Transnational Policy Dialogue for Improved Water Governance in Brahmaputra River

Water Management Practices and Policies along the Brahmaputra River Basin: India and Bangladesh

Status Report - 2014







Acknowledgements

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Executive Summary

The Brahmaputra river basin, the principal arm of the Ganges-Brahmaputra-Meghna (GBM) system is one of most critical transboundary rivers playing a significant strategic role in South Asia's water, energy and food security. Spanning a vast expanse of 5, 80,000 square kilometers, the catchment basin covers four riparian countries – China, Bhutan, India and Bangladesh. Among the top-ranking rivers of the world, the Brahmaputra River presents a picture of an economically prized, politically charged and environmentally dynamic fluvial system.

Originating from the Kanglung Kang glacier east of Manas-Sarovar at an elevation of 5150 m, it traverses 1625 km in Tibet, 918 km in India (278 km in Arunachal Pradesh and 640 km in Assam) and 363 km in Bangladesh. It is one of the most densely populated river basins in the world, supporting an estimated population of about 700 million people. It is an extremely complex system made up of an intricate web of rivers that flow through different hydro- ecological and climatic regimes, housing many ethnic groups and endemic species of flora and fauna.

The basin is unique in several ways. First, the Brahmaputra River is twenty fifth with respect to length, fourteenth with respect to drainage area, fifth with respect to water discharge, second with respect to sediment load, and first with respect to sediment discharge. Second, the basin stands out as an exception to the traditional theory that relates poverty with water scarcity. It is one of the least-developed regions of the world with an unmatched and multiple developmental potential. Third, the river carries water from drier parts of the basin to regions abundant in rainfall. Fourth, the basin has been frequently in the news, more for the natural disasters it causes along its path than for the benefits it brings to the various life forms and human livelihoods in its covering area. Loss of life and property, and ecosystem destruction are recorded, due to the regular onslaught of floods, bank erosion, channel shifting, landslides, cyclones and droughts. Statistically, about a quarter of the basin is flooded in an average hydrological year, while thousands of hectares of agricultural land get destroyed due to severe erosion, jeopardizing life, and environment.

Finally, the basin is known more for conflicts and controversies than for regional cooperation. The physical geography of the basin has bound the four riparian countries together in environmental, economic, political and security interdependencies. But such mutual dependencies have largely been beset by colonial legacies of unresolved boundary disputes and a highly skewed distribution of power resources, making hydro-diplomacy of the basin not as strategically nuanced as it ought to be.

In 2013, under the aegis of The Asia Foundation (TAF), the South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs) initiated a dialogue process in partnerships with the Indian Institute of Technology, Guwahati, (IITG) and the Institute of Water and Flood Management (IWFM) under the Bangladesh University for Engineering and Technology (BUET), Dhaka. The dialogue was titled "Transnational Policy Dialogue for Improved Water Governance of the Brahmaputra River" and took place between India and Bangladesh towards co-management of the Brahmaputra.

This State of the Sector report is one of the project outputs that aim to bring diverse facets of the Brahmaputra basin on a single platform. With a nuanced understanding of physical, social, cultural and politico-economic aspects of the two co-riparian countries, India and Bangladesh, it attempts to unravel several water management issues of the basin. It provides a synthesis of findings drawn from fieldwork, dialogue meetings and the wide body of literature on physical, economic, political and cultural dynamics of the Brahmaputra river basin.

The report makes use of theoretical and empirical insights developed from the available literature, and uses a comprehensive and comparative approach. In doing so it tries to present a balanced and unbiased perspective to analyse the multidimensional and complex aspects of the Brahmaputra basin.

Some crucial issues plaguing the basin

- Development and management of this unique basin is subjected to various geo-political constraints. The innumerable channels and tributaries, varied topographical and climatic regimes, and multiple uses of shared water across countries unequal in size and power dynamics have made a straightforward management strategy seemingly impossible. There are gaps both at the research and implementation front.

- Research, to a large extent, lacked an integrated and holistic approach. The basin has hardly been studied as a single contiguous unit incorporating upstream and downstream dynamism. There is a great dearth of data on flow, sediment transport and budget, nutrient transport and river ecology, with country-level researchers knowing very little about the river reaches in other countries. As a result, it has been difficult to prove or disprove many of the assumptions.

- A lack of correct and timely sharing of data and a limited understanding of the regional erosion pattern and of integrated flood forecasting are some of the research challenges faced at a regional level.

- The water engineering adopted so far is ad hoc and piece-meal and has largely taken a partial view of the river management. Such structural measures have essentially failed to save the life of the river and the millions intricately depending on it.

- The concerns and voices of legitimate stakeholders as well as powerful actors have largely been neglected in dialogues, forums or any other platform of negotiation.

- The dialogues and negotiations across co-riparian countries till date are bilateral in nature. Negotiations are largely formed by virtue of positional bargaining. For instance, India and China considered to be strong riparian states, have always dictated terms and conditions on water-sharing strategies and policies. The geographical position of China in the upstream has made it a major stakeholder, while Bangladesh, the lowermost riparian state, has always remained dependent on the benevolence of the upstream countries. Besides, there are internal, political factions and interest groups in both India and Bangladesh that often prevent any effective ratification. China's denial to adopt any bilateral mechanism that permits the involvement of international diplomacy marks its self-interests in the water course, disregarding the predicament of the lower riparian country.

- The roles of NGOs and civil society are often feeble, with limited opportunities for local perspectives and knowledge to trickle up, to influence a formal negotiation process. 'They are very few in numbers and microscopic in their approach', 'how much influence they have on the state' are issues that still need to be addressed definitively.

Because the Brahmaputra is an international river of immense size with a huge resource base and high-hazard potential, each of these factors needs to be addressed effectively to enable the creation of an adequate response mechanism to the problems of natural disaster, poor water quality, disappearing biota, widespread poverty and complicated hydro-politics.

Policy Implications

- Management of this dynamic and gigantic river basin has always remained a crucial challenge for policymakers and practitioners. To ensure ecological sustenance of the river and the rights of the people, it is critical to have an effective co-management strategy comprising structural and non-structural measures based on the principle of regional cooperation.

