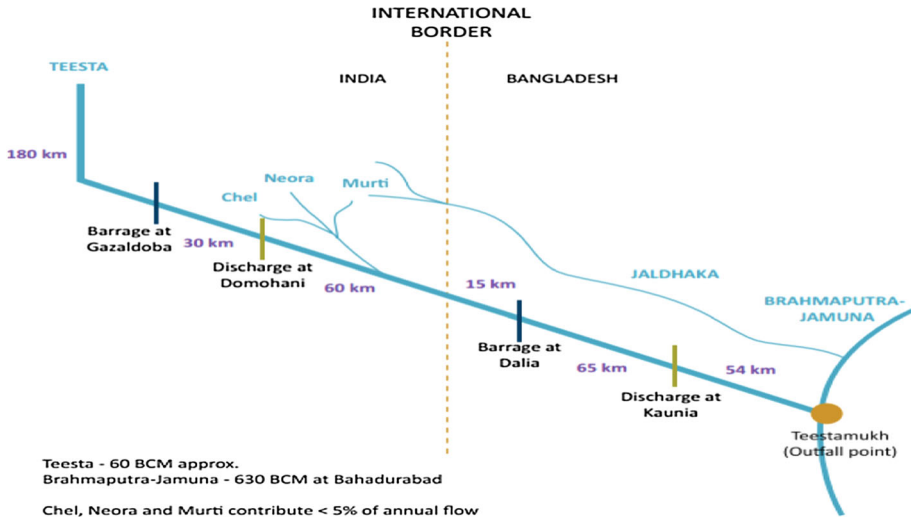


Fig. 1 Teesta river basin *Source:* Adopted from Waslekar et al. (2013)

hydropower projects are operating in the upstream Teesta, which also fuels the water shortage in the lower Teesta basin. Here, lower riparian nation is found to be deprived from utilizing the water resources due to upstream interference and experience crop loss and damages during cultivation period. This incurs the zero-sum game in terms of water resource allocation and utilization of transboundary river basin Teesta. It is found that the lower riparian farmers who are outside the command areas of the irrigation project are 11% more exposed to the threat of production compared to farmers' who usually receive irrigation benefit from the project (Bari and Haque 2016). In this backdrop, the study aims to estimate agricultural water demand and availability of water in the Teesta basin riparian countries and evaluate the water resources against the water demand condition. The study also intends to examine the ecosystem case of the river due to water withdrawal for the agriculture and hydropower purpose from the context of zero-sum game. Finally, the study seeks how the water and river basin management of other Asian transboundary rivers basin is functioning for conflict minimization and socioeconomic gain optimization, and assesses the context of zero-sum game along with the case of Teesta.

2 Methods and conceptual framework

The study endeavors to estimate the water demand of the river basin by adopting the water productivity and accounting method. Currently available discharge and virgin flow of the Teesta river were considered in the analysis for the water demand calculation.

$$W_d = \frac{A_l}{Wp_l}$$

Here, W_d signifies the demand of water, Wp_l is the water productivity of land, and A_l indicates the quantity of agricultural land in the river basin.

In addition, decadal virgin flow is considered in the analysis to minimize the biasness from the water accounting process. The quantity of the virgin flow exercised in the study is the last ten years average discharge before implementing the Gozoldoba barrage (first irrigation project in the upper Teesta basin). The total water demand estimated for the Teesta river basin comprises only the agricultural demand in India and Bangladesh, whereas demand for dam, hydroelectricity, industry, household, and ground infiltration are kept out from this study due to unavailability of data and information and resources. Water flow of Teesta river after fulfilling Indian demand is considered as the amount of water Bangladesh receives from the upstream and the water discharge after Dalia barrage point is the amount after meeting Bangladeshi demand.

The study endeavors to apply the concept of two-person zero-sum game of game theory to illustrate the case of upstream and downstream basin of Teesta river. Basically, game theory provides a mathematical framework for analyzing the decision-making processes and strategies of players in different types of competitive circumstances (Karlin 2014). The simplest type of competitive situations is two-sided, zero-sum games. These games involve only two players or side; they are called zero-sum games because one player wins necessitates another party’s loss (Parthasarathy and Raghavan 1971). A zero sum is required for each set of strategies. If there is even one strategy set for which the sum differs from zero, then the game is not zero sum.

