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Hydropower development along Teesta river basin: opportunities for cooperation

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Abstract

The aim of this research is to examine the hydropower development potentials and identifying major hydropower projects along the Teesta river basin that is shared by Bangladesh and India. The upstream of Teesta river basin is located mostly in hilly areas of Sikkim where India plans to produce electricity of over 6,500 MW by developing the hydropower potential of the basin. The downstream basin is densely populated, mostly flat land and has no hydropower potential. As of today, Bangladesh and India have been unable to agree on an integrated development plan for the Teesta river basin. Previous negotiations on Teesta river basin management have focused only on sharing water rather than sharing the wide range of benefits from water resources including hydropower. This paper identified the existing, ongoing and upcoming hydropower development projects. The hydropower sharing opportunity exists between the two riparian countries and this type of natural resource development could reduce economic tensions and provide a platform for sustainable agreements.

Keywords: Bangladesh; Energy security; Hydropower; India; Integrated Teesta river basin development; Transboundary water cooperation

Introduction

In many parts of the world, the international political boundaries were drawn without considering the watercourses and basins. Presently, about 261 rivers are being used by two or more sovereign entities. Transboundary river basins cover about 45% of the total Earth surface shared by 145 countries (Tiwary, 2006). The Teesta is a transboundary river shared by Bangladesh and India, which has a steep slope and high seasonal flow variability. Flash flooding occurs from May to September during the monsoon

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period. However, river flow decreases significantly from October to April (Mullick *et al*., 2013). Teesta river starts rising in late March due to snow melt in the Himalayas. The peak flow occurs between July and September due to heavy rain (Chowdhury, 2010).

The Teesta river originates from Chombo Chu at an elevation of 5,280 m in the north-eastern part of Sikkim, India (Prasai & Surie, 2013; EnvIS, 2019). The Jongsong peak and Chho Lhamo are also considered the sources of water for the Teesta river (Meetei *et al*., 2007; Rahaman & Varis, 2009; Singh & Goyal, 2016). At Chungthang, two rivers, namely, Lachen Chu and Lachung Chu, join together and, from the confluence is named the Teesta river. After that, the Teesta increases its width with a wide loop and drop to Singhik with an elevation of 1,550 m to 750 m from mean sea level. At Singhik, the Teesta joins with Talung Chu which originates from the Khangchendzonga range and Rangpo Chu joins at Rangpo. Then, the Teesta river gradually increases its width and joins with Rangit river at Teesta Bazar in Sikkim and enters West Bengal (Goyal & Goswami, 2018).

At Shevok in West Bengal, the Teesta starts flowing through the flat land and its width spreads. After entering into Bangladesh, the Teesta flows through Lalmonirhat, Nilphamari and Rangpur districts before finally joining with the mighty Brahmaputra river at Kamarjani village in Kurigram district (Islam, 2016). The Teesta river travels about 414 km before joining with the Brahmaputra river and it has a catchment area of about 12,370 km^2 (Figure 1 and Table 1) (Rudhra, 2018).

Prior to 1787, the Teesta was part of the Ganges river system and historically flowed southward through Jalpaiguri district of West Bengal, instead of the present southeast flow direction. The name 'Teesta' comes from the Sanskrit word 'Triosta', which refers to the three main channels of the historic Teesta river basin: Karatoa, Purnabhaba and Atrai (Prasai & Surie, 2013). Teesta river and most of its tributaries flow with high velocity and carry boulders and suspended sediments (Goyal & Goswami, 2018). The velocity of water of Teesta river is about 6 m/sec and the average suspended sediment load is about 15.89×10^6 ton per year (Roy, 2011; Acharjee & Barat, 2013). The Teesta river system has the most active floodplain of North Bengal which is bounded with the Himalayan terraces in the northern and northwestern region, the Barind tract in the western and southwestern region, the Ganges floodplain in the southern region and the Jamuna river in the eastern region (Islam, 2016).

The upper portion of the basin is mostly covered with snow and glaciers, but the lower portion is mostly flat land and some parts are covered with forest (Singh, 2018). Sikkim and part of West Bengal (Darjeeling) have vast potential for hydropower development. It is expected that within a few years the Sikkim-Darjeeling region of India could produce over 6,000 MW of hydropower (Khawas, 2016). The upper part of the basin has a very low population density, but it has all the hydropower potential, unlike the lower part of the basin which is densely populated but lacks electricity. To date, both riparian countries (Bangladesh and India) have proposed several plans for effective negotiation of the issues related to the Teesta river (cf., Wirsing & Jasparrto, 2007; Mullick *et al*., 2013). Most of the proposed plans only focus on sharing water rather than sharing the benefits from water resources including hydropower.

Objectives of the research

This research has two primary objectives: (1) examine the hydropower development potential and identify the existing or proposed hydropower development projects; and (2) assess the hydropower sharing opportunity between Bangladesh and India within the Teesta river basin, useful for integrated future development.