- It is important to take a basin-wide hydro-ecological approach in which the concerns and opportunities of the upstream and downstream can be thoroughly integrated. Resource planning needs joint and participatory fact-finding and assessment, one that is transparent and can effectively engage the community, reduce vulnerability, empower local populations, ensure food, health and ecological security, and strengthen existing institutions.

- There should be a knowledge-management hub and data-sharing portal (like the Wikipedia / Brahmaputra Portal) that can be shared by the co-riparian countries and can be accessed by the common public and researchers as well. Youth should be actively involved to undertake a sustained campaign in effective river management.

- Research and dialogue initiatives in the co-management of the Brahmaputra River should be gender-sensitive. It is imperative to incorporate the perspectives of women professionals, bureaucrats, media personnel, academicians, community representatives, etc., while designing any sharing mechanism.

- The dialogue should relinquish bilateralism and head toward a multilateral format. Utmost emphasis should be given to both inter-state and inter-country dialogue based on the principle of equitable and reasonable utilization; obligation not to cause significant harm; and principles of cooperation, information exchange, notification, consultation and peaceful settlement of disputes.

- Most importantly, a strong political will at state and national levels needs to be developed, with a sustained effort to convert the water resources of the region into a force for sustainable development through an integrated, multi-disciplinary approach including technology as well as social, economic and environmental factors.

Actualization of each of these strategies requires a proactive and continued multilateral dialogue and negotiation process across co-riparian countries through track-2 diplomacy.

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Introduction

Transboundary river basins of South Asia are often perceived as important engines of regional economic development, crucial bases of livelihood resources, and sites of biodiversity conservation (Sneddon & Fox 2006; Uprety, Salman & Salman 2011). These often competing and sometimes conflicting roles make governance and management particularly challenging. The last fifty years of transnational water governance in South Asia have been the story of an unfolding disaster of scarcity, ill faith and bad governance.

The countries sharing most of these basins are beset by a number of water management problems due to gross inequalities in the temporal and spatial distribution of water. These problems are caused mainly by floods, droughts, and earthquakes. Governance is marred by a deep-seated distrust as much as political tensions and histories of armed conflict (Uprety, Salman & Salman 2011; TAF 2013).There has been a multitude of treaties, agreements, and customary laws drafted so far to promote cooperation with respect to transboundary South Asian rivers. But they largely reflect state-centric, technocratic, exclusionary, and nationalistic hydro-political viewpoints (TAF 2013) of elite actors (Ganoulis, Duckstein, Literathy & Bogardi 1996; Albert 2000; Kliot, Shmueli & Shamir 2001; Tarlock, 2001; Yetim 2002; Sneddon & Fox 2006). Understanding and identifying the blind spots of the multi-scalar, multi-actor character of water governance and management of such basins has been arguably overlooked. Neither the transnational institutional arrangements nor the vast body of literature on international hydro-politics effectively talks about the intensification of ecological alterations, resource degradation and socio-ecological disruptions of the river basins themselves and the people who depend on it for their livelihoods.

The Brahmaputra river basin, the principal arm of the Ganges-Brahmaputra-Meghna system is one of the most critical transboundary rivers playing a significant strategic role in South Asia's water, energy and food security. Located at a longitude of 82°-97°east and latitude of 21°-31° north, with a total length of about 2,880 kilometres, it is one of the most densely populated river basins in the world, supporting an estimated population of 700 million people. It is an extremely complex system made up of an intricate web of rivers that flow through different hydro-ecological regimes, housing many ethnic groups and endemic species of flora and fauna.

Among the top ranking rivers of the world, the Brahmaputra River is twenty fifth with respect to length, fourteenth with respect to drainage area, fifth with respect to water discharge, second with respect to sediment load, and first with respect to sediment discharge. The river is characterized by an extremely large and variable flow and a significant rate of sediment discharge as well as rapid channel aggradations and climate change variations. In spite of being a frontier river it has received a perfunctory attention both in academic and policy discourse. The basin has rarely been studied as a contiguous ecological unit spreading across four sovereign states – China, Bhutan, India and Bangladesh. The morphological dynamics, drainage network forms, fluvial processes, and channel patterns across a zone of erosion and sediment supply (comprising Tibet, Bhutan and India), a zone of transportation (India) and a zone of deposition of the lower reaches (India and Bangladesh) have not been looked at holistically (Best et al. 2007)

Studies show that in spite of having a huge potential for being a great example of regional cooperation (Brichieri-Colombi & Bradnock 2003; Salehin, Khan, Prakash & Goodrich 2011) and significant confidence-building measures among India, China, Bhutan and Bangladesh (Hukil 2013), mutual cooperation has not been encouraging so far (Khan 2005; Biswas 2008).The role of the Joint River Commission (JRC) is extremely inadequate. Significantly, it is the central institutional actor responsible for transboundary environmental governance of 54 rivers in the region including the Brahmaputra.

Negotiations and developments are largely formed by virtue of positional bargaining. For instance, the geographical location of China and India in the upstream and midstream reaches has played a very crucial role in shaping the nature of hydro-politics in the entire basin. The concerns and voices of legitimate stakeholders as well as powerful actors have largely been neglected in dialogues, forums or any other platform of negotiation. The most critical gap lies with fact that most policy documents and agreements have considered the Brahmaputra a set of or watercourses whose flowing water needs to be shared among the basin's 'owners'. This has obfuscated its existence as a multi-dimensional basin shaped up by numerous processes.

To understand the governance and management issues of the Brahmaputra basin, the South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs) initiated a dialogue process in 2013, under the aegis of The Asia Foundation (TAF). This was done in partnerships with the Indian Institute of Technology (IITG), Guwahati in India, and the Institute of Water and Flood Management (IWFM) under the Bangladesh University for Engineering and Technology (BUET), Dhaka in Bangladesh. The dialogue was titled "Transnational Policy Dialogue for Improved Water Governance of the Brahmaputra River".

