INTEGRATED WATER MANAGEMENT OF THE BRAHMAPUTRA BASIN: PERSPECTIVES AND HOPE FOR REGIONAL DEVELOPMENT

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Abstract
This paper analyses the current status of Brahmaputra water resources and identifies the perspectives of riparian countries regarding the development of the Brahmaputra basin. Water is strongly linked with the overall development framework of the Brahmaputra basin. However, the absence of integrated management of Brahmaputra water resources and lack of coordination among the riparian states constitutes an ongoing threat to future development plans within the basin. Brahmaputra's abundant hydropower potential can help give riparian countries a safer energy future that is the key driving force behind the prospect of potential cooperation. This paper identifies the opportunities for cooperation and regional development through integrated water development and management of the Brahmaputra basin. It is essential to develop an integrated water resources management approach involving all riparians intended to foster regional development and overcome the prospect of sever water conflict along the Brahmaputra basin.
Key words: Brahmaputra basin; integrated water resources management; water cooperation; regional development.

1. Introduction

The Brahmaputra river basin is located 82°-97° east longitude and 21°-31° north latitude. The river has a total length of 2880 kilometres that is 22nd longest river in the world (Sarma, 2005: 72). The total drainage area of Brahmaputra is around 573394 square kilometres and shared by China, India, Bhutan and Bangladesh (Table 1; Figure 6).

Table 1: Brahmaputra Basin Area distribution (n/a means *not available*)

Country	Drainage area (10^3 km^2)	% of area of basin	% of total area of country	Arable land (km^2)	Population (million) (1999)	Hydropower potential (10^3 MW)	% of basin's total hydropower potential
China (Tibet)	293	51.1	3.1	n/a	2	110	53.4
Bhutan	38.4	6.7	100	2,956	0.635	30	14.6
India	195	34.0	59.32	55,000	31	66	32
Bangladesh	47	8.2	32.64	36,000	47	0	0
Total	573.4	100		93,956	80	206	100

Sources: Sarma, 2005: 73; NHPC, 2008; Tianchou, 2001:110; World Bank, 2008; Rangachari & Verghese, 2001:82; CWC, 2008; DOT, 2007; NPB, 2008.

The Brahmaputra is known as Tsangpo or Yarlung Zangbo in China, Brahmaputra in India and Jamuna in Bangladesh. The Tsangpo originates at an altitude of 5150 m about 250 km to the northeast, in the Kailash range in Tibet, north of the Himalayan crestline (Bandayopadhyay, 1995: 417). This river is thought to be the highest river on earth with an average altitude of 4000 m (Tianchou, 2001:104).

Five major tributaries join the Yarlung Zangbo inside China, i.e. the Xiong Zangbo river, the Nianchu river, the Lhasa river, the Niyang river and the Ponong Zangbo river (Tianchou, 2001:104). After passing 1700 km and draining 293000 square kilometres of area in Tibet, Yarlung Zangbo enters India across the Sadiya frontiers in Arunachal Pradesh, where it is known as Dihang or Siang (Sarma, 2005:73; Rao, 1979:75).

In India, three major tributaries join this mighty river, namely: Dibang, Lohit and Subansiri. Entering Assam, the river becomes named as Brahmaputra. Inside India, Brahmaputra has a total length of 760 km. Its drainage area covers 97.23% of Arunachal Pradesh (81,424 km^2), 90% of Assam (70,634 km^2), 50% of Meghalaya (11,667 km^2), 65% Nagaland (10,803 km^2), 100% Sikkim 7,300 km^2 and 15% of West Bengal (12,585 km^2) (Sharma 2005:452; Sarma, 2005:73; Ojha & Singh, 2005:1; CWC, 2008).

The entire territory of Bhutan belongs to the Brahmaputra basin (Table 1). Four major tributaries have their origins in Bhutan. They are Amochu or Torsa, Wang Chu, Sankosh, and Manash. Wangchu, Sankosh and Manash joins with Brahmaputra inside India and Amochu joins inside Bangladesh (Rao, 1979:78). After that, the Brahmaputra finally enters Bangladesh through Lalmanirhat district of northern Bangladesh. After passing 50 km inside Bangladesh, another major tributary, Tista river joins with Brahmaputra near Chilmari river port. From the confluence point of Tista and Brahmaputra, the river once again changes its name, now known as Jamuna. Many small tributaries join with Jamuna inside Bangladesh e.g. Korotoya and Atrai.

The Brahmaputra river flows across the plains of Bangladesh for 337 km before joining the Ganges, another great river of South Asia, at Goalanda (Sarma, 2005:73). The combined flow of these two rivers is now known as the Padma. After flowing another 105 km (Rao, 1979:77), the Padma merges with another major transboundary river, Meghna, at Chandpur. From this confluence, the combined course of these three mighty rivers known as the Lower Meghna. Finally, the three rivers, Ganges, Brahmaputra and Meghna, empty into the Bay of Bengal with a name Lower Meghna.

1.1 Water Resources and Hydropower

At Pandu (Assam), the Brahmaputra has an average annual (1956-1979) flow rate of 18,099 $m^3 s^{-1}$ and flow volume of 571 x 10^9 m^3 (GRDC, 2006). At Bahadurabad (Bangldesh), the Brahmaputra has an average annual (1956-1979) flow rate of 19,331 $m^3 s^{-1}$ and flow volume of 610 x10^9 m^3 (BWDB, 2007) (Figure 1). At Bahadurabad, during January-April average flow is 5186 $m^3 s^{-1}$, whereas during June to October average flow is 35,712.5 $m^3 s^{-1}$. Of the total annual flow 77% occurs during the monsoon season (June-October). At Bahadurabad (1956-2006), the highest recorded flow is 103,128 $m^3 s^{-1}$ on 8 September 1998 and the lowest recorded flow is 2702 $m^3 s^{-1}$ on 1 April 2001 (BWDB, 2007).

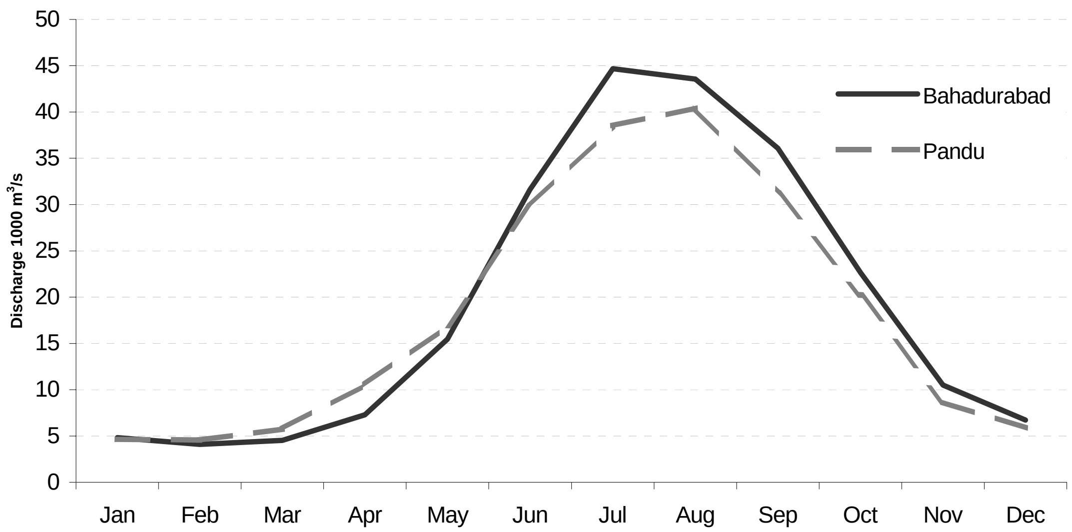


Figure 1: Brahmaputra River: Average monthly discharge (1956-1979) measured at Bahadurabad and Pandu. (**Sources:** Discharge data obtained from GRDC, 2006; BWDB, 2007).

The enormous hydropower potential of Brahmaputra basin is still mostly untapped (Table 1; Figure 2). The electricity consumption in the riparian countries is far below than the world average (Figure 3).