In a two-person zero-sum game, each of the two players is given a preference between several prescribed strategies at each turn, and each player’s loss is equivalent to the other player’s gain.

The following payoff matrix of a two-person zero-sum game has rows labeled by the row player’s strategies and columns labeled by the column player’s strategies (Raghavan 1978).

$$\begin{array}{cc}
 & \begin{array}{c} I \quad II \end{array} \\
 \begin{array}{c} I \\ II \end{array} & \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{array}{c} q \\ 1-q \end{array} \\
 & \begin{array}{c} p \quad 1-p \end{array}
 \end{array}$$

A rational choice of actions (strategies) of the players in the course of a two-person zero-sum game is based on a minimax principle: If (Vorob’ev 1977).

$$\max_{a \in A} \inf_{b \in B} H(a, b) = \min_{b \in B} \sup_{a \in A} H(a, b),$$

or

$$\sup_{a \in A} \inf_{b \in B} H(a, b) = \inf_{b \in B} \sup_{a \in A} H(a, b),$$

The term virgin flow used in the study basically implies the pre-project discharge of the river where no infrastructure or irrigation project was constructed in the basin. In this study, three different seasonal, i.e., dry, wet and lean period, flows are considered for the analysis. Here, dry and lean seasonal flows are characterized as pre- and post-monsoon flow. Wet season flow can be categorized as a monsoon flow.

Moreover, according to the World Bank “Environmental flows can be described as “the quality, quantity, and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems which provide goods and services to people.” Alternatively, water that is left in a river system, or released into it, for the specific purpose of managing the condition of that ecosystem is known as environmental

flow (King and Brown 2003). Besides, an ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Alcamo 2003). If any of the services of river ecosystem is disrupted by the project or human intervention, it is called degradation of ecosystem.

3 Results and discussion

Like other Trans-Himalayan rivers, water resources of Teesta play a commendable role to sustain economic, social, cultural, and environmental benefits in the mountain and flood-plains and also recognized as a source of water tension between upper and lower basin (Waslekar et al. 2013; Lopez-Hoffman et al. 2010). In order to ensure the food security, rural income and eradicate the poverty as well as make certain the social safety net of the river basin communities through boosted agricultural production, both riparian nations India and Bangladesh have constructed grand irrigation projects in the Teesta river, which triggers the demand for water in the river basin areas. The table 1 demonstrates that the command areas of Indian and Bangladeshi projects are 1,214,000 and 750,000 ha, respectively, where developed irrigable areas are 922,000 and 540,000 ha for the same.

In order to provide the irrigation facility in the entire command area of India and Bangladesh, total $2648 \text{ m}^3\text{s}^{-1}$ water is required in all the cropping seasons. The virgin flow of the Teesta river are recorded $1,981,472$ and $793 \text{ m}^3\text{s}^{-1}$ in dry, wet and lean seasons correspondingly. The virgin flow assessment designates that development of such large command areas is quite ambitious and unattainable by the riparian nations.

As shown in Table 2, in order to fulfill the water demand in the irrigable area 1243 and $728 \text{ m}^3\text{s}^{-1}$ water is required in India and Bangladesh, respectively, from this

Table 1 Barrage structure in the Teesta river basin *Source:* BWDB, and Government of Sikkim

	India	Bangladesh
Location	Gazaldoba	Dalia-Doani
Landscape	Hilly and plain land	Plain land
Climate	Tropical, mild winter, hot, humid summer, warm rainy monsoon	Tropical Savana, and humid subtropical
Command area	12,14,000 ha	7,50,000 ha
Irrigable area	9,22,000 ha	5,40,000 ha
Under irrigation	5,40,000 ha	1,11,406 ha
Soil type	Sandy or clayey loam	Sandy and alluvial
Hydroelectricity	67.50 MW	N/A
Link canals	210.79 km	275 km
Beneficiaries	8 million	21 million
Year of operation	1989	1993

Table 2 Water demand in the entire Teesta basin against the virgin flow *Source:* Author's estimation based on the data from Joint Rivers Commission