This State of the Sector report is an outcome of the dialogue. It aims to provide an analytical document on the Brahmaputra basin. It attempts to integrate information on physical, socio-economic and political aspects of the basin into one platform. It provides a conceptual understanding of the Brahmaputra basin, its environments, hydro-politics, and co-management strategies through a review of viewpoints of scholars and journalists. The report draws from three categories of literature.

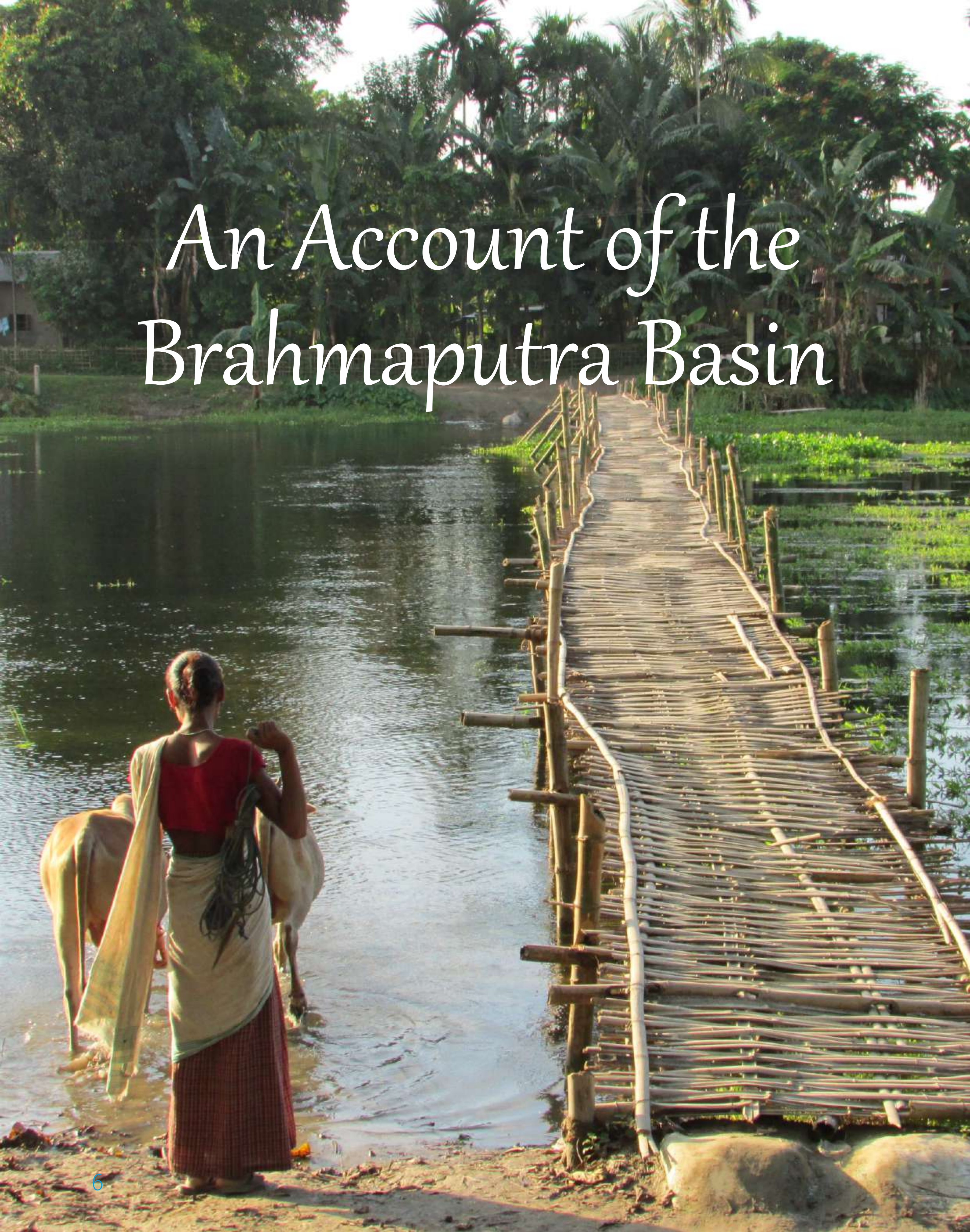
First, publications on topographical, morphological, and hydrological dynamics with special emphasis on bank erosion, flow discharge, sediment load and discharge, and on bar (char) and in-channel deposition (e. g. Coleman 1969; Williams & Rust 1969; Rust 1972; Smith 1974; Ashmore 1982,1991; Ferguson & Werritty 1983; Goswami 1985; Davoren & Mosely 1986; Bristow 1987; Dawson 1988, Thorne et al. 1993; Islam 2006). Most of this literature has tried to establish an inter-linkage of physical processes, climate change, population growth, urbanization, industrialization, livelihood security and associated hazards. Inductive in their approach, they have given an account of several case studies regarding different sections of the basin. But they mostly lack an integrated and holistic framework incorporating upstream and downstream dynamics.

Second, documents on effective disaster management strategies, hydro-electricity generation, ground and surface water utilization potential, and capacity and usage of the Brahmaputra basin form another assemblage of literature. Studies of this genre talk about the big energy needs of the basin and the opportunities for cooperation (Just & Netanyahu 1998; Beach et al. 2000; Dinar & Dinar 2000; Biswas 2001). But there are substantial gaps in understanding the environmental and social cost, and the trade-offs associated with them at basin level. Several management strategies like an eco-hydrological approach (Rahman 2012), holistic engineering, and hydro-diplomacy (Bandopadhaya & Ghosh 2009) have been proposed for a comprehensive assessment to create an integrated framework at regional level (Faisal 2002; Chowdhury 2005; Blackmore 2006; Singh 2006; Thakkar 2006; Gupta 2008; Rahaman &Varis 2009; Borah, Ahmed & Sarma 2010; Parua 2010; Jha & Bairagya 2011; Singh

& Goswami 2012; Bhatt, Rao, Begum, Manjusree, Sharma, Prasanna & Bhanumurthy 2013).