1.2 Objectives of the research

This paper has two objectives. Firstly, it examines the perspectives and future plans of the riparian countries for the Brahmaputra basin water resources development. Secondly, it identifies the constraints and opportunities for cooperation and regional development through integrated water development and management of the Brahmaputra basin. It categorises the potential benefits of integrated Brahmaputra water development into four groups, (1) benefits to the river; (2) benefits from the river; (3) benefits because of the river; and (4) benefits beyond the river.

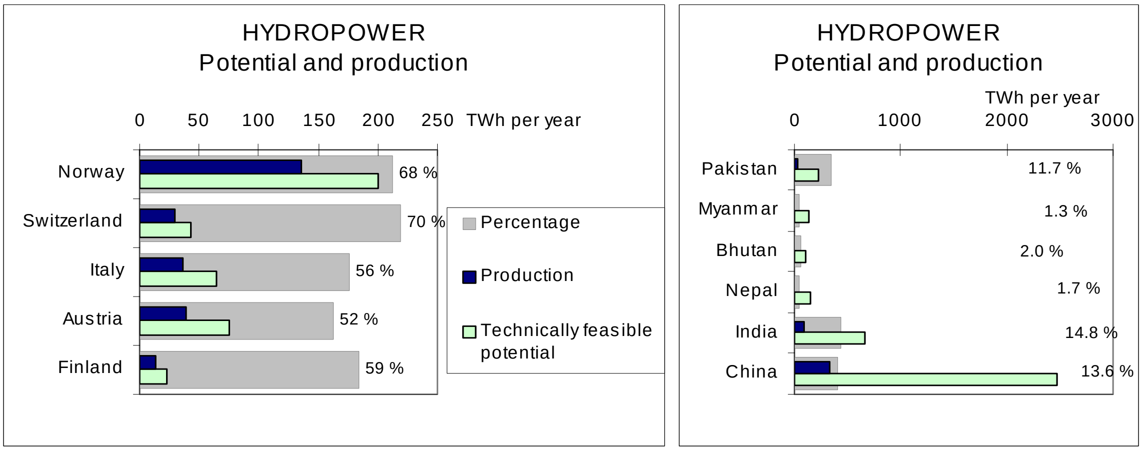


Figure 2: Hydropower Potential and Production from Hydro Plants (at end-2005) in some developed countries (on the left) and Brahmaputra basin's and neighbouring countries (on the right).
Source: WEC, 2007:277-291.

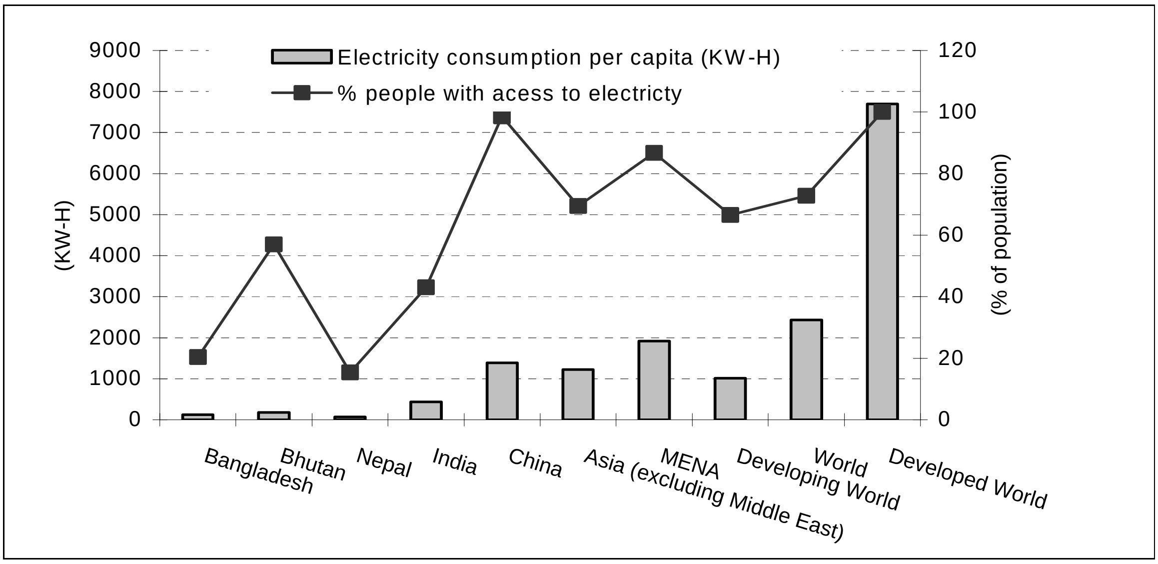


Figure 3: Electricity consumption and access in Brahmaputra riparian countries and in some selected region. (**Source:** WRI, 2008).

1.3 Data and information sources

Data has been collected both from primary and secondary sources. Primary data and information have been collected from relevant organisations and experts during six months research trips to the study area by the first author in 2004, 2005 and 2007. Secondary data have been collected from various international, governmental and local organisations as well as published articles, books, documents and reports. Discharge data for the Ganges and Brahmaputra rivers obtained from *Bangladesh Water Development Board* and *The Global Runoff Data Centre*, Germany.

2 Conflict and cooperation: Perspectives of India and Bangladesh

After the commissioning of the Farakka barrage along the mainstream of the Ganges in 1975 and subsequent conflict regarding the water shortage in downstream Bangladesh, Bangladesh and India signed two agreements, respectively in 1977 and 1996, to resolve Ganges conflict. Rahaman (2005; 2006) analysed these treaties and Rahaman (2008) scrutinises the conflict and cooperation between the riparian countries and integrated development potential of the Ganges basin water resources. This study focuses on Brahmaputra river basin.

2.1 Bangladesh Perspective

Of the total annual flow of Bangladesh about 67% is contributed by Brahmaputra River, 18% by the Ganges and about 15% by the Meghna and other major rivers (Rahaman, 2008).

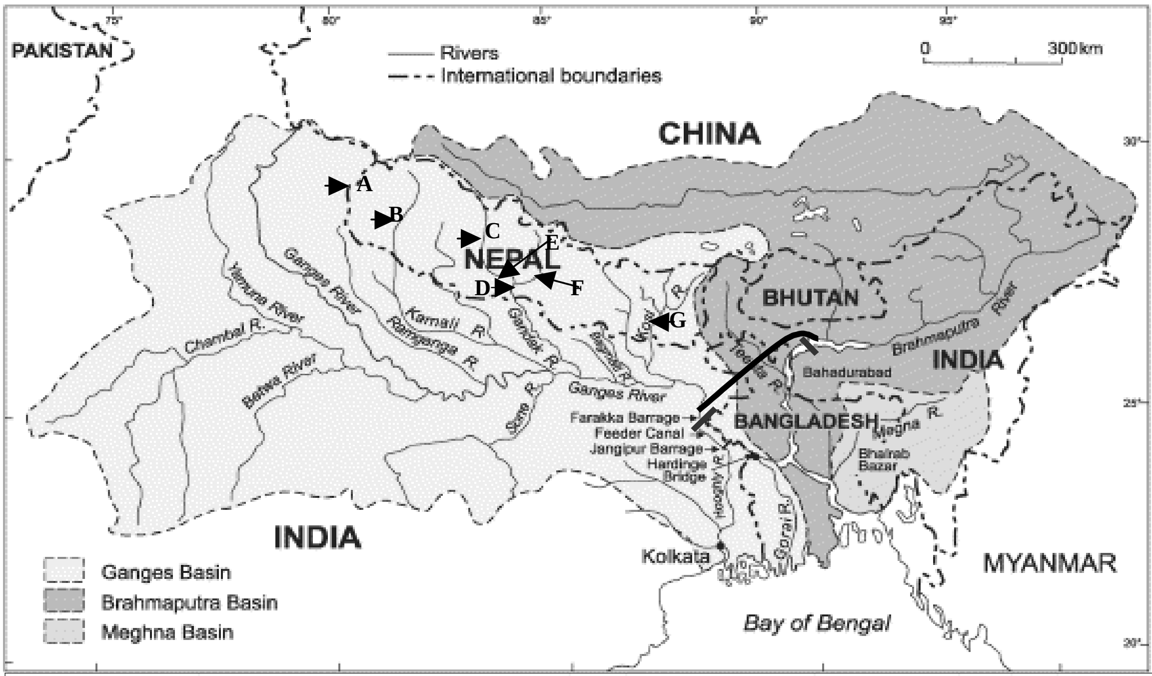
The official discussion about Brahmaputra Basin water management between Bangladesh and India was initiated by section B (Articles VIII-XI) of the 1977 Ganges agreement that deals with the long term arrangement for augmenting Ganges water at Farakka. Article IX instructed Indo-Bangladesh Joint River Commission (JRC) to carry out investigation and study of schemes for augmenting dry season flow of the Ganges with a view to finding a solution which is economical and feasible. According to the instruction, in 1978, Bangladesh and India exchanged their official proposals for augmenting the dry season flow of the Ganges. These were subsequently updated in 1983. However, the principles of the 1983 proposals were identical to the 1978 proposals (Crow *et al.*, 1995:262).