	Estimates of water demand for agriculture (cumec)			Virgin flow: 1973–1985 (cumec)		
	Demand in India	Demand in Bangladesh	Demand in overall basin	Dry season	Wet season	Lean season
Command Area	1637	1011	2648	198	1472	793
Irrigable area	1243	728	1971			
Under Irrigation	728	150	878			

Virgin flow is the pre-project flow of a river, where no infrastructure was built in the river basin to divert the natural flow

transboundary river Teesta. Since the pre-project period flow of Teesta river was measured $1472 \text{ m}^3\text{s}^{-1}$ during the monsoon season, it is beyond the capacity of the river to supply total $1971 \text{ m}^3\text{s}^{-1}$ water for the irrigation purpose round the year. Since the water discharge in the dry and lean season was not much substantial during the pre-project period, water demand can be met a bit better in the wet season agriculture at present, which is vice versa for the dry and lean season agriculture. Furthermore, the areas of the projects which are currently under irrigation also cannot be met by the river's water except wet season. For the squeezed flow in the dry and lean season, a major part of water demand cannot be fulfilled in the entire Teesta basin. However, scarcity of water is higher in the lower stream which may be attributed to upstream withdrawal of water. It appears that, in dry and lean seasons 1971 and $86 \text{ m}^3\text{s}^{-1}$ water deficit remains to be addressed in the area which is currently under irrigation schemes in the upstream and downstream basin due to unavailability of the water. For the irrigable area, 1774, 1779 and $500 \text{ m}^3\text{s}^{-1}$ water shortage arises in dry, lean and wet seasons, respectively, in the entire Teesta basin. Additionally, irrigation water shortage also arises due to the operation of mega hydropower projects in the upstream. As an upstream country, India is found to manage, store, and divert the water of Teesta river for irrigation, storage, and hydroelectricity generation purposes, which drastically reduces the availability of water in the lower Teesta floodplain of Bangladesh (Arfanuzzaman and Ahmad 2015). Till 2012, six hydroelectricity plants with total 3405 MW power generation capacity are implemented in the upstream and few others are under construction and yet to be examined from the environment and engineering plan standpoint in the upper Teesta region of India (MoEFCC 2010). Existing dam and hydropower plants requires tremendous water resources, which drastically trims down the water availability for agriculture in both upstream and downstream regions, which is found very acute in dry season. This situation indicates a clear tradeoff between the agriculture and hydropower scheme in the dry and lean season which affects the inter-sectoral water demand in the upper basin. It is anticipated that the upcoming hydroelectricity projects will bring overwhelming impact on the agricultural water demand, ecological balance, biodiversity, rivers ecosystem health, and climate in the Teesta basin areas as well.

Based on the water availability, currently 540,000 and 111,406 hectares areas of the barrages are receiving irrigation facility in India and Bangladesh. It is found that India has already brought about 58% of its total irrigable area under irrigation. Whereas, Bangladesh brought only 20% of its total irrigable area under irrigation (BWDB 2015). This is happened due to not receiving the equitable water share from the upstream as maximum water is diverted and harnessed by the Gazaldoba barrage, dam and power plant of the upstream. After meeting the water demand in upper basin the amount of water Bangladesh receives is

very insufficient to meet half of its irrigation target (Arfanuzzaman 2015). Here, the gain of upstream is equivalent to the loss incurred by the downstream region. Thus, the net change in wealth or benefit is zero, which is an ideal situation of a zero-sum game of two players in the river basin. In such situation, it is impossible for one riparian to advance its position without imposing loss of equivalent amount to the other riparian. If one side gets \$500 more, that means the other side gets \$500 less. At this juncture, the wins and losses add up to zero. These situations typically arise in distributive bargaining cases where a “fixed pie” must be divided between the parties. For example, if two individuals are splitting up a fixed amount of money, the more one gets the less available to the other. Similarly, in case of a transboundary river, as much water the upstream user withdraws much amount of water will not be available to the downstream user. This is what upstream state is practicing over downstream country Bangladesh for the water resource of Teesta. This case is also similar to the other transboundary rivers around the world, where water-sharing treaty and joint river basin management initiative are lacking. If there is no water sharing treaty, upstream state always tends to exploit the water resource by the cost of downstream nation (Islam and Higano 2002). Since Bangladesh is not receiving the equal share of water, the win-win situation for optimum uses of water resources does not exist over this transboundary river Teesta. Therefore, the exclusion and welfare loss is taking place in the lower riparian region of Bangladesh.