Third, there are studies on contestations, conflict and hydro-political complexes associated with the Brahmaputra basin. Critically reviewing this extensive body of literature on contentious politics, riparian relationship, and institutional and legal arrangements the report attempts to offer a balanced and unbiased perspective to analyse the multidimensional and complex aspects of the Brahmaputra basin, with focus on India and Bangladesh in particular.

An Account of the Brahmaputra Basin



2

An Account of the Brahmaputra Basin

2.1 Introduction

'A river extraordinaire, the Brahmaputra presents a picture of awesome expanse, enchanting grandeur, overwhelming sobriety and immense vigour' (Goswami 2008:2). 'Flowing across Tibet, India and Bangladesh, the Brahmaputra has a total length of 2,880 kilometres, and is the 22nd longest river in the world' (Sarma 2005: 72). It originates from the Kanglung Kang glacier east of Manas–Sarovar at an elevation of 5150 metres and traverses 1625 kilometres in Tibet, 918 kilometres in India (278 kilometres in Arunachal Pradesh and 640 kilometres in Assam) and 363 kilometres in Bangladesh. Its vast catchment area extends over 5,80,000 square kilometres out of which 2,93,000 square kilometres are in Tibet, 2,40,000 square kilometres in India and Bhutan, and 47,000 square kilometres in Bangladesh. The river is known as Tsangpo or Yarlung Zangbo in China, Brahmaputra in India and Jamuna in Bangladesh.

2.2 Course of the Brahmaputra River

In the course of its 2,880 kilometre journey the Brahmaputra receives as many as 22 major tributaries in Tibet, 33 in India, and 3 in Bangladesh. The northern and southern tributaries differ considerably in their hydro-geomorphological characteristics, owing to different geological, physiographic and climatic conditions. The Subansiri, Jia Bharali and Manas are the major trans-Himalayan tributaries of the Brahmaputra with the first two having their origin in Tibet, while the last one comes from Bhutan. They have drainage areas of more than 10,000 square kilometres. The Dibang and Lohit are two other large tributaries emerging from the extreme eastern flank of the Himalayas. The Jiadhal, Ranganadi, Puthimari, and Pagladiya are major rivers with sources in the sub-Himalayas, the latter two in Bhutan. Among the south-bank tributaries, the Burhidihing originates at the Nagaland-Myanmar border, the Dhansiri and Dikhow in the Naga Hills, the Kopili on the Karbi plateau, while the Kulsi and the Krishnai flow from the Meghalaya hills (Sarma 2004; Goswami 2008).

'The Tsangpo, as it is known in Tibet, originates at an altitude of 5,150 metres, about 250 kilometres to the northeast in the Kailash range in China, north of the Himalayan crestline' (Bandayopadhyay 1995: 417). 'This river is thought to be the highest river on earth with an average altitude of 4,000 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. At places it has a wide channel and has a moderate gradient' (Tianchou 2001: 104). Flowing eastward for 1,625 kilometres over the Tibetan plateau, the Tsangpo enters a deep and narrow gorge at Pe (3,500 metres) and continues southward across the east-west trending ranges of the Himalayas (IIT Rourkee 2012). The Yarlung Zangbo gets to the Indo-China border near Monku at 660 metres and flows for 5 kilometres as international boundary to arrive at Korbo in Arunachal Pradesh, India. It is known as Siang till it appears in the plains near Pasighat, where it is called Dihang (Rao1979: 75; Sarma 2005: 73).

The Dihang flows through the Himalayas of Arunachal Pradesh first in south-west direction. After meeting the Siang River on its right bank it takes a right-angled turn to flow south-east and finally southward to cut across the strike of the geological formations. About 52 kilometres downstream from Pasighat, the river takes its characteristic braided pattern and is joined by two other transboundary rivers, viz. Dibang and Lohit near Laikaghat. From this point, the combined flow of three rivers is the 'Brahmaputra' (IIT Rourkee 2012).It flows through a narrow valley known as Assam Valley or Brahmaputra Valley in about east-west direction for 640 kilometres at a very low gradient. The river then flows westward through Assam for about 700 kilometres until downstream of Dhubri town, where it abruptly turns south and enters Bangladesh.

In the plains of Assam and Bangladesh, the Brahmaputra flows in a highly braided channel with some well-defined nodal points where the river is narrow and restricted by stable banks. The gradient of the Brahmaputra River is as steep as 4.3 to 16.8 metres/kilometres in the gorge section upstream of Pasighat, but near Guwahati it is as flat as 0.1metre/kilometre. The valley is like a winnowing fan bounded on three sides by hill ranges and a plateau on the south. The dramatic reduction in the slope of the Brahmaputra as it cascades through one of the world's deepest gorges in the Himalayas before flowing into the Assam plains explains the sudden dissipation of the enormous energy locked in it and the resultant unloading of large amounts of sediments in the valley downstream (Sarma, Acharjee, & Murgant 2013). On the west the Assam Valley is open and the Brahmaputra is further joined by the Kameng River (or Jia Bhoreli) at Sonitpur. Between Dibrugarh and Lakhimpur districts the river divides into two channels Mjuli in lower Brahmaputra valleyand joins again downstream to form Majuli Island (929 kilometres), the largest river island in the world.

After crossing the Assam valley, the Brahmaputra finally enters Bangladesh through Lalmanirhat District of northern Bangladesh. After passing 50 kilometres inside the country, a major tributary, the Teesta River, joins the Brahmaputra near the Chilmari River Port. From the confluence point of the Teesta and Brahmaputra, the river once again changes its name. It is then known as Jamuna. Many small tributaries join the Jamuna inside Bangladesh like the Korotoya and Atrai. The Brahmaputra River flows across the plains of Bangladesh for 337 kilometres before joining the Ganges, at Goalanda (Sarma 2005: 73). 'The combined flow of these two rivers is known as the Padma. After flowing for another 105 kilometres, the Padma merges with another major transboundary river, Meghna, at Chandpur' (Rao 1979: 77). From this confluence, the combined course of these three mighty rivers is known as the Lower Meghna. Finally, the three rivers, Ganges, Brahmaputra and Meghna, empty into the Bay of Bengal under the same name, Lower Meghna.