Bangladesh's 1978 proposal recommended augmenting the dry season flow of the Ganges by conserving a part of its monsoon flow through construction of storage dams in Nepal (Abbas, 1984:124; Figure 4). The proposal implied that the water stored in reservoirs to be built in Nepal should be allocated for the needs of Bangladesh and of Kolkata port (Crow *et al.*, 1995:176). Bangladesh also proposed a canal to be constructed along the Terai in Nepal that could convey the waters from the Gandak and the Kosi rivers to augment dry season flows of the Mahananda river in West Bengal as well as Korotoya and Atrai rivers in Bangladesh. This canal could serve as an international navigational route that would provide landlocked Nepal a direct access to the sea via Bangladesh (Abbas, 1984:125). Bangladesh kept insisting India that joint approach to Nepal for the data and effective multilateral cooperation is vital in this regard (Crow *et al.*, 1995:180; Verghese 1999:366). In updated 1983 proposal, Bangladesh highlights seven storage dams in Nepal (Figure 4; for details see Rahaman, 2008).

During 1983 to 1987, one segment of Bangladesh government was stressing on a new proposal, which is widely known as *new line*. It principally focused on immediate permanent water sharing mechanisms for all transboundary rivers bilaterally with India and augmenting the flow through regional cooperation in the long term. The proponents rationalised the proposal on the ground that long term sharing arrangement would help Bangladesh to develop its water resources solely inside Bangladesh. The essential engineering factors behind this proposal were to construct two barrages inside Bangladesh, one across the Brahmaputra (at Bahadurabad, Jamalpur) and another across the Ganges (at Pangsha, Kushtia), and a link canal to connect the two rivers to allow transfer of water from the Brahmaputra and the Ganges. However, this proposal did not have clear support from all sections of the government and technical officials (for details, see Crow *et al*, 1995:185-217). It is worth noting that this *new line* had never been officially approved or publicly declared by Bangladesh government (Rahaman, 2008).

2.2 India's Perspective

India advocates for inter-basin water transfer from the Brahmaputra basin to the Ganges basin through a link canal to address the dry season scarcity in the Ganges basin. India's 1978 proposal had two parts: first, a 2460 m long barrage across the Brahmaputra at Jogigopa in Assam with a 324 km long, 274 m wide and 9 m deep feeder canal across Bangladesh to a point just above the Farakka in West Bengal (Figure 4; Crow *et al.*, 1995). The link would have a capacity of 2832 m^3 s^{-1} at its head (Sinha, 1995:311). The idea is to divert Brahmaputra water from February to April to Ganges when (according to India's estimate) water is abundant in the Brahmaputra and scarce in the Ganges (Figures 5 and 6). The second part of the proposal envisaged the construction of three storage reservoirs (Subansiri, Dihang and Tipaimukh) in the eastern foothills of the Himalayas (Table 2) to supplement the dry season flow of the Brahmaputra. The Dihang and Subansiri were estimated to lower the flood peak of Bangladesh by 1.3 m while the Tipaimukh dam would reduce the flood in the Meghna basin of Bangladesh especially to Dhaka (Crow *et al.*, 1995:164-168; Verghese, 1999:363).



<u>India's proposal</u>: Brahmaputra- Ganges Link Canal

<u>Bangladesh's proposal</u>: Reservoirs in Nepal

A-Pancheswar **B-**Chisapani **C-**Kaligandaki (1) **D-**Kaligandaki (2)
E-Seti **F-**Trisulganga **G-**Sapt Kosi

Figure 4: Bangladesh and India's 1978 official proposals for Ganges and Brahmaputra Water Management. (**Sources:** Mirza, 2004;Rahaman, 2008).

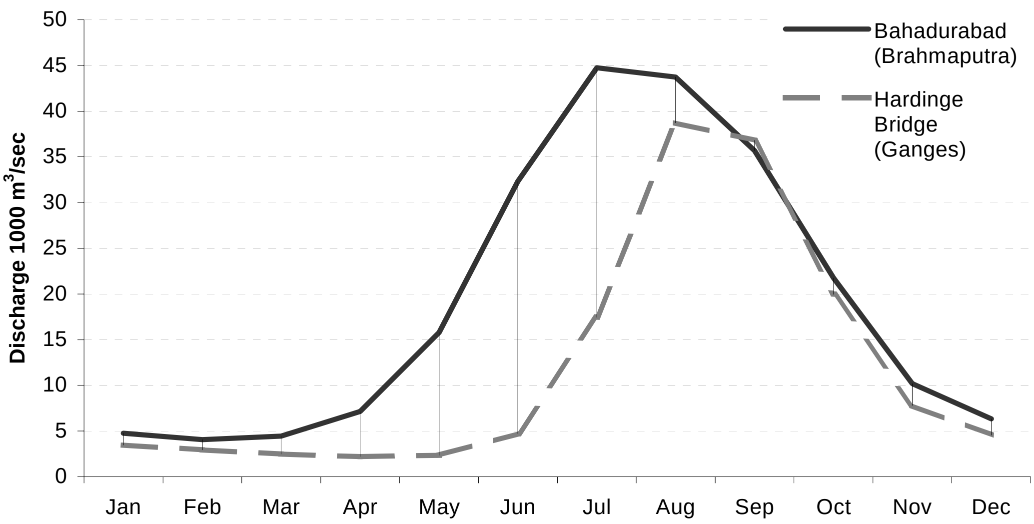


Figure 5: Brahmaputra and Ganges Rivers: Average monthly discharge (1956-1974) measured at Bahadurabad and Hardinge Bridge measurement stations in Bangladesh.
Source: Data for analysis obtained from BWDB, 2007.

Table 2: Identified large storage reservoirs in Brahmaputra and Meghna basins (India)

Reservoir	Catchment area (km^2)	Flow at site (10^6 m^3)	Dam height (m)	Gross storage (10^6 m^3)	Live storage (10^6 m^3)	Hydropower generation capacity (MW)
Lohit	19,100	37,000	296	5,160	3,310	3,000
Dibang	10,350	33,900	236	6,200	4,700	2,500
Subansiri	27,000	52,700	257	14,000	10,000	4,800
Jia Bhareli	9,980	25,900	211	6,500	5,100	20,000
Dihang	247,500	179,000	296	47,000	35,500	7,600
Tipaimukh	12,758	12,500	161	15,900	9,000	1,500

Sources: Rangachari & Verghese, 2001:118; Crow *et al.*, 1995: 167-175; Verghese, 1999; Sharma, 2005:454.

India rejected Bangladesh's plan claiming that the possibilities of water storage in Nepal is very low. India's proposal mentioned four potential reservoir sites, but estimated that the water from these reservoirs would not be enough to meet the demand of the three countries. Bangladesh also rejected India's plan claiming that it is technically not feasible (Crow *et al.*, 1995:170-174; Rahaman, 2008). In addition, Bangladesh claims that dry season flow of Brahmaputra is not abundant. Bangladesh has objected to this India's plan on the ground that Bangladesh needs 5100 m^3/s of water alone for irrigation from the Brahmaputra during February to April (Figure 6; Verghese, 1999:364). At Bahadurabad, Bangladesh, during February to April the average flow (1956-2003) is 5684 m^3 s^{-1} (Figure 6). The average flows (1956-2003) in February, March and April are respectively 4262 m^3 s^{-1}, 4804 m^3 s^{-1}, and 7988 m^3 s^{-1} (BWDB, 2007).