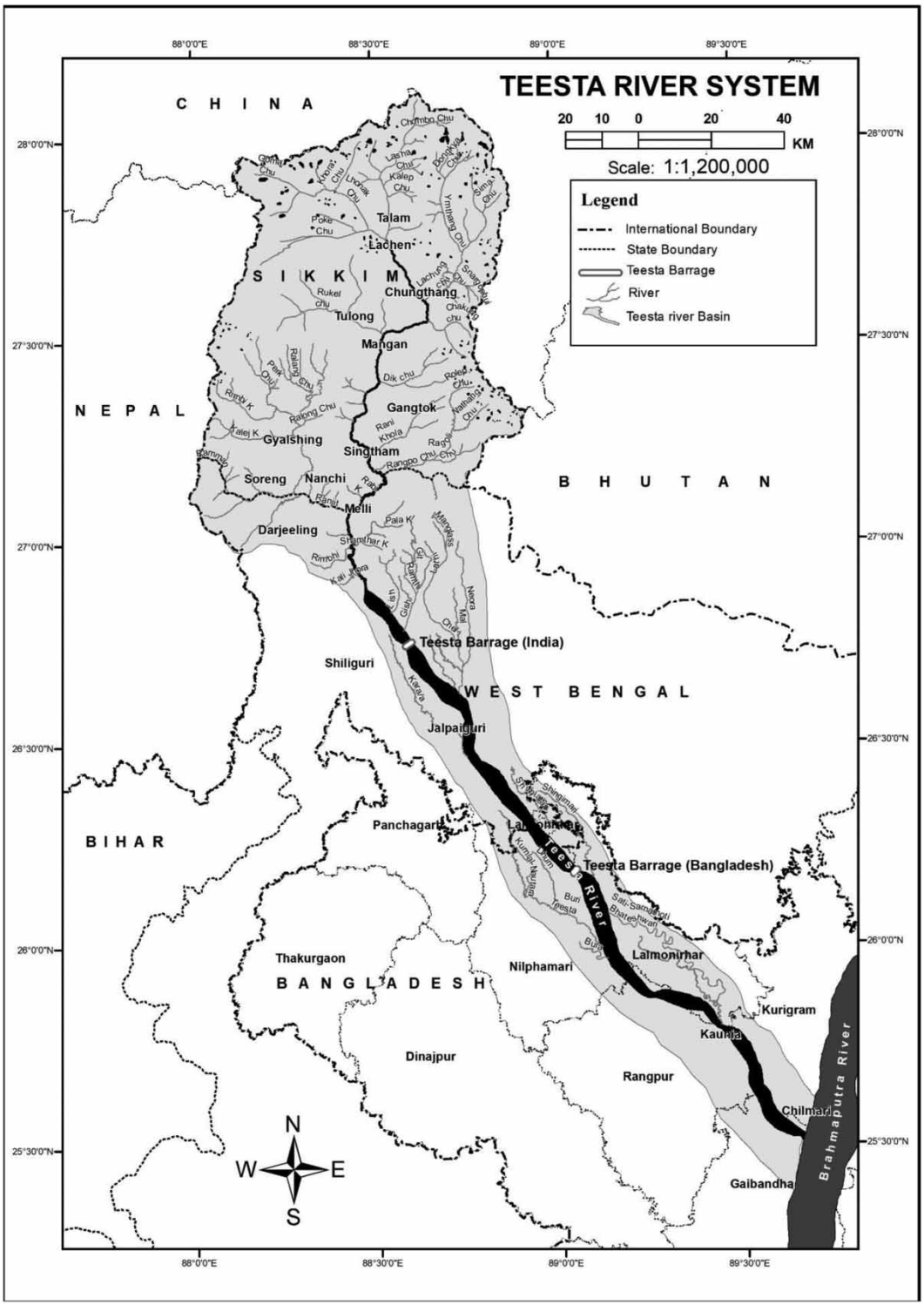

Fig. 1. Teesta river system.

Table 1. Teesta river basin area distribution and hydropower potential.

State/ Country	River length (in km)	Basin area (in km^2)	Population (in 2011)	Population intensity (per km^2)	Installed capacity (MW)	% of basin's total hydropower potential
Sikkim	170	7,039	610,577	87	5353	65
West Bengal	123	3,294	1,729,899	525	2841	35
Bangladesh	121	2,037	2,221,550	1,091	0	0
Total	414	12,370	4,562,026	369	8194	100

Sources: Khawas (2016), Rudhra (2018), EDPS (2019).

Data and information sources

Primary data have been collected from relevant government reports of Bangladesh and India, official websites of government organizations of Bangladesh and India and other international organizations (e.g., World Bank, International Energy Agency, etc.). Secondary data have been collected from various international, national and local organizations as well as published articles, books, documents and reports. The data of hydropower projects have been collected and cross-matched from CEA (2016), EDPS (2019), India-WRIS WebGIS (2018), NHPC (2019) and NTPC (2019). To improve the accuracy of the schematic diagram of the Teesta river system (Supplementary material, Figure A1) and the locations of the hydropower projects, data have been collected from several sources, e.g., EnvIS (2019), BWBD (2011), SANDRP (2019), etc. Great emphasis has been placed on the accuracy and reliability of the data.

Major human interventions along the Teesta river basin

From the earliest civilizations, river basins have played a vital role in sustaining communities, economic and social development, and also the accessibility and dependability of water. Human intervention along the river basin is a common issue for this era. When a river crosses two or more countries, the situation could become worse (cf., Rahaman, 2009a; Rahaman & Varis, 2009). Riparian countries have tried to use the water of the river for electricity generation, irrigation, drinking purposes and to serve other needs. The situation of the Teesta river basin of South Asia is no exception.