Another major river covering a large part of southern Assam that eventually joins the Brahmaputra River in Bangladesh, is the Barak, known there as the Meghna. The Barak with its network of tributaries is the second largest river system in the north- eastern region.

It is a part of the Ganga-Brahmaputra-Meghna system. After traversing the Barak Valley in a westerly direction up to Karimganj, it bifurcates into two branches known as the Surma and the Kushiyara. These reunite near Bhairab Bazar in Bangladesh. The joint stream is called the Meghna that later meets the Brahmaputra (known locally as the Padma), and eventually flows into the Bay of Bengal.

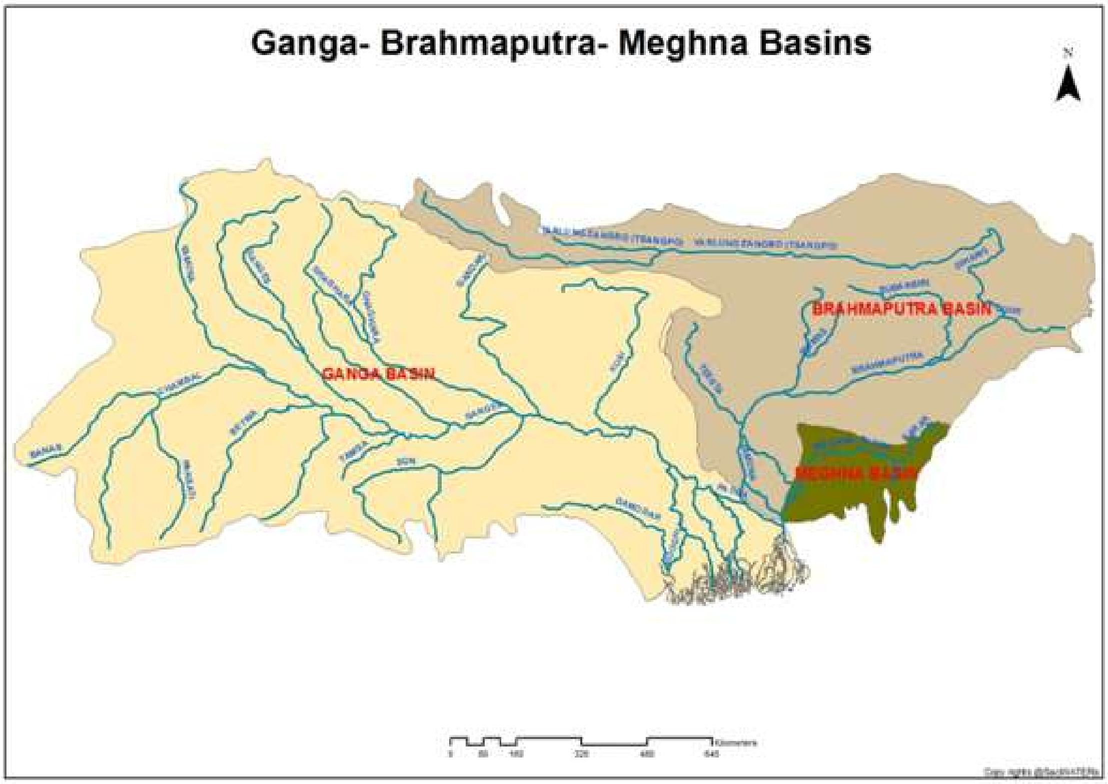


Figure 2.1 Ganges-Brahmaputra and Meghna Basin and Major Rivers

Source: SaciWATERs (2013)

Table 2.1 Brahmaputra Basin Area Distribution

Country	Drainage area	% of area of basin	% of total area of the country	Arable land (km^2)	Population (millions)	Hydropower potential	% basin total hydropower potential
China	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	5.10	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: Rangachari & Verghese (2001: 82); Tianchou (2001: 110); Sarma (2005: 73); DOT (2007); CWC (2008); NHPC (2008); NPB (2008); World Bank (2008)