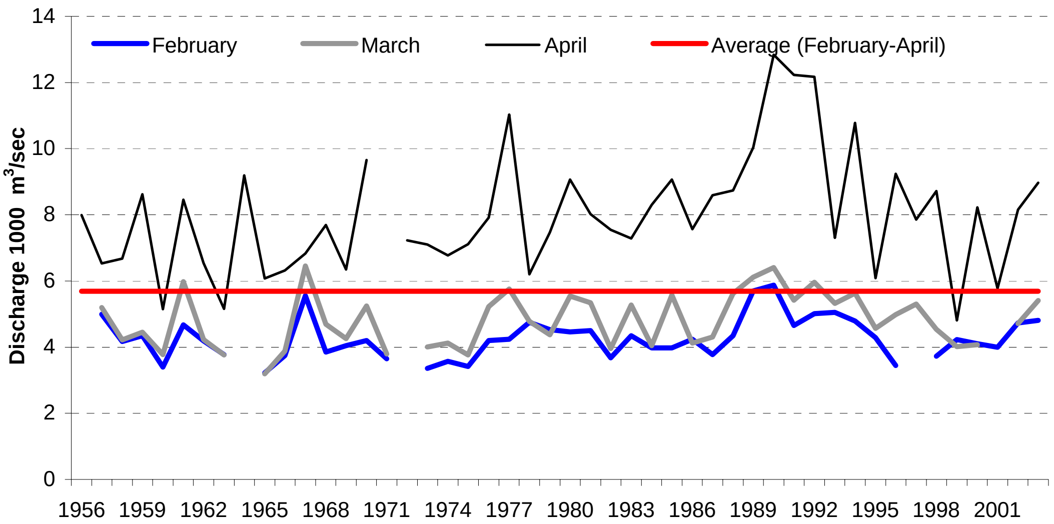


Figure 6: Brahmaputra River: Monthly discharge (February-April) measured at Bahadurabad, Bangladesh, 1956-2003. Data for the year 1964 (Feb-Mar), 1972 (Feb-Mar), 1997 (Jan) is not available. (**Source**: Data for analysis obtained from BWDB, 2007).

Recently, under US$200 x 10^9 Rivers Interlinking Project (RIP), India is planning to unilaterally divert water from the Brahmaputra to the Ganges by two major links entirely through Indian territory (the 32 km narrow part of India separating Nepal from Bangladesh) (NWDA, 2008). This can be termed as "New Indian line". Under RIP, 46 rivers across India would be linked by 2016 through 30 major links involving 10,000 km of canal length and 32 dams (Fairless, 2008; NWDA, 2008; Rahaman, 2008).

The first Brahmaputra-Ganges link canal, known as Jogighopa-Tista-Farakka, involves constructing large dams in India (e.g., Dihang, Subansiri and Lohit) to divert water from Brahmaputra through Jogighopa barrage in Assam to Ganges at Farakka via Tista river (Figure 7; NWDA, 2008). Due to topographic factor this link would involve large lifts of 60 m and require 7500 MW of power (Verghese, 1999:380).

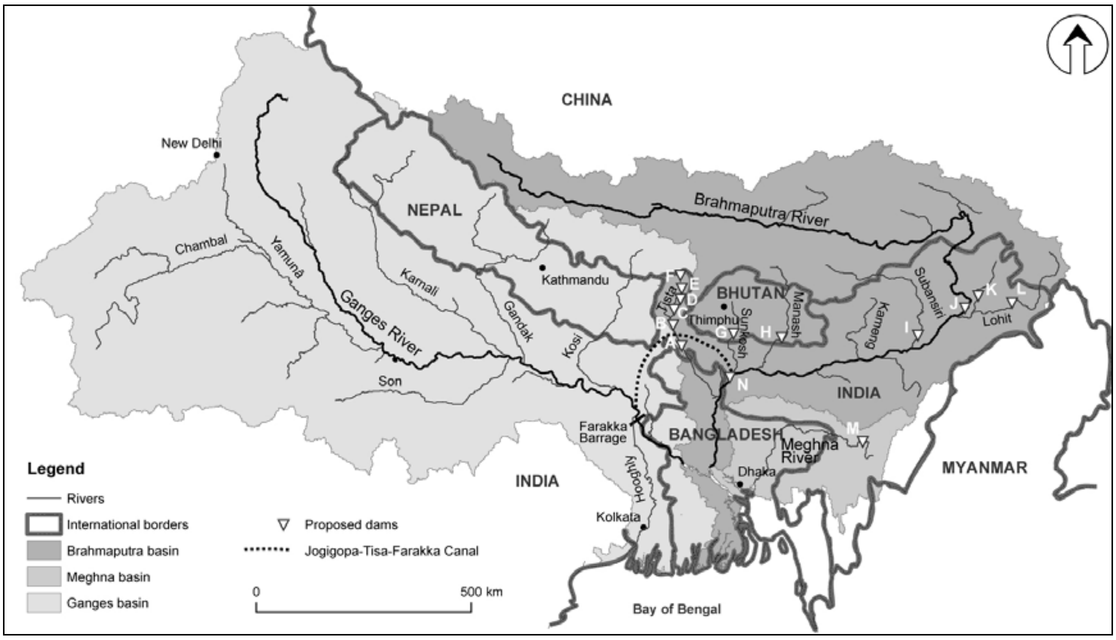


Figure 7: The *New Indian line* and some proposed dams in the Brahmaputra. **A**. Tista Low Dam III, **B.** Tista Low Dam IV **C.** Rangit **D.** Tista IV **E.** Lachen **F.** Tista V **G.** Sunkosh **H.** Manash **I.** Subansiri **J.** Dihang **K.** Dibang **L.** Lohit **M.** Tipaimukh **N.** Jogigopa barrage.
Sources: NHPC, 2008; NEEPCO, 2008; Rahaman, 2008.

The second Brahmaputra-Ganges link canal, known as Manash-Sunkosh-Tista-Ganga, includes construction of two multipurpose projects on Manash and Sunkosh rivers in Bhutan and diverting water to Ganges via Tista river (NWDA, 2008). The Manash Multipurpose Project along the Manash river with an installed hydropower capacity of 2800 MW in under consideration by Bhutan and India. Preliminary Feasibility Report (PFR) has already been prepared (MPI, 2008b). The Sunkosh Multipurpose Project (see Table 7) costing around Rs. $150x10^9$ (2000 estimates) envisages a 250 m high main dam on the Sunkosh river near Kalikhola area in Bhutan. The water from Sunkosh river would be diverted through 141 km long, 60 m wide, 6 m deep with a bed of 26 m canal across the northern part of West Bengal into the Tista River (Gaan, 2000: 167). From Tista the water will be finally diverted to the Ganges at Farakka.

2.3 Tista Cooperation

Tista river originates from Jongsong Peak in Sikkim and flows through West Bengal, India and joined with Brahmaputra in Bangladesh (Encarta, 2001). It is 315 km long and flows 115 km inside Bangladesh before falling into Bhrahmaputra (Majumder, 2004:44). It has a catchment area of 12500 km and average annual flow (1959-2005) rate of 886 $m^3 s^{-1}$ (BWDB, 2007). The lowest recorded flow is 4.48 $m^3 s^{-1}$ on 26 March 2001 and the highest recorded flow is 8710 $m^3 s^{-1}$ on 14 August 1987 (BWDB, 2007).

On July 20, 1983, Bangladesh and India reached an agreement on ad hoc sharing of the Tista waters (UNEP, 2002:59). According to the agreement 36% of water is allocated for Bangladesh, 39% for India and the rest 25% water is allocated for environment. Upon its expiry on 31 December 1985, it was extended up to 31 December 1987. This agreement was never implemented and extended further. As of today, the sharing of Tista water is a source of tension between Bangladesh and India. Wirsing & Jasparro (2007) elaborately described the conflict and negotiations regarding the Tista river.