The Fig. 2 shows the trend of water flow in lower Teesta basin after meeting the water demand by Indian and Bangladeshi irrigation infrastructure in dry season, when pre-monsoon crop Boro and maize are mostly cultivated. Initially it is found that water discharge in the lower Teesta basin is nearly unchanged from the actual flow entering as of the upstream country India. This means during late 1990s no significant water has been used for irrigation in Bangladesh part during dry season through any irrigation project. Since 2005, it appears that water discharge reduced significantly from the Indian part and a notable diversion is also emerged in the Bangladesh part to meet its irrigation demand, where discharge is found less than $28.31 \text{ m}^3\text{s}^{-1}$ in rest of the downstream part. For the intense irrigation needs in the agriculture sector, Teesta river looks empty, indicating no discharge at all in several periods during dry season in the lower basin. In order to meet the

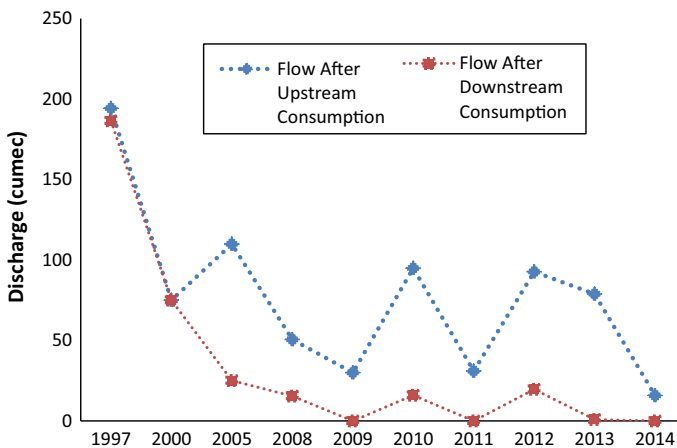


Fig. 2 Water discharge in Teesta river during dry season after meeting the economic demand *Source:* Author's estimation based on the data of BWDB

irrigation demand, entire available volume water of Bangladesh part was diverted to the cropping area of Teesta barrage project in 2009, 2011, 2013 and 2014. This is happened due to lower water availability in the lower stream compared to the pre-project period discharge, which is largely triggered by the water diversion and storage in the upstream.