Notes: n/a - not available

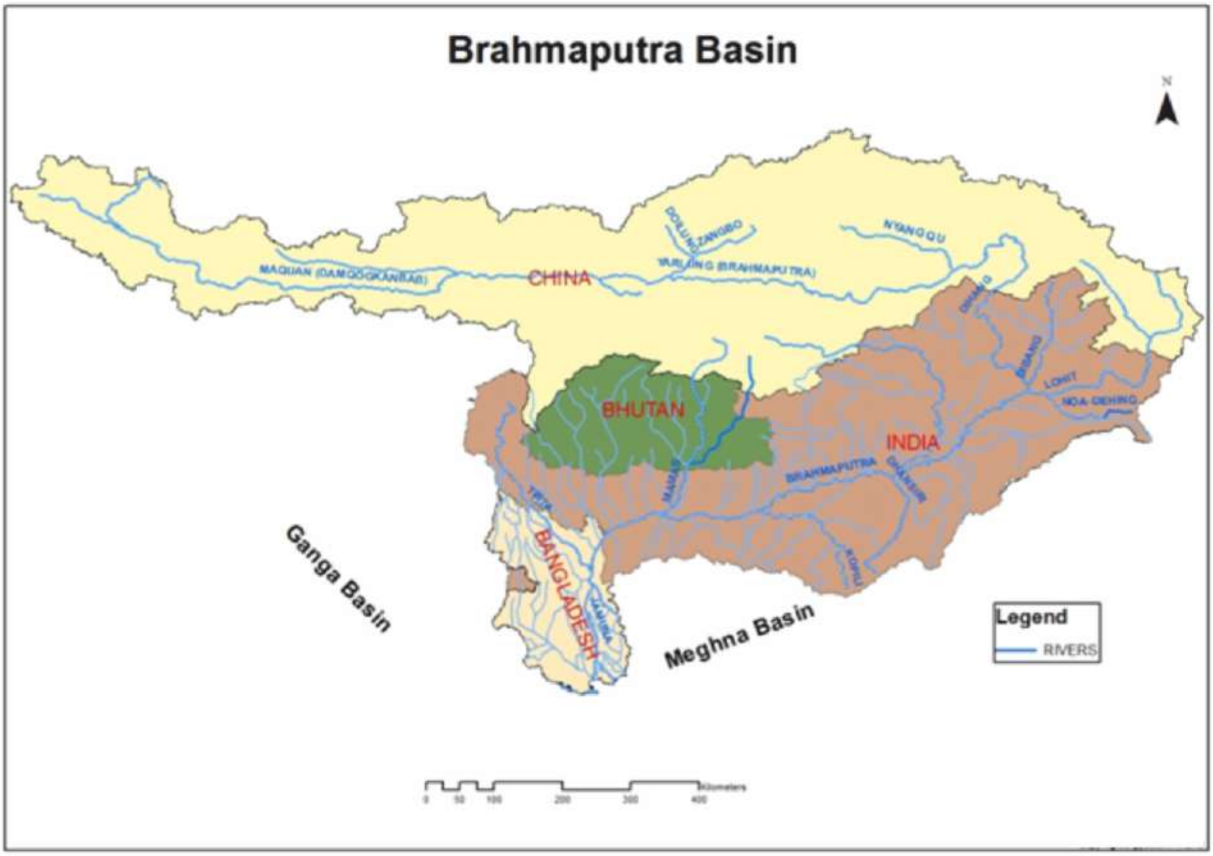


Figure 2.2 Brahmaputra Basin and Major Rivers

Source: SaciWATERs 2013

2.3 Physical Characteristics of the Brahmaputra Basin

2.3.1 Physiography of the Brahmaputra Basin

The Brahmaputra basin forms part of the larger natural setting of Southeast Asia and shares many common characteristics. The basin is an example of an extremely heterogeneous watershed with a complex topography and great spatial variability in land cover.

In addition, the climate is complex within the catchment because of the altitudinal range, the geographical location, and the influence of the South Asian monsoon systems.

Based on the lithology and climate, the Brahmaputra basin is divided into several sub-basins. Singh (2006), in his work on spatial variability of erosion in the Brahmaputra basin, mentioned five sub-basins, namely (i) Tibet, (ii) Eastern Syntaxis, (iii) Eastern Drainage/Mishmi Hills, (iv) Himalaya, and (v) Southern Drainage.

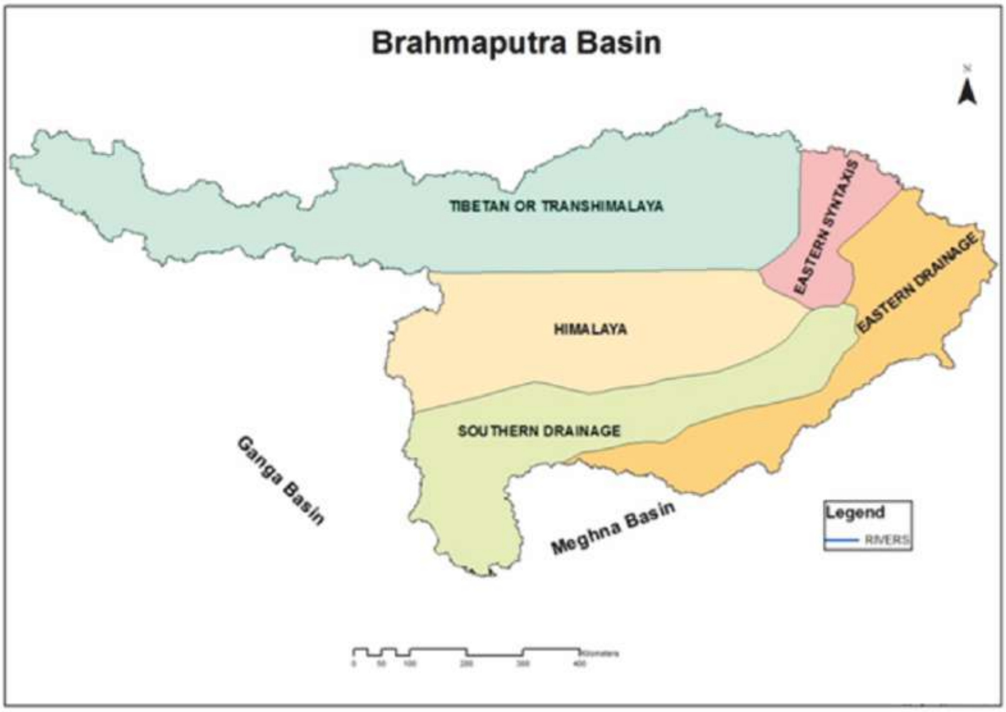


Figure 2.3 Different Sub-basins of the Brahmaputra

Source: Singh 2006

Table 2.2 Various Sub-Basins of the Brahmaputra

Name of the basins	Coverage Area	lithology	Erosion rate
Tibet	44.4%	Sedimentary rocks and gabbros, dolerite of the Trans-Himalayan plutonic batholiths	Lowest erosion rate
Eastern Syntaxis	4%	Gneisses and calc-alkaline plutons of the Trans-Himalayan plutonic belt	Highest erosion rate in the world
Eastern Drainage/Mishmi Hills	27.0%	Calc-alkaline diorite-granodiorite- tonalite rocks of the Trans-Himalayan plutonic belt	Medium to low erosion rate
Himalaya	28.6%	Crystallines and sedimentaries	Medium to low erosion rate
Southern Drainage	40%	Ophiolites of Naga Patkoi Ranges	Medium to low erosion rate

Source: Singh 2006

Depending on the topography and morphology the basin is divided into 5 geomorphic regions

Table 2.3 Physiographic Divisions of the Brahmaputra Basin

Nature of topography	Area under topography (km^2)	Geological locations
High Tibetan plateau	293,000	Southern part of the Tibet province of china
High Himalayan mountains	137,050	Part of Himalayan kingdom of Bhutan, and of 3 states of India: Arunachal Pradesh, West Bengal and Sikkim.
Brahmaputra Valley	56,200	Part of Assam State of India
Lower (Assam) Mountainous Region	37,200	Part of 3 states of India: Nagaland, Assam and Meghalaya.
Plains	56,550	Part of the 2 plains districts of West Bengal (India) and part of Bangladesh
Coastal Region	Negligible	Coastal region of Bangladesh

Source: http://www.nih.ernet.in/rbis/basin%20maps/brahmaputra_about.htm

2.3.2 Climate of the Brahmaputra Basin

The Brahmaputra basin drains diverse environments: from the cold dry plateau of Tibet and the rain-drenched Himalayan slopes to the landlocked alluvial plains of Assam and the vast deltaic lowlands of Bangladesh (Immerzee 2008; Singh & Goswami 2012).