Both India and Bangladesh constructed two barrages along the Tista river. Gazoldoba barrage in India was commissioned in 1980s (Wirsing & Jasparro, 2007). The Gazoldoba barrage project consists of two canals. The right canal has a carrying capacity of 455 $m^3 s^{-1}$ and left canal 142 $m^3 s^{-1}$ (Mazumder, 2004:44).

Tista Barrage Project (TBP) (Phase-I) in Bangladesh, located 20 km south of the border with India, was commissioned in 1985. Total irrigation command area of TBP Phase-I is 111,406 hectares (1114.06 km^2) of land. Construction of the phase-II of TBP began in 2005, which has a total irrigation command area of 448,774 hectares (4487.74 km^2) (Wirsing & Jasparro, 2007, Nayadiganta, 2008).

The Tista has insufficient flows to meet the requirements of the twin Tista projects in India and Bangladesh (Verghese, 1999:417; Figure 8). TBP project engineers claim that India's increased diversion of the Tista water for its own use through Gazoldoba barrage causes persistent water shortages at the height of the dry planting season (February-March) and threat to the TBP in Bangladesh (Wirsling & Jasparro, 2007, Figure 8).

Currently four hydropower projects on Tista river, with an installed hydropower generation capacity of 1297 MW, are under construction in India (see Table 4; NHPC, 2008). These projects are going ahead without any formal agreement with lower riparian Bangladesh and thus have the potential of future conflict.

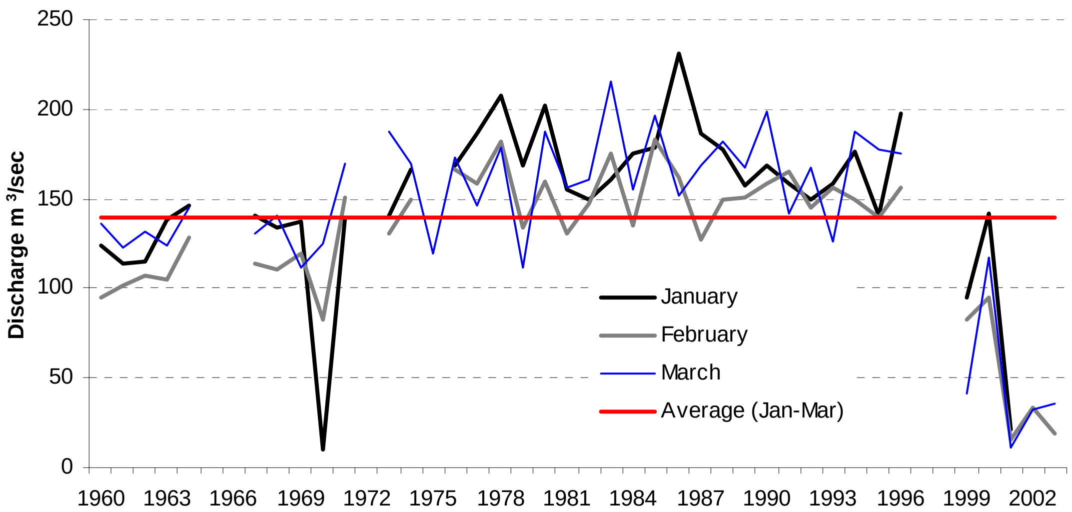


Figure 8: Tista River: Monthly discharge (January-March) measured at Kaunia, Bangladesh, 1960-2003. Data for 1965, 1966, 1972, 1975, 1997 and 1998 is not available.
Source: Data for analysis obtained from BWDB, 2007.

2.4 Brahmaputra Basin: Hydropower centre of India

The total hydropower potential of India is 148,701 MW. Out of which, 34,680 MW (23.3%) potential has been developed. Thus, 76.7% of the hydro-potential remains untapped.

As of 31 December 2007, hydropower and thermal power respectively contributes 24.7% and 64.7% of the total electricity generation capacity of India (Table 3). The National Policy for Hydropower Development (1998) sets the goal to maintain the ideal hydro-thermal ratio of 40:60 (NPHD, 1998). Power generation accounts for about 70% of India's total coal consumption (EIA, 2006).

Table 3: Electricity generation capacity of India (as of 31 December 2007)

Fuel	Installed capacity (MW)	% of Total
Coal based Thermal Power	74,752.38	53.3
Gas based Thermal Power	14,691.71	10.5
Oil based Thermal Power	1,201.75	0.9
Total Thermal	90,645.84	64.7
Hydropower	34,680.76	24.7
Nuclear	4,120	2.9
Renewable	10,855.24	7.7
Total	**140,301.84**	**100**

Source: MPI, 2008a.

In India more than 400 million people do not have access to electricity (Naím, 2008:95). The government sets the ambitious mission to ensure “power for all by 2012”, which requires an installed generation capacity of 200,000 MW by 2012 (MPI, 2008a) from current level of 140,301 MW. At present India is very power hungry and it energy demand is increasing at a rapid speed.

Of the total hydropower potential of India, 44.42 % (66,065 MW) potential lies in the Brahmaputra basin. Out of this, Arunachal Pradesh alone has the 67.5% (44 593 MW) of the total hydropower potential of the Brahmaputra basin. State wise, the largest hydropower potential is available in Arunachal Pradesh about 30 % (44,593 MW) of the total hydropower potential in the country followed by Himachal Pradesh that is about 13.6 % (19411 MW) (Mathur & Chawla, 2005:43). The total estimated live storage capacity of the storage reservoirs projects in Arunachal Pradesh that are under consideration is 45.5 $*10^9$ m^3. (Siddiqi & Tahir-Kheli, 2004: 38).

Under the “50,000 MW initiatives” launched on 24th May 2003, Central Electricity Authority (CEF) identified 162 new hydroelectric schemes totaling of 47,920 MW for preparation of PFR. Out of which, 63 schemes with total capacity of 29,693 MW is located in Brahmaputra basin. 42 schemes with total capacity of 27,293 MW are located in Arunachal Pradesh, 11 schemes with total capacity of 931 MW are located in Meghalaya and another 10 schemes with total capacity of 1469 are in Sikkim. Table 3 shows the major hydropower projects initiated by India.

Table 4: Major Hydropower Projects in Brahmaputra basin inside India (As of 14.12.2007). (n/a means *not available*; MOU means *Memorandum of Understanding*).

Projects	**State**	**Installed Capacity (MW)**	**River**	**Dam height (m)**	**Status/Remarks**
Rangit	Sikkim	60	Rangit	45	Commissioned in 1999.
Tista Low Dam -III	West Bengal	132	Tista	32.5	Under Construction by National Hydroelectric Power Corporation Limited (NHPC). Anticipated date of completion: September 2008.
Tista Low Dam-IV	West Bengal	160	Tista	88.5	Under Construction by NHPC, Anticipated date of completion: September 2009.
Tista Stage-V	Sikkim	510	Tista	96.45	Under Construction by NHPC. Anticipated date of completion: January 2008.
Subansiri (Lower)	Arunachal Pradesh	2000	Subansiri	116	Under Construction by NHPC. Anticipated date of completion: January 2012.
Tista- IV	Sikkim	495	Tista	88.5	Under survey and investigation by NHPC.
Lachen	Sikkim	210	Tista	85	Under survey and investigation by NHPC.
Tawang-I	Arunachal Pradesh	750	Tawangchu	90	Under survey and investigation by NHPC.
Tawang-II	Arunachal Pradesh	750	Tawangchu	32	Under survey and investigation by NHPC.
Subansiri (Upper)	Arunachal Pradesh	2000	Subansiri	230	Under survey and investigation by NHPC.
Subansiri (Middle)	Arunachal Pradesh	1600	Kamala	195	Under survey and investigation by NHPC.
Dibang	Arunachal Pradesh	3000	Dibang	288	Awaiting Clearance from Government of India.
Siang (Upper)	Arunachal Pradesh	11000	Dihang	n/a	Under Investigation by NHPC.
Siang (middle)	Arunachal Pradesh	1000	Dihang	n/a	Under investigation.