The Teesta river is prone to flash flooding which contributes a huge amount of sediment and water every year to the huge Brahmaputra river. However, a vast area of the northern part of Bangladesh suffers from a scarcity of water for irrigating agricultural land throughout the year, even during the monsoon. In an effort to resolve the water scarcity, the idea of gravity irrigation with water from the Teesta river was conceived in 1945 during British rule. After achieving independence, the government of Pakistan finished the feasibility survey and took an initiative to start this irrigation project. According to the Project Proforma (PP) of Teesta Barrage Project, the proposed date of commencement was 1960/61. After the independence of Bangladesh, the engineers of Bangladesh Water Development Board (BWDB) and Bangladesh University of Engineering and Technology (BUET) reviewed the previous feasibility survey and redesigned the project and selected Doani, Nilphamari for the barrage (BWBD, 1990). The construction of the barrage was started in 1979 and completed in 1992. Phase-I of the Teesta Barrage Project was completed in 1998, and was located 20 km south of the border with

India. The total command area of Phase-I and Phase-II of the Teesta Barrage Project are about 111,406 hectares and 448,774 hectares, respectively. The construction of Phase-II began in 2005, but due to insufficient water flow in the non-monsoon period, the project is still incomplete (Wirsing & Jasparro, 2007).

The Government of West Bengal planned the Teesta Barrage Project at Gajaldoba in 1975/76 to create new irrigable land in six northern districts of West Bengal, supply drinking water to Shiliguri municipality and generating hydropower. This is one of the largest irrigation projects of the northeastern region of India. The Teesta Barrage Project was under the Accelerated Irrigation Benefit Program (AIBP) of India and the funding proportion varied from 1:1 to 1:3 (Central:State). The project has three different phases: the target for the first phase is irrigating 922,000 hectares of land, generating 650 MW of electricity in the second phase and finally linking the Ganga and Brahmaputra together in the third phase. The first phase consists of three stages: to irrigate 545,000 hectares of land under the first stage, 223,000 hectares of land under the second stage and 153,000 hectares of land under the third stage (Mukherjee & Saha, 2016). The Central Water Commission (CWC) finalized the estimated cost for the Teesta Barrage Project in the first phase, first stage, first sub-stage as Rs. 2,988.61 Crore in 2008, which was about Rs. 69.72 Crore at the time of commissioning in 1975 (IWD, 2019). The expected completion time for the first phase was March 2015 but the construction is still ongoing.

In 1983, an ad-hoc agreement was signed between Bangladesh and India. According to that agreement, India and Bangladesh share 39% and 36% of water, respectively. The remaining 25% of water was allocated for the environment. The 1983 ad-hoc agreement was extended until 1987, but the governments of Bangladesh and India were unable to sign any treaty over sharing of water of the Teesta river. As well, India took initiatives for inter-basin water transfer projects that could increase the water scarcity of Bangladesh during the non-monsoon season (Abbas, 1984; Nishat & Faisal, 2000; Rahaman & Varis, 2009). Through the Brahmaputra–Ganges link canal, known as Jogighopa-Teesta-Farakka, India plans to create a series of dams to divert water from the Brahmaputra through the Jogigopa barrage in Assam to the Ganges at Farakka via the Teesta river (Rahaman, 2009a; Rasul, 2014).

The following section discusses hydropower development in the Teesta river basin in detail.

Hydropower development along Teesta river basin

In 2004, the Central Electricity Authority of India prepared a preliminary feasibility report of 162 new hydroelectric schemes with a total potential of over 50,000 MW, where Sikkim has ten schemes with an installed capacity of 1,469 MW (CEA, 2015). In 1974, a committee was formed to study the hydropower potential in Sikkim. Sikkim welcomes private developers for developing and exploiting its hydropower potential, which has been assessed as 8,000 MW peak with a firm base of 3,000 MW. Total hydropower potential in the state so far is 5,352.7 MW and there are different stages of implementation (EPDS, 2019).

About 47 hydropower development projects are in different stages. Existing hydropower projects in the Teesta river basin of Sikkim and West Bengal are listed in Table 2. Currently, 15 hydropower development projects are at different construction stages. According to the Draft National Electricity Plan 2018, all of these projects will be completed by 2022. The present status of all ongoing projects is listed in Table 3. The hydropower development projects which have faced financial issues or are in the planning phase are listed in Table 4.

Table 2. Existing hydropower projects along Teesta river basin (as of 28.07.2019).

Project name	Location	Installed capacity (MW)	River	Latest status/Remarks
Ramman II	West Bengal	50	Ramman	In operation. Project completed in 1995
Ranjit III	West Sikkim	60	Ranjit	In operation. Commissioned in February 2000. Project completed by NHPC
Teesta Low Dam III	West Bengal	132	Teesta	In operation. Commissioned in March 2013. Project completed by NHPC
Teesta Low Dam IV	West Bengal	160	Teesta	In operation. Commissioned in August 2016. Project completed by NHPC
Teesta Stage V	East Sikkim	510	Teesta	In operation. Commissioned in March 2008. Project completed by NHPC

Sources: CEA (2016), EDPS (2019), India-WRIS (2018), NHPC (2019).