Excluding the Tibetan portion, it forms an integral part of the monsoon regime of East Asia with a mean annual rainfall of 230 cm and a variability of 15-10% (Bhattachariya & Sindhu 1984; Mohanta, Goswami & Singh 2002; Goswami 2008; Singh & Goswami 2012). The Himalayas exercise a dominating influence on the prevailing weather of the basin, due to their location directly on the path of the moisture-bearing east monsoon (Amarasinghe 2005; Goswami 2008; Singh & Goswami 2012).

The basin is characterized by recurring flood and drought events, with an immense and often tragic impact on human life, property, and infrastructure. Several instances of floods in parts of India and Bangladesh have been recorded. Goswami (2008) and Goswami & Singh (2012), for instance, have given a detailed account of floods in Assam, India. The floods of 1988, 1998 and 2004 were the worst in recent history, with the flood damage cost rising up to 664 crores in 1988 and 700 crores in 1998 (Goswami 1998). The 2004 floods broke all records for flood damage, affecting 12.3 million people, 12.57 million hectares of cropland, and 10,560 villages (Goswami 2007). The flood waters submerged the Kaziranga National Park for almost a month with 1-3 m depth of water, taking a toll of 652 wild animals.

In the case of Bangladesh, about 20% (3 million hectares) is flooded annually by many types of floods (Chowdhury et al. 1996; Mirza et al. 2002).

Floods analysed during 1954–1999 show more area inundated during 1980–1999 than during 1960–1980. The former period was characterized by two catastrophic and one exceptional flood. Estimates of flood damage were also high in recent decades, due to the depth and duration of flooding. The 1987 flood completely or partially damaged 2.06 million houses (or 16.67% of the total national housing). The 1988 flood had displaced and affected an estimated 45 million people, and destroyed or partially damaged 12.8 million houses. The 1998 flood affected about 31 million people in 52 out of the 64 districts in the country. An estimated 2.4 million houses were completely or partially destroyed.

Scientist have contemplated that such unequal spatial distribution of rainfall will be aggravated by climate change (Rackhecha & Soman 1994; Aerts, Kriek & Schepel 1999; Mirza 2001; Mirza, Warrick, Ericksen 2003; Sharma, Johnson, Hutton & Cark 2006; Palmer, Liermann, Nilsson, Flörke, Alcamo, Lake & Bond 2008; Ghosh & Dutta 2012; Immerzeel, Ludovicus, Beek & Bierken 2013). Although the exact impact of climate variability and change on river discharge, occurrence of floods, etc. in the Brahmaputra basin is a matter of future research, scientists are of the opinion that compared to the Ganges or Meghna, the Brahmaputra basin is extremely sensitive to any form of climatic hazard. With the increase of climatic variability, almost all tributaries of the Brahmaputra River system are likely to carry an increased peak discharge with greater variation in the annual peak discharge series (Ghosh & Dutta 2012). This will affect the timing, magnitude, frequency, depth, extent, and duration of floods. An increased magnitude, depth and duration of floods will bring a dramatic change in agricultural practices and the livelihoods of the poor and marginalized in Bangladesh and India (Postel et al.1996; Kitoh et al. 1997; Lal & Aggarwal 2001; Lal & Harasawa 2001; Mirza 2002; Sharma 2005; Ghosh & Dutta 2012).

2.3.3 River Erosion, Sediment Load and River Discharge

'The flow regime of the Brahmaputra that responds to the seasonal rhythm of the monsoon and freeze-thaw cycle of the Himalayan snow, is characterized by an extremely large and variable flow, enormous rates of sediment discharge, rapid channel aggradations, accelerated rates of basin denudation and unique patterns of river morphology'(Goswami 2008: 2). With an average annual discharge of 19,830 cubic metres per second (cumecs) at its mouth, it ranks fourth among the large rivers of the world. Water yields (volume of water drained by unit area of the basin) of the Brahmaputra and some tributaries like the Subansiri, Jia Bharali, and Manas are exceedingly high, surpassing most of the world's major rivers.

The unique geology and geomorphology responsible for the highly erosive characteristics of the Brahmaputra River have been studied by various authors (e.g., Coleman 1969; Goswami 1985; Sarma 2005; Pahuja & Goswami 2006; Wiebe 2006; Sarkar & Thorne 2012). Singh & France-Lanord (2002) observed there are significant variations in erosion rates among the various sub-basins of the Brahmaputra.

The Eastern Syntaxis, which occupies about 4% of the basin area, contributes about one and a half billion tons of sediments per year to the river (Singh & Lanord 2002; Ahmad & Ahmed 2003; Singh 2006; Biswas 2008).In fact, among the various trans-Himalayan rivers, the Brahmaputra alone supplies about1000 million tons of suspended material to the Bay of Bengal (Goswami 1985; Chaudhari & Sinha 1999; Pahuja & Goswami 2006). In terms of sediment transport, it is second only to the Yellow river (Hwang Ho) with a sediment transport per unit drainage area of 1,128 metric tons per square kilometre. The enormous sediment load the river carries, causes increased river bank erosion at the lower reaches, influencing the channel's self-adjustment processes. This, in turn, results in changes in channel morphology, navigation bottleneck zones, loss of livelihood, contamination of drinking water, outbreak of diseases, loss of infrastructure and loss of ecosystems in the Brahmaputra basin (Sharma, Johnson, Hutton & Clark 2006).