Projects	State	Installed Capacity (MW)	River	Dam height (m)	Status/Remarks
Siang (Lower)	Arunachal Pradesh	1600	Dihang	n/a	Under investigation.
Pare	Arunachal Pradesh	110	Dikrong	78	Proposed by *North Eastern Power Corporation Limited (NEEPCO).* MoU with Arunachal Pradesh Government for the implementation of the project signed on 21.09.2006.
Dibbin	Arunachal Pradesh	100	Bichom	27	Proposed by NEEPCO.
Ranganadi-Stage II	Arunachal Pradesh	130	Ranga	123	Proposed by NEEPCO. DPR completed on February 2006. Draft MOU submitted to Arunachal Pradesh government for approval.
Badao H.E.Project	Arunachal Pradesh	120	Kameng	65.85	Proposed by NEEPCO. DPR submitted on March 2006 and updated on April 2007. Draft MOU submitted to the Arunachal Pradesh government for approval.
Kapak Layek	Arunachal Pradesh	160	Pachuk (A tributary of Kameng River)	18	Proposed by NEEPCO. DPR under preparation. Draft MOU submitted to the Arunachal Pradesh government for approval.
Kameng-I	Arunachal Pradesh	1120	Kameng	123	Proposed by NEEPCO. DPR under preparation. MoU with the Government of Arunachal Pradesh for the implementation of the project signed on 21.09.2006.
Doyang	Nagaland	75	Doyang	87.5	In operation since 2000. Constructed by NEEPCO.
Ranganadi-Stage I	Arunachal Pradesh	405	Dikrong and Ranga	68.5	In operation since 2002. Constructed by NEEPCO.
Kameng	Arunachal Pradesh	600	Kameng, Bichom, Tenga	Bichom Dam:72 Tenga Dam: 27	Under Construction. Anticipated date of commissioning: November 2009.
Mawphu	Meghalaya	90	Umiew	48	Undertaken by NEEPCO. DPR submitted on March 2007. MoU with the Government of Meghalaya for the implementation of the project signed on 20.12.2007.
Jaldhaka - Phase I	West Bengal	27	Jaldhaka	n/a	In operation since 1972. Constructed under the 1961 *Jaldhaka Agreement* between Bhutan and India.
Jaldhaka – Phase II	West Bengal	8	Jaldhaka	n/a	In operation since 1983. Constructed under the 1961 *Jaldhaka Agreement*.

Projects	State	Installed Capacity (MW)	River	Dam height (m)	Status/Remarks
Kynshi – Stage I	Meghalaya	450	Kynshi	n/a	Undertaken by NEEPCO. DPR under preparation. Draft MOU submitted to the Meghalaya Government for approval.

Sources: NHPC, 2008; NEEPCO, 2008, Sharma, 2005:454

3. Bhutan Perspective

Bhutan has an estimated hydropower resources potential of 30,000 MW with 120,000 GWh electricity generation potential. Out of which around 23,467 MW is techno-economically feasible. As of 2007, only 1488 MW (5%) potential has been developed (Tables 5 to 7). Bhutan exports most of the hydropower to India after meeting is domestic energy demand that is around 230 MW.

The financial and technical cooperation with India regarding hydropower development helps Bhutan to enhance overall development (Biswas, 2004). The cooperation between India and Bhutan regarding water resources started in 1961 with the singing of Jaldhaka agreement (BNO, 2008). There are ten major agreements between the India and Bhutan regarding hydropower development in Bhutan. These are as follows:

1. Agreement regarding the construction of 35 MW Jaldhaka Hydro Power Project, 1961.
2. Agreement regarding the Chukha Hyrdro-electric Project, New Delhi, 23 March 1974.
3. Agreement regarding the feasibility study of the Sunkosh Multipurpose Project (SMP), 4 January 1993 (Biswas 2004:11; Sinha, 1995:110).
4. Agreement between regarding the execution of the Kurichu Hydro-Electric Project, February 1994.
5. Agreement between regarding the execution of Tala Hydroelectric Project (1020 MW), 5 March 1996 (MEA, 2006; MPI, 2008b).
6. MOU regarding the preparation of Detailed Project Report (DPR) for the Punatsangchu I Hydro-Electric Project, Bhutan, 15 September 2003 (MEA, 2007a).
7. MOU regarding the preparation of DPRs for Punatsangchhu II and Mangdechhu Hydro-Electric Projects, January, 2005 (MPI, 2008b).
8. Agreement concerning cooperation in the field of hydroelectric power between India and Bhutan, New Delhi, 28 July 2006 (MEA, 2006; MPI, 2008b).
9. Protocol to the 1996 Tala agreement on the setting up of the Tala Hydroelectric Project, New Delhi, 28 July 2006. (MEA, 2006)
10. Agreement regarding the implementation of the Punatsanchu-I Hydro-Electric Project, Thimphu, 28 July 2007 (MEA, 2007a).

Table 5: Existing Hydropower Projects in Bhutan (as of 1.08.2007)

Projects	Installed Capacity (MW)	River	Status
Tala (Chukha-II)	1020	Wangchu	In operation. Commissioned July 2006. Joint project by Bhutan and India.
Chukha-I	336	Wangchu	In operation. Commissioned in 1998. Joint project by Bhutan and India.
Basochu	64	Basochu/Sunkosh	In operation. Commissioned in January 2002 (Phase I) and March 26, 2005 (Phase II). Financial assistance from Austrian Government.
Kurichu	60	Kurichu/Manas	In operation. Commissioned on 26 April 2006. Fully financed by Government of India.
Small Hydels	8		In operation
Total	1488		

Sources: DOE, 2007;NPB (2007).

Table 6: Ongoing hydropower projects in Bhutan (as of 1.08.2007)

Projects	**Installed capacity (MW)**	**River**	**Status**
Punatsangchu - I	1095	Punatsangchu/ Sunkosh	Under construction. Joint project by Bhutan and India. To be completed by 2014
Punatsangchu - II	992	Punatsangchu/ Sunkosh	DPR is at the final stage of completion. Joint project by Bhutan and India.
Mangdechu	672	Mangdechu/ Manas	DPR is at the final stage of completion. Joint project by Bhutan and India.
Dagachu	114	Dagachu/ Sunkosh	Under Construction.
Total	2873		

Sources: DOE, 2007; NPB, 2007.

Table 7: Projects under consideration

Projects	**Installed capacity (MW)**	**River**	**Status**
Chukha III	900	Wangchu	DPR prepared. Joint project by India and Bhutan
Sunkosh Multipurpose Project	4060	Sunkosh	DPR submitted to Bhutan Government on December 30, 1997. Joint project by India and Bhutan
Manash Multipurpose Project	2800	Manash	PFR prepared. Joint project by India and Bhutan
Total	7760		

Source: MPI, 2008b.

India invested Rs. 50 x 10^9 in three hydropower projects that are currently in operation i.e. Chukha-I, Tala and Kurichu (see Table 5). Under 2006 hydropower agreement, India has agreed to import a minimum of 5000 MW of electricity from Bhutan by 2020 (MEA 2007b). Exporting hydropower to India from jointly built hydropower projects is the prime concern for Bhutan.

4. China Perspective

Tibet Autonomous Region (TAR) of China has a total hydropower potential of about 200-300 GW and fresh water availability of about 627 km^3. Less than 10% of TAR water is currently utilised and rest 90% goes into transboundary flows. The electricity generation capacity of TAR was only 91 MW (data for 1995) (Sinha: 1995:310). This is due to the low local demand in TAR for water, low population, and poor accessibility (Sinha, 1995; Cathcart, 1999). For this reason, China is interested to divert water from TAR to other water deficit regions in North and to exploit the enormous hydropower potential.

In 2004, China has total installed electricity generation capacity of 391.4 GW, out of which hydropower and thermal power respectively contribute 15.8% and 74% (EIA, 2006). By the end of 2005, China utilised only 13.6% of the total hydropower potential (Figure 2).