In 1997, Bangladesh receives nearly $198 \text{ m}^3\text{s}^{-1}$ water during dry season, which shrinks nearly $14 \text{ m}^3\text{s}^{-1}$ in 2014. The period was very crucial for the Teesta riparian of Bangladesh to meet their water demand for agriculture, fishing and other livelihood activities. It emerges in Fig. 1 that in last decade Teesta river was waterless for four time in extreme dry season to fulfill the water demand in upper and lower riparian region of the basin. Empty river cannot perform the ecological function and fails to provide the cultural, provisioning, and regulatory ecosystem services. In other words, waterless river cannot give any ecosystem goods and services to the nature and people. Further, construction of dam and power plant are putting tremendous threat to the natural environment and ecosystem health of the Teesta basin areas. With a number of the biggest deposit levels, the formation of a tank will result in a higher stress on an active fault region of Teesta basin catchment region. It is apprehending that construction of such mega infrastructures may cause river-stimulated seismicity. Water utilization of these upstream water projects is fueling environmental degradation in the lower Teesta floodplain of Bangladesh. Besides, reduced water discharge is causing to rise and split the river bed, and sand deposition in the crop land of many parts of Bangladeshi floodplains including Dimla, Kaunia, Hatibandha, Ulipur and Sundarganj. It suggested that about 90 to $120 \text{ m}^3\text{s}^{-1}$ for the dry period particularly in January and February is highly required for the sustenance of the Teesta river itself in the lower basin of Bangladesh (Mullick et al. 2010), which requires the limiting of upstream water projects activities to a large extent and form an equitable water treaty. If the healthy water flow does not come from the upstream part, lower Teesta basin in Bangladesh will experience more dryness in the pre- and post-monsoon period and hence the ecosystem service and ecological balance both will be badly affected for the long run which may bring some irreversible effect in the environment, ecosystem services and climate in the river-dependent region. Consequently, the livelihood, fishing and agriculture activities will also be hampered in the downstream and upper floodplain of Indian part as well. Since Teesta is a tributary of Brahmaputra–Jamuna river system, it cannot supply water to the Brahmaputra–Jamuna too, if it becomes waterless itself in the dry season. Thus, the water discharge of Brahmaputra–Jamuna river will also be affected considerably. In this way, the adverse consequences are circulated from sub-basin to core basin. Hence, a fair and sustainable water sharing agreement is required to ensure the win–win condition of the Teesta riparian nations to meet their water demand and development goals. In the vast majority of reported negotiations on river sharing, the focus of negotiation is the allocation of physical units of water, rather than the benefits derived from water utilization. One well-known example is the 1959 Nile Waters Agreement which allocates at least 48 BCM/year to Egypt and 4 BCM/year to the Sudan, but this was not an equitable one and zero-sum game is also found to be reflected here (Abdalla 1971). Further, Nile Basin Initiative (1999) was established as a cooperative framework between all riparians except Eritrea for the sustainable development and management of the Nile river basin. It is expected that this initiative will ensure the long-run benefit of the Nile riparians from the river basin, but the question of equitable water share is still unsolved in this juncture. Another non-cooperative game of physical water distribution is reflected in Almaty agreement between Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan for the Sur Darya and Amu Darya river basin of Central Asia. Here, Kazakhstan, Kyrgyzstan, and Tajikistan receive 38.1, 1, and 9.2% water from the Sur Darya river and 0, 0.4, and 13.6% water from the Amu Darya,

respectively. In addition, Turkmenistan and Uzbekistan obtain water 0 and 51.7% from Sur Darya and equally 43% from Amu Darya river basin (Bedford 1996). But this agreement was also not done in an equitable manner and also not practiced effectively as upper riparian state Kyrgyzstan withdraw more water to produce hydroelectricity by reducing the deserved water availability for the downstream Uzbekistan and Kazakhstan. This is a post treaty consequence of zero-sum game, which is also applicable for the Indus basin between India and Pakistan, where tension is growing up for constructing a series of dam and hydropower in the upper western rivers by India without consultation with Pakistan (Bagla 2010; Rahaman 2012). After a serious tension, the Amu Darya riparian countries reach to a barter agreement, but this approach also did not work properly due to lack of trust and commitments of the basin's players.

The Mekong is the 12th longest river in the world and the 7th in Asia, and it is a main navigation and trade route for the six countries namely China, Myanmar, Laos, Thailand, Cambodia and Vietnam through which it flows. The Mekong River Commission (MRC) is an inter-governmental organization that works with the governments of Cambodia, Lao PDR, Thailand and Viet Nam to fulfill their common interests such as joint management of shared water resources and sustainable development of the Mekong River (MRC 2011). The present economic and social needs of all six countries of the basin have led to massive infrastructural developments along the river and its core tributaries. If well planned, the developments would be positive for the nations, but the inverse would have sharp economic, social and environmental impact. However, poor collaboration among these nations on how to manage the river has resulted in its incisive dilapidation. The IWRM strategy of MRC provides regional and transboundary perspectives for the river basin development planning, representing over a decade of collaboration between Member Countries on their shared understanding of the river's opportunities and risks associated with development. The authority of the commission is confined to carry out specific studies and collect data, and it cannot implement any projects in the basin areas. Project formulation and implementation decisions remain with the countries concerned within the river basin. However, the MRC is unable to affiliate upstream nation China and Myanmar with it but able to bring them in the discussion table as a dialogue partner, which is a sign of non-rival water game. Finally, its endeavor to promote and coordinate sustainable management and development of water and related resources for the countries mutual benefit and the people's well-being can be classified as a win-win situation for the riparian nations.