The locations of hydropower development projects are shown in Figure 2. Figure 2 reveals that the majority of the hydropower development projects are located in the northern part of Sikkim, India. In Sikkim, some projects have been cancelled as they are located in areas in the vicinity of Kanchanjonga National Park. Since 1995, because of the anti-dam movement, Sikkim's government has cancelled at least eight dam projects (Bosoni, 2017). Rammam II, Teesta Low Dam III and Teesta Low Dam IV are the major hydropower development projects of West Bengal. The West Bengal government signed a Memorandum of Understanding (MoU) with National Hydroelectric Power Corporation (NHPC) in 2015 for constructing Ramman I, Teesta Lower Dam I and II (combined) and Teesta Lower Dam IV.

Concerns for future electricity demand: Bangladesh and India

As of 2014, the electricity consumption per capita of Bangladesh and India is about 311 KWh and 806 KWh, respectively (WB, 2018a). As both countries are part of the developing world, the consumption of electricity increases rapidly (Table 5). In every five years, the percentage of increased electricity consumption varies from 120% to 135% from the previous five years. To fulfil the increasing demand, both countries have undertaken several initiatives.

In 2017, the electricity production of Bangladesh and India was about 57.28 TWh and 1,206.31 TWh (Table 6). Currently, the main source of electricity production in Bangladesh is gas (53.48%) (BPDB, 2019). On the other hand, India depends on coal (54.3%) based power plants (MoP, 2019). India has taken some initiatives to switch their main source of electricity from coal to renewable energy (hydropower, wind, solar, etc.) to fulfil the future demand for electricity. About 47 major hydropower projects (each above 25 MW) throughout India are under construction. It is expected that these projects will contribute to around 14,000 MW additional electricity in the Indian national grid by 2022 (CEA, 2019).

Bangladesh has a GDP growth rate of 8.13 in the economic year 2018/19 (BBS, 2018). High GDP growth rate means more development and purchasing power, which indicates the rapidly increasing demand for electricity. The government of Bangladesh expects that electricity generation capacity will be 16,495 MW by 2020 (BPDB, 2018). However, the electricity demand of Bangladesh will be 66,804 MW by 2030 and the gap between electricity demand and generation capacity will be 50,309 MW (Mondal *et al.*, 2010).

Table 3. Ongoing hydropower projects along Teesta river basin (as of 28.07.2019).

Project name	Location	Installed capacity (MW)	Latest status/Remark
Bakchachu	North Sikkim	40	Project under survey and investigation by Sanvijay Power and Allied Industries Ltd
Bhasmey	East Sikkim	51	Project under construction by Gati Infrastructures Ltd. As per MoU, date of commissioning was December 2013. Project progress is around 28%
Chuzachen	East Sikkim	99	Project under construction by Gati Infrastructures Ltd. As per MoU, date of commissioning was June 2013
Dikchu	North/East Sikkim	96	Project under construction by Sneha Kinetic Power Projects Ltd. As per MoU, date of commissioning was December 2013 and project declared COD on March 2017
Jorethang	South Sikkim	96	Project under construction by DANS Energy Pvt Ltd. As per MoU, date of commissioning was June 2013 and project declared COD on September 2017
Paanan	North Sikkim	300	Project under construction by Himagiri Hydro Energy Pvt Ltd. As per MoU, date of commissioning was September 2013 and only preliminary construction works started
Rahi Kyoung	North Sikkim	26	Project under survey and investigation by Sikkim Engineering Pvt Ltd. DPR is under preparation. Public hearing has been concluded by SPCB
Ramman III	West Bengal	120	Project under construction by NTPC
Ranjit II	West Sikkim	66	Project under construction by Sikkim Hydro Ventures Ltd. As per MoU, date of commissioning was May 2013. Project progress is around 12%
Ranjit IV	West Sikkim	120	Project under construction by Jal Power Corporation Ltd. As per MoU, date of commissioning was July 2015. Project progress is around 49%
Ronginichu	East Sikkim	96	Project under construction by Madhya Bharati Power Corpora. As per MoU, date of commissioning was December 2013. Project progress is around 64%
Tashiding	West Sikkim	99	Project under construction by Shiga Energy Pvt Ltd. As per MoU, date of commissioning was September 2015. Project declared COD on September 2017
Teesta Stage III	North Sikkim	1,200	Project under construction by Teesta Urja Limited. As per MoU, date of commissioning was December 2013 and project declared COD on February 2017
Teesta Stage IV	North Sikkim	520	Project under construction by NHPC. Only preliminary construction works started. First stage environment clearance is obtained
Teesta Stage VI	North/ South Sikkim	500	Project under construction by Lanco Energy Pvt Ltd. As per MoU, date of commissioning was July 2013. Project progress is around 48%

Sources: CEA (2016), EDPS (2019), NHPC (2019), NTPC (2019).
COD, Commercial operation date; DPR, detailed project report; SPCB, State Pollution Control Board; MoU, memorandum of understanding.

Mondal *et al.* (2010) forecasted that the electricity demand of Bangladesh will be 131.58 TWh by 2035 in a low GDP growth scenario which is about eight times higher than the electricity consumption of 2005. In the average and high GDP growth scenarios, the demand will increase by about 11 to 16

Table 4. Upcoming/Proposed hydropower projects along Teesta river basin (as of 28.07.2019).