China is the world second largest coal producing country with proved recoverable reserves of 114,500 million tonnes. However, in 2004, 56% of the coal is consumed by power stations. As a result of combined pressure of high energy demand and under utilisation of hydropower potential, China’s coal exports have fallen back sharply from 95 million tonnes in 2003 to 72 million tonnes in 2005 (WEC, 2007:26). As 75% of the proved recoverable coal reserves are in the North and Northwest provinces, China is naturally interested to exploit the hydropower potential of TAR (WEC, 2007; Cathcart, 1999)

The hydropower potential of the main stem and five main tributaries of the Yarlung Zangbo river is about 110 x 10^3 MW, the second highest in China following Yangtze river basin. But hydropower reserve per unit area, about 460 KW per km^2, is the highest in China and around three times more than that of Yangtze river (Tianchou; 2001:110). In the TAR region, the Yarlung Zangbo river has an average annual freshwater discharge of ~4160 m^3s^{-1} and a flow volume of ~131x10^9 m^3 (Cathcart, 1999:854).

The current literature includes several proposals on the Yarlung Zangpo water resources development. The Yarulung Zangbo canyon, formed by a U-shaped bend in the river where it flows around Namcha Barwa, is the deepest and, possibly, longest canyon in the world. The length and depth of the canyon are respectively 496.3 km and 5382 m. The canyon has a drop 2600 m and a potential generation capacity of 68,800 MW. A dam is proposed near Pai with a normal water level of 2970 m, a head of 2340 m, an average discharge of 1900 m^3 s^{-1} and an installed capacity of 38,000 MW. If constructed this will be the world largest hydropower station with over twice the generation capacity of the Three-Gorges Hydropower station (SETQPCAS, 1981; Yang & Gao, 1996; Yang, 1991; cited in Tianchou, 2001).

Rao (1979:144) envisioned another proposal through cooperation between China and India. He estimated that at the point where the Brahmaputra enters India from Tibet, the river drops from an altitude of 3350 m in Tibetan Plateau to 800 m in India giving a head of 2200 m to 2500 m. The minimum discharge of water at this diversion point is 1000 m^3 s^{-1}. By diverting the run-of-the river from the plateau to join straight into the river by a 20 km tunnel, Rao (1979) estimated that around 30,000 MW of hydropower could be produced. However, as the point of diversion is in China and site of the power station is in Arunachal Pradesh, it requires cooperation between the two countries. As of today, there is no cooperation regarding this proposed idea.

In 1995, Chinese Academy of Engineering Physics discussed about a macro-engineering plan involving peaceful nuclear explosions to excavate a 20 km long canal through an intervening mountain range north of the Yarlung Zangbo in order to convey irrigation-quality water to the Gobi Desert (Horgan, 1996; Cathcart, 1999).

Another proposed project, *Greater Western Route Water Diversion Project*, includes diverting around 200 x 10^9 m^3 of water annually from Brahmaputra, Salween and Mekong river basins to the Northern river basins in China especially to the Yellow river basin (TOI, 2006; Chellaney, 2007). This project is part of China’s gigantic *South to North Water Diversion Project* (SNWDP).

The details of Brahmaputra water diversion project in China are yet not available and the project is still in planning phase and not officially declared. But already this project cause tensions in India and Bangladesh (Chellaney, 2007). For India, this diversion means the low availability of downstream Brahmaputra, thus hindering the implementation of the water diversion plans from the Brahmaputra to the Ganges, i.e. “New Indian Line”, as well as proposed hydropower projects (see Figure 7; Table 4). On the other hand, the water diversion from the upstream Brahmaputra, both in China and India, will reduce water availability in downstream Bangladesh during non-monsoon season.

5. Discussion on riparian perspectives

Bangladesh insists that Ganges and Brahmaputra are two separate river basins and those should be managed independently without any inter-basin water transfer (Rahaman, 2008). Accordingly, the augmentation of the Ganges water should be solved within the Ganges basin through storage reservoirs in Nepal and that there is enough water. On the other hand, India insists that diverting water from the Brahmaputra is the best solution for flow augmentation and resolving water problem in both Ganges and Brahmaputra basins.

In short, there is an unresolved dilemma in between the proposals of Bangladesh and India, whether to share water over time or space. The problems that Farakka barrage in the Ganges river has caused, really frightens Bangladesh that India has a similar plans to siphon off water from the Brahmaputra river as well as the Meghna river (Crow *et al.*, 1995; Rahaman, 2008; Figure 7).

India wants to divert water from the Brahmaputra basin to the Ganges basin to increase agricultural production. In India, arable land in the Ganges basin (600,000 km^2) is considerably higher than that of the Brahmaputra basin (55,000 km^2). India is striving to develop the enormous hydropower potential in Brahmaputra basin for meeting the increasing energy demand of the country (Table 4). India promotes Brahmaputra water resources and hydropower development through bilateral cooperation with Bhutan excluding China and Bangladesh (Tables 5 to 7).

Bhutan has a history of friendly cooperation with India regarding hydropower development. The country has achieved economic and social development through exporting hydropower to India (cf. Biswas, 2004). Thus, for Bhutan, exploiting hydropower potential with financial and technical support from India is a prime concern.

China wants to utilise the huge hydropower potential of Brahmaputra to meet its growing energy demand and divert water from this basin to other water scarce river basins of the country. Like India, China has also chosen unilateral approach of Brahmaputra basin's hydropower and water resources development excluding India and Bangladesh.

6. Potentials benefits from coordinated development

Water management in the Brahmaputra as well as Ganges became associated with security concerns, and these two river basins came increasingly in regional and global political focus (cf. Rahaman, 2008). Philips *et al.* (2006) termed this tendency as "*securitisation of water resources management*", which links water issues to national security concerns, thereby taking them out of the normal domain of technical management. This is one reason behind the low level of data and information sharing in between the riparian countries (cf. Ohja & Singh, 2005:2), even though everyone theoretically agrees that such sharing is beneficial for the region.

Water resources management is a powerful driver for regional integration and development. However, water resources management should rely on the high level of shared dependence on transboundary rivers and consequently as a driver of peaceful negotiation and cooperation (Philips *et al.***,** 2006:35). Integrated water management of the Brahmaputra through regional cooperation is an issue that embedded in wider regional development goals. Coordinated management approach of the Brahmaputra basin could offer four types of benefits: benefits to the river, benefits from the river, reduction of costs because of the river, and benefits beyond the river. Sadoff and Grey (2002) first envisioned that cooperation in any international river could offer these four types of benefits. Below, these four types of benefits in the Brahmaputra basin are briefly described.

6.1. Benefits to the river - ecological Brahmaputra

Integrated Brahmaputra river basin management will offer the opportunity to improve water quality, sustain biodiversity, maintain river flow characteristics, sediment management, and salinity control in the downstream, increase fisheries and reduce industrial pollution to the river. Joint cooperation in water quality monitoring and combined efforts of water quality management at all rivers in the basin, inter-country standardisation of water quality parameters, pollution reduction strategies and real time data exchange regarding water quality through an integrated mechanism will ensure safe and cleaner water quality (cf. Sadoff & Grey, 2002). One of the main challenges for water quality improvement in international rivers, streamlining legislation for improving water quality, also can be achieved through cooperation between riparian countries.

6.2 Benefits from the river-economic Brahmaputra

Integrated and coordinated management of the Brahmaputra water resources is one of the best tools to achieve IWRM objectives, i.e. economic growth, environmental sustainability and social development and Millennium Development Goals (MDGs) along the riparian countries. The most imminent field of cooperation are hydropower and meeting agricultural needs of the region as well as flood and drought management.

The basin's huge hydropower potential that is around 206,000 MW could be developed and utilised by coordinated efforts in between India, China and Bhutan to meet the growing energy demand of Bangladesh, north-eastern India and China. The electricity consumption in the Brahmaputra basin countries is very low (Figure 3) and most electricity generation depend on thermal power plants. So, exploiting untapped hydropower potential (Figure 2) could increase electricity supply and reduce the dependency on thermal power.

Ensuring food security and rural development is one of the key elements on integrated water resources management (Rahaman & Varis, 2008:181). Water regulation upstream through coordinated plans between China, India and Bangladesh would reduce the threat of flooding in downstream India and Bangladesh. In addition, coordinated plans could ensure that the existing and future plans of both India and China supplement each other. After meeting the water requirements of the Brahmaputra drainage basin both in India and Bangladesh, access water from Brahmaputra might be diverted to other water deficit region in India, China and Bangladesh. The total arable land in Brahmaputra is 93,000 km^2, which is less than the Ganges basin's 658,000 km^2 (Rahaman 2008).