Some light of mutual trust and confidence has been created in the South Asia through the signing of the Mahakali treaty between India and Nepal (January 1996) and the Ganges Water Sharing Treaty between Bangladesh and India (December 1996). Here, The Mahakali Treaty was concerning the integrated development of the Mahakali river basin including the Sarada barrage, Tanakpur Barrage and Pancheshwar Project (Malla et al. 2001). Moreover, Bangladesh is not much benefited at expected level due to availing nearly 50% less than the pre-Farakka average flow at Hardinge Bridge point of Bangladesh, which means that signing of the Treaty in 1996 is unlikely to make any noticeable difference in solving the water crisis in the dry season in the southwestern part of Bangladesh (Tanzeema and Faisal 2001). If Ganges basin can be managed by an integrated plan with the participation of all riparian countries, it will reduce the risks for conflict and mistrust. It is recognized that only water sharing treaty will not endow optimum benefit to the river basin nations (Dombrowsky 2009), which is reflected in the discussed river basins also. If Teesta treaty takes learning from other unsuccessful water treaties and considers the equity and environmental issues critically, the way out from the existing impasse and losses will be much easier. In addition, mutual trust, accountability, and proper

commitment to implement the treaty can provide optimum environmental, economic, political, and accelerated regional benefit for the river riparian countries.

4 Conclusion and recommendation

Infrastructure projects of the river should be designed by considering the proper utilization of water resources, conservation of water, and ecosystem protection as well as ensuring the required environmental flow (e-flow) in the river basin region. Integrated water demand management approach need to be incorporated in the Teesta basin during peak season with considering surface water availability. When demand for water exceeds the supply capacity of a river, the river ecosystem starts to deteriorate. The situation becomes crucial to the river-dependent communities, biodiversity, and ecosystem when excess withdrawal is taking place without considering the minimum e-flow of a river. This situation has been noticed for the Teesta river consistently during the dry seasons of recent years, where downstream basin remains empty for the upstream water withdrawal.

Farmers can use unlimited water for agriculture at a minimum tariff in the barrage areas of riparian countries, which cause technical and allocative inefficiency and wastage of water. Thus, irrigation efficiency is needed to be attained for the optimum water use and conservation and it can be attained by adopting improved irrigation system, effective administrative measures, and engineering intervention. Besides, both nations can store the excess water of monsoon for meeting the dry season agricultural demand. In this case, a number of reservoirs can be created in the river basin catchment areas along with the linkage provision with existing canal network of barrages to supply water in the crop land during dry and lean period. Since the command areas of the irrigation projects are unfeasible to irrigate by the water resource of Teesta, both riparian nations should develop economically and environmentally feasible command and irrigable area for the effective water demand administration. Besides ecologically harmful dam, power plant should be wiped out from the upper basin for the environmental protection and to stop human displacement. The sharp tradeoff between hydropower projects and rivers ecosystem sustenance need to be understood cautiously, and necessary policy reform is obligatory in this regard. It is also important to promote less thirsty crop in the command area of barrage along with regular crop to balance the water demand in the dry and lean season. Some ground water irrigation scheme can also be a good initiative to effectively manage the surface water demand in the Teesta basin. The successful implementation of these water resource management mechanism is not only able to regulate the water demand but also build the resilient to climate change and reduce the magnitude of zero-sum game from the riparian countries. It is highly recommended to ensure the minimum e-flow in the Teesta basin to attain the long-term benefit, ecosystem services flow, and environmental sustainability as well.

To conclude, in order to lessen water inequality and conflict, protect the river ecosystem, biodiversity, traditional values and culture, and ensure the livelihood options of the river-dependent communities, cooperative game is the much better option compared to the zero-sum game. A long-lasting theory of zero-sum games practiced in the transboundary basin Teesta will jeopardize regional prosperity between India and Bangladesh. Irreversible environmental effect is also anticipated to be taking place in the water-scarce downstream region as well, whereas avoiding non-cooperative game and adopting water cooperation between the two close neighbors can gift mutually beneficial prospects such as

ecotourism, power trade, knowledge sharing, technology transfer, water connectivity, joint disaster management, environmental protection, blue peace, and water security as well.

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