Project name	Location	Installed capacity (MW)	Latest status/Remark
Bhimkyong	North Sikkim	99	MoU/IA was terminated in June 2012. High Court of Sikkim has given a new timeline up to 2018 for the development of the project to Teesta Hydro Power Pvt. Ltd
Bop	North Sikkim	99	MoU/IA was terminated in June 2012. High Court of Sikkim has given a new timeline up to 2018 for the development of the project to Teesta Hydro Power Pvt. Ltd
Chakhungchu	North Sikkim	50	The project was allotted on 2002. An arbitration case is underway with Sikkim Govt. and Amalgamated Trans Power India Ltd
Kalez Khola I	West Sikkim	27.5	MoU/IA terminated due to non-performance of the West Sikkim Cosmic Infra Powergen Pvt Ltd in September 2016
Kalez Khola II	West Sikkim	54	MoU/IA terminated due to non-performance of the Pentacle Power Pvt Ltd in February 2017
Lachung	North Sikkim	99	MoU/IA was terminated in June 2012. High Court of Sikkim has given a new timeline up to 2018 for development of the project to Lachung Hydro Power Pvt. Ltd
Lethang	West Sikkim	96	Project not granted clearance by National Wild Life Board, Govt. of India. Project cancelled vide Notification No. 12/Home/2012
Lingza	North Sikkim	120	Project cancelled/not taken up as this area fell within Dzongu area and in the vicinity of Kanchanjonga National Park
Ramman I	West Bengal	48	MoU/IA signed with NHPC in July 2015
Manul and Mangan	North Sikkim	30	MoU/IA terminated due to non-performance of the Higen in September 2017
Ralang	South Sikkim	40	The project was allotted in 2002. An arbitration case is underway with Sikkim Govt. and Amalgamated Trans Power India Ltd
Rangyong	North Sikkim	80	Project cancelled/not taken up as this area fell within Dzongu area and in the vicinity of Kanchanjonga National Park
Rathangchu	West Sikkim	30	Projects scraped due to religious sentiments
Rechu-Meyongchu	North Sikkim	26	MoU/IA terminated due to non-performance of Planet Infra Projects Pvt. Ltd
Ringpi	North Sikkim	320	Project cancelled/not taken up as this area fell within Dzongu area and in the vicinity of Kanchanjonga National Park
Rolep	East Sikkim	36	The project was allotted in 2002. An arbitration case is underway with Sikkim Govt. and Amalgamated Trans Power India Ltd
Rukel	North Sikkim	33	Project cancelled/not taken up as this area fell within Dzongu area and in the vicinity of Kanchanjonga National Park
Sada-Mangder	West/South Sikkim	71	MoU/IA terminated due to non-achievement of the stipulated milestones by Gati Infrastructures Ltd in February 2017
Suntaleytar	East Sikkim	40	MoU/IA terminated due to non-performance of Moser Baer Electric Power Ltd/Shreya Powertech Pvt Ltd in February 2017
Teesta Low Dam I and II (Combined)	West Bengal	81	MoU/IA signed with NHPC in July 2015
Teesta Low Dam V	West Bengal	80	MoU/IA signed with NHPC in July 2015
Teesta Intermediate Stage	West Bengal	84	MoU/IA signed with NHPC in July 2015
Teesta Stage I	North Sikkim	280	MoU/IA cancelled as this area fell within the vicinity of Kanchanjonga National Park

(*Continued.*)

Table 4. (*Continued.*)

Project name	Location	Installed capacity (MW)	Latest status/Remark
Teesta Stage II	North Sikkim	330	MoU/IA terminated in September 2018 due to non-performance of Him Urja Infra Pvt. Ltd
Ting Ting	West Sikkim	99	Project cancelled vide Govt. Notification No. 12/Home/2012 as milestones as per MOU not achieved by T.T. Energy Pvt. Ltd
Upper Rolep (Nathangchu)	East Sikkim	30	MoU/IA terminated in September 2016 due to non-performance of Cosmic Infrapowergen Pvt Ltd
Upper Rolep (Tshanguchu)	East Sikkim	30	MoU/IA terminated in September 2016 due to non-performance of Cosmic Infrapowergen Pvt Ltd

Sources: CEA (2016), EDPS (2019), NHPC (2019).
IA, Interagency agreement.

times that of 2005. Saravanan *et al.* (2012) forecasted that, by 2030, the electricity demand will be 2,755.45 MW (Table 7). Bangladesh has a natural gas reserve of 27.12 TCF (trillion cubic feet) and, unfortunately, about 15.22 TCF of gas has already been used by the end of 2017. To meet the future electricity demand, regional hydropower cooperation is needed.

Cooperation: hydropower trade in South Asia

There are very few electricity trade agreements among South Asian countries (see Table 8). Bangladesh and India have an agreement to share electricity from India to Bangladesh that includes about 500 MW electricity, which could be extended up to 1,000 MW. Under the CASA-1000 project, Afghanistan and Pakistan have imported electricity from Central Asia. The transmission line of CASA could be extended up to India and Bangladesh. After fulfilling its own demands, Bhutan exports about 75% of its total electricity generation to India (Singh, 2013). India has invested in several power projects in Bhutan. Under the agreement between Bhutan and India, India committed to importing a minimum of 5,000 MW electricity from Bhutan (Singh *et al.*, 2015). Under a high growth scenario, by 2027, the power development projects of Nepal will earn huge revenues by developing a total hydropower capacity of 22,000 MW, including 15,000 MW for exports (Srivastava & Misra, 2007). Sri Lanka is expected to import around 1,000 MW of electricity from India.