6.3 Reducing the costs because of the river-Political Brahmaputra

Sadoff and Grey (2002) mentioned that water plays a significant role in a number of recent and current disputes and conflicts around the world and hence, it is complicated to unbundle the importance of shared waters in the dynamics between riparian states from other contributory factors in conflict. International cooperation can ease tensions over shared water, and provide gains in the form of the savings that can be achieved, or save the costs of non-cooperation or dispute that can be averted. Long-term benefits from cooperation in the Brahmaputra basin development may save the costs of non-cooperation arising because of the river.

India's plan for Brahmaputra water development involves constructing major hydropower dams along the Brahmaputra and water diversion from the Brahmaputra basin to the Ganges basin. China's plan for Brahmaputra development involves water diversion from Brahmaputra to other river basins within China.

Both the Indian and Chinese plans could become major sources of water conflict in this century, as these plans have not incorporated the concerns and development plans of other riparian countries (cf. BBC, 2003; Thakkar, 2003; Chellaney, 2007). These projects created tensions between Bangladesh, India and China.

Environmentalists and scientists fear that India's unilateral RIP project may create a long-term crisis in the region (The Guardian, 2003; Thakkar, 2003; Shankari, 2004). On 13 August 2003, Bangladesh Government placed an official note to India claiming that RIP would cause serious socio-economical and environmental losses for Bangladesh. Bangladesh fears that diversion of water from the Brahmaputra, which provides 67% of the country's fresh water flow in the dry season, would cause an ecological disaster (Figure 7; BBC, 2003; Thakkar, 2003).

The Tista has insufficient flow to meet the requirement of the twin Tista projects in India and Bangladesh (Verghese, 1999:417; Wirsing & Jasparro, 2007). The conflict over Tista water would further deteriorate if the hydropower projects along the main stem of Tista that are under construction by India continue without formal agreement with Bangladesh.

Ganges and Brahmaputra basins are closely interlinked. Any unilateral development and diversion of Brahmaputra basin water resources based on nationalistic approach could undermine the integrated development potentials of the Brahmaputra basin as well as the Ganges basin (cf. Rahaman, 2008).

Co-operation with regards to share water in the Brahmaputra basin definitely strengthens relations between the riparian countries and catalyses broader cooperation, integration, and stability. Cooperation in shared water resources between countries will enhance the cooperation and integration in other fields *beyond the river*.

6.4 Benefits beyond the river-catalytic Brahmaputra

Cooperation in the management of international rivers often contributes to the political processes and institutional capacities that open the door to other coordinated actions between riparian countries, promoting cross-border cooperation beyond the river (Sadoff & Grey, 2002). The easing of tensions between the riparian states due to water sometimes offers cooperation in other sector unrelated to water that would not have been feasible under strained relations.

The indirect opportunities for development through integrated management of the Brahmaputra basin are increase in regional trade, development due to access to electricity, as well as achieving regional energy security.

The geographically and strategically important "Siliguri Chicken Neck", the 32 kilometres narrow part of India separating Nepal and Bhutan from Bangladesh, lies in Brahmaputra basin. Due to lack of cooperation and mistrust, Bhutan, Nepal, India and Bangladesh are yet to reach the full potential of globalisation. UNESCAP proposed Asian highways (for details see UNESCAP, 2008) could give direct access to landlocked Bhutan, Nepal and Sikkim, North-eastern India to and from Bangladesh as well as to two seaports in Bangladesh, Mongla and Chittagong. The international trade of Bhutan, Nepal and North-eastern India could increase substantially with direct access to the seaports in Bangladesh.

A direct road link between Kunming (China) to Chittagong (Bangladesh) through Myanmar is under negotiation (Rahaman, 2008). When constructed, this road could connect with the proposed Asian Highway in Bangladesh and thus become a meeting point of South and South-East Asia via Myanmar. The easing of tensions between the riparian states due to the Brahmaputra basin water cooperation could facilitate connecting South and South East Asia too.

Bangladesh and India want to import natural gas and hydropower from Myanmar. Myanmar has 39720 MW hydropower potential, out of which current installed capacity is only 745 MW and 1786 MW is under construction (WEC, 2007: 286). The hydropower cooperation between India and Myanmar is ongoing and between Bangladesh and India is under discussion. The PFR of the Tamanti multpurpose project (Stage-I) (1200 MW) on river Chindwin is prepared by India's NHPC and submitted to Myanmar on April 2005. The future cooperation regarding Tamanti Stage-II (about 400 MW) and Stage-III (about 700 MW) projects is also under discussion (MPI, 2008b).

As India and Bangladesh are willing to import hydropower from Nepal, Bhutan (Rahaman, 2008) and Myanmar, a regional energy grid could be built which will go through Bhutan, India, Nepal, Bangladesh and Myanmar. For details about water storage and hydropower potential in Nepal, see Rahaman (2008).

The proposed tri-nation gas pipeline from Myanmar to India through Bangladesh (Rahaman, 2008) could be linked with Bhutan and Nepal and hence, Bhutan and Nepal could get gas supply from the pipeline. Bhutan and Nepal could export Hydropower to Bangladesh and India and in return buy gas from Myanmar and Bangladesh.

7. Concluding remarks: The way forward

A Chinese proverb - the water which supports a boat can also sink it - perfectly resembles the relationship between human being and water. Water, which supports the life systems, can also be a threat to human survival if not managed properly. This Chinese wisdom is particularly true for the unilateral Brahmaputra basin development plans by India and, unfortunately, China itself.

Had the riparians been more attentive to the potential benefits of the integrated management of the Brahmaputra basin water resources, the regional development might have taken place earlier and perhaps most important, the split between Bangladesh and India over Ganges and Brahmaputra basins water management might have not developed, changing completely the character of South-Asian water conflicts.

Integrated and coordinated Brahmaputra water resources management offers prospects for development of the entire South Asia region. To achieve that following issues, based on the outcome of the present paper, would be worth considering.

1. Long-term energy security is at the heart of the Brahmaputra basin development due to its huge untapped hydropower potential. However, the absence of bilateral and/or multilateral institutional arrangements and agreements between the riparian countries for the integrated management of Brahmaputra water resources constitutes an ongoing threat to future development plans within the basin.

2. Sustainable and integrated management of water and energy involving all co-riparian of the Brahmaputra basin, i.e. Bhutan, Bangladesh, India and China should be ensured. In this respect, streamlining water and energy policies of the riparian countries is utmost important.

Principles of integrated water resources management and development should be incorporated in the national water policies. Rahaman & Varis (2005; 2008) identified and analysed these principles in details.

3. Due to geographical proximity and huge hydropower potential that is around 122720 MW, Nepal and Myanmar are important for ensuring regional energy security. So cooperating with Nepal and Myanmar to achieve integrated water resources management and regional energy security is also a worthwhile consideration. However, the social and environmental cost of hydropower development, emphasised by Agenda 21 and other major water declarations, should be considered carefully (Rahaman & Varis, 2008).

4. Sharing hydro-meteorological, physical, and environmental data among riparian countries are very important. Although Tibet constitutes 51.10% of the Brahmaputra basin, due to lack of data and information, most previous studies, including this one, left out in-depth discussion Brahmaputra basin water resources and development plans in Tibet. This is true for India as well where key data regarding Brahmaputra and Ganges basin water resources are classified (cf. Fairless, 2008:280; Ohja & Singh, 2005:2).

5. Internationally accepted transboundary water resources management principles, e.g., theory of limited territorial sovereignty; principle of equitable and reasonable utilisation; obligation not to cause significant harm; principles of cooperation, information exchange, notification, consultation and peaceful settlement of disputes could serve as guidelines for ensuring effective integrated water resources management of international river basins (for details see, Rahaman, 2005). To reduce conflict and utilise the full potential of the integrated water resources management, future bilateral and multilateral treaties between the riparian countries should include these principles. In addition, as none of the countries in the region singed UN Watercourse Convention (1997), it is worthwhile to consider signing the convention (cf. Rahaman, 2005).

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