Why hydropower sharing (India–Bangladesh) in the Teesta river basin?

Hydropower sharing between Bangladesh and the state of Sikkim, India, in the Teesta river basin, India could be beneficial for both countries for the following reasons:

- The electricity demand of the state of Sikkim, India, is about 264.7 kWh per capita (as of 2016/17) (EnvIS, 2019). It is expected that by 2022, the hydropower projects that are under construction and under survey and investigation will be completed (Table 2 and CEA, 2016). This will add about

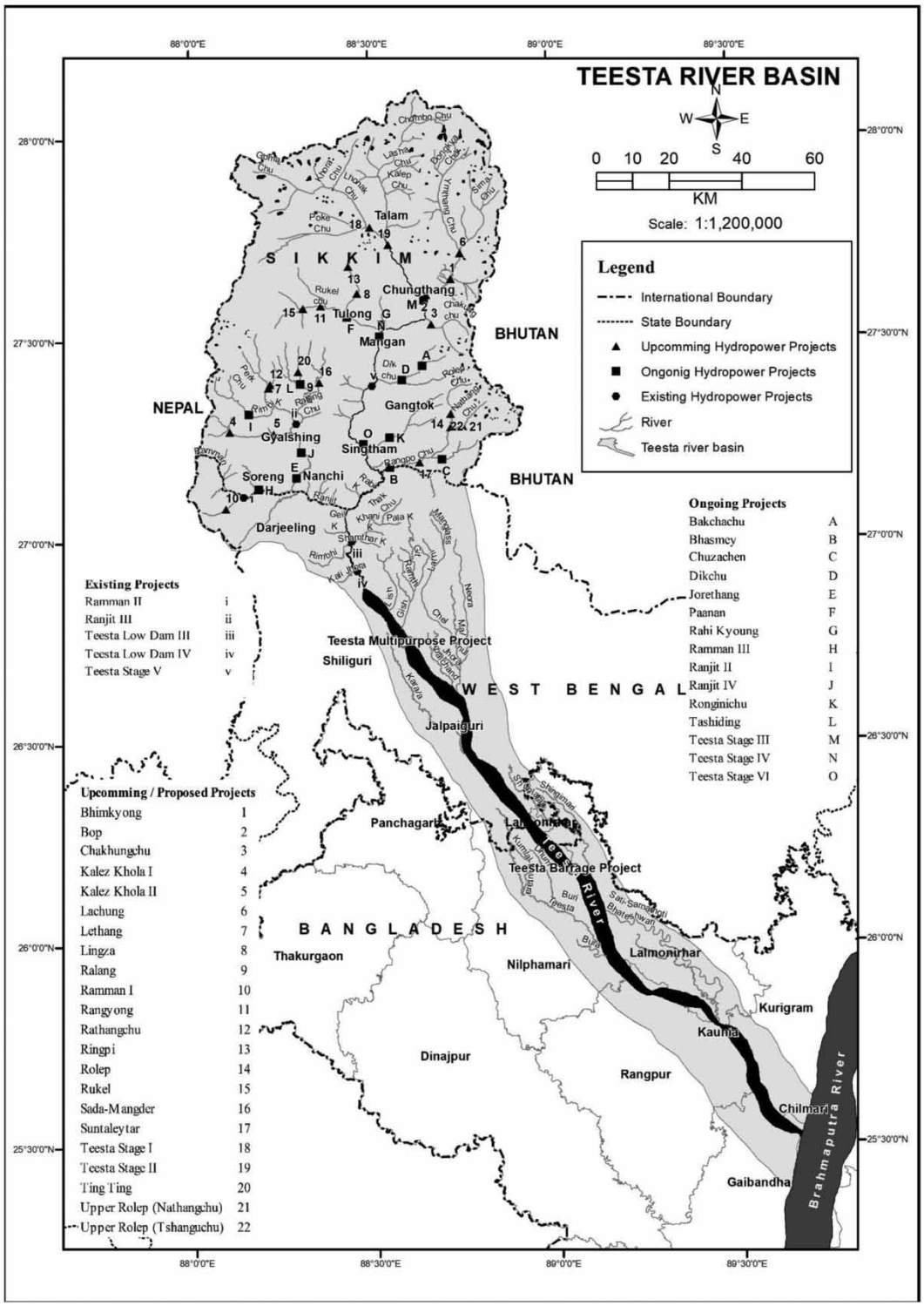

Fig. 2. Locations of hydropower projects along Teesta river basin.

Table 5. Electricity consumption and accessibility.

	% of population with access to electricity		Electric power consumption (kWh per capita)	
Year	Bangladesh	India	Bangladesh	India
1990	8.54	43.29	48.37	273.05
1995	20.76	51.50	75.90	360.05
2000	32.00	59.40	101.49	394.96
2005	44.23	66.93	170.68	469.45
2010	55.26	76.30	239.83	642.11
2014	62.40	81.24	310.39	805.60

Source: WB (2018a).
KWh, Kilowatt-hour.

Table 6. Electricity production of Bangladesh and India (TWh).

	Thermal (coal, oil, gas)	Hydro	Nuclear	Import	Total
Bangladesh (as of 2017)	51.64	0.98	0	4.66	57.28
India (as of 2017–2018)	1,037.06	126.12	38.35	4.78	1,206.31

Sources: BPDB (2017), CEA (2018).
TWh, Terawatt-hour.

Table 7. Forecasted demand of electricity of Bangladesh and India (TWh).

	2015	2020	2025	2030
Bangladesh	48.6	74.86	107.3	146.3
India	1,036.96	1,414.82	1,950.34	2,755.45

Sources: Mondal *et al*. (2010), Saravanan *et al*. (2012).

3,500 MW of electricity to their grid. After fulfilling the state of Sikkim's local demands, India could export electricity, which could give a strong base to the economy of Sikkim.

- Due to close proximity, exporting electricity from the Teesta river basin to Nepal, Bhutan and Bangladesh is feasible for the state of Sikkim. However, Bhutan already exports electricity and Nepal is also expected to be an electricity exporter by 2022. Hence, exporting hydropower to Bangladesh is the most feasible option for Sikkim.
- According to international law, as a riparian of the Teesta river basin, Bangladesh deserves first priority to import hydropower from the state of Sikkim, India (Helsinki Rules, 1966).
- Government of the state of Sikkim, India, aims to export hydropower to Bangladesh. The Power Trading Corporation (PTC) has been tasked to explore possibilities for exporting electricity to Bangladesh from Teesta III (1,200 MW) hydropower project (Dahal, 2016).
- Sikkim sells the hydro-electricity of Teesta III HEP (1,200 MW) to Punjab, Haryana, Rajasthan and Uttar Pradesh states of India at a very cheap rate of 3 INR/unit (about 0.041 USD/unit) (CFA, 2019). Sikkim could export the generated hydropower for a negotiable rate to downstream Bangladesh that could help to ensure the energy security in the basin.

Table 8. Recent regional cooperation for sharing of electricity in South Asia.

Participant countries	Description
Afghanistan and Central Asia	In 2011, Afghanistan imported about 2,246.2 GWh electricity from Iran, Uzbekistan, Turkmenistan and Tajikistan. CASA – 1000 has expected to increase the electricity trade
Bangladesh and India	In 2013, Bangladesh imported about 500 MW (expandable to 1,000 MW in future) electricity from India
India and Bhutan	In 2013/2014, India imported 5,556 GWh electricity from Bhutan. India and Bhutan have signed an agreement by which India will import a minimum of 5,000 MW electricity by 2020
Nepal and India	In 2013, Nepal imported 793 GWh electricity from India
Sri Lanka and India	A feasibility study has been conducted by Sri Lanka for importing up to 1,000 MW electricity from India
Pakistan and India	Pakistan submitted a draft MoU to India for importing about 1,200 MW electricity. CASA could be extended up to India
Pakistan and Iran	In 2014, Pakistan imported 419 GWh electricity from Iran

Source: Singh *et al*. (2015).
CASA-1000, Central Asia-South Asia power project.

- This is an excellent opportunity for Bangladesh to improve existing capacities and use clean energy to meet the climate change and other environmental targets. It could reduce tension due to future demands of electricity in Bangladesh.

Potential benefits from coordinated development: Teesta river basin

In the past, river basin management was looked after by hydraulic engineers, who managed the river for a single purpose only, such as navigation or hydropower. Nowadays, river basin management is often based on multi-purpose uses and basin-wide approach and involves many more actors (Ridder *et al*., 2005). Coordinated development of the Teesta river basin can change the present scenarios and reduce tension for both Bangladesh and India by reducing water-related tension, increasing irrigation, food security and energy security that could also potentially open a new path of broader water cooperation in other river basins in South Asia. Below these potential benefits are summarized.

Optimal water sharing: reducing tension

Bangladesh and India have negotiated several times to sign a treaty to solve the Teesta river dispute. Most recently, in 2011, the governments of Bangladesh and India were supposed to sign a 15-year interim deal in a water sharing ratio of 37.5% (Bangladesh):45.5% (India). However, the state government of West Bengal and Sikkim of India opposed the interim deal and since then the deal remains unsigned (Salman & Uprety, 2018).

In most cases, the upper riparian of an international river basin has tended to prefer the 'Harmon Doctrine' or 'theory of absolute territorial sovereignty' that claims every nation can utilize the waters of an international river flowing through its territory, as it likes; whereas the downstream riparian countries tend to favour the 'theory of absolute territorial integrity' that ensures the right to claim the continued and uninterrupted flow of water from the territory of the upper riparian (Wolf, 2007; Rahaman, 2009b;

Melesse *et al*., 2014). But, until now, all the disputes that have been solved are not rights based, but needs based (e.g., irrigable lands, population or specific projects). For example, the Nile River Treaty (1929 and 1959) was based on existing uses and development projects; the Johnston Accord (1956) of the Jordan river was based on irrigable land in the riparian countries; the Israel–Palestinian shared aquifers Interim Agreement (1995) was also based on population pattern and irrigation need; the Indus river treaty (1960) has provided a framework for irrigation and hydropower development (Wolf, 2007; WB, 2018b).

In 1961, Canada and the USA signed a treaty to share benefits of the Columbia river which could be an excellent example for Teesta river cooperation. Canada has storage tanks in the upstream and USA has developed flood control systems and hydropower dams in the downstream and both countries share benefits equally (Krutilla, 1969; Islam & Higano, 2001). An optimal benefit sharing treaty based on needs over the Teesta river basin could reduce water and energy scarcity and increase food security.

Increasing irrigation and food security

The riparian people of the lower Teesta basin are economically affected due to the rising cost of groundwater lifting and rising installation cost of deep tubewell compared to past years as a result of the declining groundwater table. The declining groundwater table has also created water quality problems in the lower Teesta basin (e.g., Lalmonirhat, Rangpur and Nilphamari districts of Bangladesh) (Raihan *et al*., 2017). A cooperative development of the Teesta river basin could ensure the water for cultivation of about 750,000 hectares in the lower Teesta basin in Bangladesh and about 922,000 hectares in the upper Teesta basin in India (Mukherjee & Saha, 2016; Islam, 2016). Irrigated crops from both Teesta barrage projects located in Bangladesh and India (see Figures 1 and 2) could be shared to fulfil the needs of the riparian people of the Teesta river.

Regional energy security: New path for broader cooperation

Bangladesh and Sikkim (India) could develop hydropower in a cooperative manner following the example of India–Bhutan cross-border electricity trade. With financial assistance and cooperation from India, Bhutan has developed several hydropower projects and is exporting hydropower to India. India has invested, as loans, about 57 billion INR and 88% of the investment is targeted at the development of the power sector of Bhutan. Under the existing agreements between India and Bhutan, around 10,000 MW hydropower will be produced in Bhutan by 2020 (Tortajada & Saklani, 2018). Hydropower cooperation over the Teesta river basin could also open the door for cross-border electricity trade of Bangladesh–Bhutan by following the same pattern as the Bhutan–India hydropower cooperation.

The Teesta dispute is a bilateral issue of Bangladesh and India and if the cooperation along the Teesta becomes successful, it could enhance the possibility of broader multilateral water and hydropower cooperation in the Brahmaputra basin (Bangladesh–China–India–Bhutan) and Ganges river basin (Bangladesh–India–Nepal) (cf., Rahaman & Varis, 2009; Rahaman, 2012) (see Table 9).

Conclusion and recommendations

This paper assessed the present condition of hydropower development within the Teesta river basin. The total hydropower potential of the basin is over 8,000 MW, mostly located in the states of Sikkim

Table 9. Technically feasible unexploited hydropower potential (MW) in south Asian countries.

Country	Technically feasible hydropower potential (MW)	Access to electricity (% of population)	Required access to electricity (% of population)	Future target
India	194,413	79.17	20.83	Meeting domestic demand and export
Nepal	41,930	84.9	15.1	Meeting domestic demand and export
Bhutan	23,467	100	0	Export
Myanmar	39,720	52	48	Meeting domestic demand
China		100	0	Export
Total	**299,530**			

Source: Rahaman & Hossain (2019).

and West Bengal of India. Currently, a total of 47 hydropower projects of Sikkim and West Bengal within the Teesta river basin are in different stages and have a total installed capacity of around 6,753.5 MW (see Tables 2–4). The governments of the states of Sikkim and West Bengal, India, are taking numerous initiatives to explore more hydropower potential within the Teesta river basin.

Hydropower plays an important role in achieving Goal 7 of the Sustainable Development Goals (SDGs), which has a target to ensure universal access to affordable, reliable and modern energy services by 2030 (Target 7.1) (UN, 2015). Hydropower is an affordable, reliable, sustainable and modern technology that can help the communities or regions to acquire a reliable supply of electricity. Coordinated hydropower development could increase the access to electricity at an affordable rate and, in turn, help the countries to achieve target 7.1 of SDG 7. As SDG 7 is closely interlinked with SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action) (UNFCC, 2018), coordinated hydropower development in the Teesta basin could also help both countries to mitigate the challenges related to climate change (e.g., reducing greenhouse gas emissions).

To have an effective hydropower sharing agreement, the governments of Bangladesh and India should consider the following issues:

- After fulfilling its own electricity demand, the state government of Sikkim could export electricity to Bangladesh which would improve the economic condition of Sikkim.
- The state of Sikkim, India, should have a clear policy to export hydropower to Bangladesh.
- The cost of electricity should be based on market price, which will ensure both parties are in a win-win condition.
- Agreement should be for the longer term as short-term agreement often does not produce effective cooperation due to lack of continuous commitment.
- The socio-economic and socio-political conditions of both countries should be considered.
- A feasibility study should be conducted, which will reduce the risks to financial investment, environment and society.

Management of transboundary water resources has evolved gradually according to changing social needs, increasing demands for water resources and climatic effects. Bangladesh and India already have an agreement for electricity sharing (see Table 8). The effectiveness of the agreement could

influence the future hydropower sharing opportunities between Bangladesh and India. The findings of this study should be carefully interpreted. If political leadership shows a strong will and strengthens regional cooperation and electricity trade, hydropower development along the Teesta river basin could significantly contribute to economic development in the riparian countries, i.e., Bangladesh and India.

Supplementary material

The Supplementary Material for this paper is available online at https://dx.doi.org/10.2166/wp.2020.136.

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