2.3.4 Basin Biodiversity and Ecology

The Brahmaputra basin in north-east India is part of the Indo-Myanmar biodiversity hotspot, one of the

25 hotspots of mega bio-diversity on earth recognized by the World Conservation Union. The outstanding feature of the region is its great diversity of flora and fauna and enormous variation in both vertical and horizontal distributions. While extraordinary luxuriance and great diversity in vegetation mark the monsoon-dominated wetter parts, vegetation in the ice-covered mountain-tops and other rain-deficient areas with thin soil cover is strikingly sparse or completely absent. The region supports all types of vegetation right from cultivated plains to grasslands, meadows, marshes, and swamps, scrub forests, mixed deciduous forests, humid evergreen forests, temperate and even alpine vegetation.

The north-eastern region, especially the floodplains of the Brahmaputra, is dotted with a large number of wetlands or beels, which are flood-water retention basins and reservoirs for traditional fisheries (Goswami & Das 2003). Over 3,500 such wetlands have been identified in Assam, of which 177 are more than 100 hectares in size. Most of these wetlands are now in a degraded condition. A considerable number have been totally destroyed due to siltation, eutrophication, harmful land use practices and encroachment for settlement, construction of roads, railways, embankments, etc.

2.4 Socio-Economic Characteristics of the Brahmaputra Basin

The Brahmaputra is a river whose dynamism is an amalgamation of its sheer size, complexities, multinational character, socio-political, economic and cultural intricacies (Ahmad et al. 2001; Biswas & Uitto 2001). The basin, located in the southeastern part of Asia, has much significance in the context of its rapid population growth, intense use of land and agricultural practices

The basin has a total population of more than 80 million with an average population density of 182 persons/km2 (IUCN, IWMI, Ramsar Convention Bureau 2002; ICIMOD 2005). The spatial distribution as well as density of population is quite uneven in the basin. The highest density of 828 persons/km2 is recorded in the Bangladesh portion of the basin followed by India (143 persons/km2), Bhutan (26 persons/ km2) and Tibet (6 persons/ km2). In fact, the general pattern of population distribution in the Brahmaputra basin follows the physiographic and climatic zones from north to south with a very sparsely populated Greater Himalayan region in the north succeeded by the zone of relatively modest density in the middle Himalayan valleys followed by the more densely populated south zone occupying the submontane belt and the floodplain areas.

The basin is home to 200 indigenous, multi-ethnic communities, each with its distinct history, culture and geographic space. They are widely scattered from the Tibetan highlands through the mountains of Arunachal to the plains of Assam. High population growth along with acute poverty has made management of the water resources in the basin particularly challenging. The countries downstream of the Brahmaputra, India and Bangladesh, depend mostly on water resources that are available in adequate quantity and quality in the upstream countries, Tibet and Bhutan. But because of their large(r) populations, water demand is high, while the population keeps on growing. More specifically, consumptive demands include water for drinking, agriculture, irrigation, and fisheries.

Now, because of this geographical situation, conflicts (may and do) arise because of competitive water demands between respective countries. No effective institutional arrangement exists that is responsible for water management on an overall basin scale. China and India have different river linking plans to divert water from the Brahmaputra to mitigate water problems. For instance, China wants to divert water from the Brahmaputra to the north, India wants to divert the river water to solve water supply problems in the Ganga basin in low flow times. Both plans are not feasible for they would have grave impacts on the other countries involved.

This constitutes a high conflict potential, and no solution to the advantage of all riparian countries has been found so far. A superior authority would help to solve these conflicts by supporting communication between them.

Brahmaputra in India

3

Brahmaputra in India

3.1 Introduction

In India, the Brahmaputra basin drains 197,316 km2 of area, covering the six states of Arunachal Pradesh (41.9%), Assam (36.3%), Meghalaya (6.1%), Nagaland (5.6%), Sikkim (3.8%) and West Bengal (6.3%) (Goswami 2003; Sarma, Acharjee & Murgant 2013). The Indian part of the basin has a maximum east-west length of about 1,540 Kilometers and a maximum north-south width of about 682 Kilometers. It is characterized by large variations in relief, slope, landforms, climate, vegetation and land use (Sarma, Acharjee & Murgant 2013; http://sandrp.wordpress.com/2013/07/17/brahmaputra-the-beautiful-river-or-thebattleground/). The dynamic structural behaviour of the basin is manifested by frequent shifting of its confluence points (Goswami 2003; Blackmore 2006; Singh & Goswami 2011; Lahiri & Sinha 2012; Sharma, Garg, Sarkar, Akhtar & Kumar 2012). For instance, according to Lahiri & Sinha (2012), old topographic maps show the confluence point of three rivers (the Siang, the Dibang, and the Lohit) at Kobo in Assam. This point shifted by 16 Kilometers downstream to Laikaghat by 1975, with a further downstream shift of 19 Kilometers by 2005.

The basin has been regularly in the news, more for the natural disasters it causes along its path than for the benefits it brings to the various life forms and human livelihoods downstream. Life and property loss, ecosystem destruction and long-term effects on resources are recorded results, due to the regular onslaught of floods, landslides, cyclones and

Table 3.1 State-wise Drainage Area of the Brahmaputra Basin in India

State	Drainage Area	% of State Area Under the Basin	Channel Length (Km)
Arunachal Pradesh	83,740	100	278
Assam	71,216	90.79	640
West Bengal	12,585	14.18	--
Meghalaya	11,780	52.52	--
Nagaland	10,895	65.71	--
Sikkim	7,100	100	--
Total	194,413		918

Source: 'Integrated Water Resource Development: A Plan for Action', MoWR, Govt. of India, September 1999 droughts. Its unique glacial origin and location in a highly seismic zone coupled with a multitude of historical, political, social, cultural and strategic factors, has the potential to bring about acute interstate and intra-state conflicts on the one hand and long-term cooperation on the other. This makes it one of those critical transboundary rivers in the third world that require urgent attention.

The following section briefly outlines some of the basin's most salient features for the Indian part, including: geomorphology, hydrology, water quality, current socio-economic status, development potential and existing institutional barriers. It attempts to combine these parameters for a nuanced understanding of the hydro-political complexes of this economically prized, politically charged, and environmentally sensitive river basin. Focus is on Assam and Arunachal Pradesh, representative states in the basin, on account of their immense significance and value.

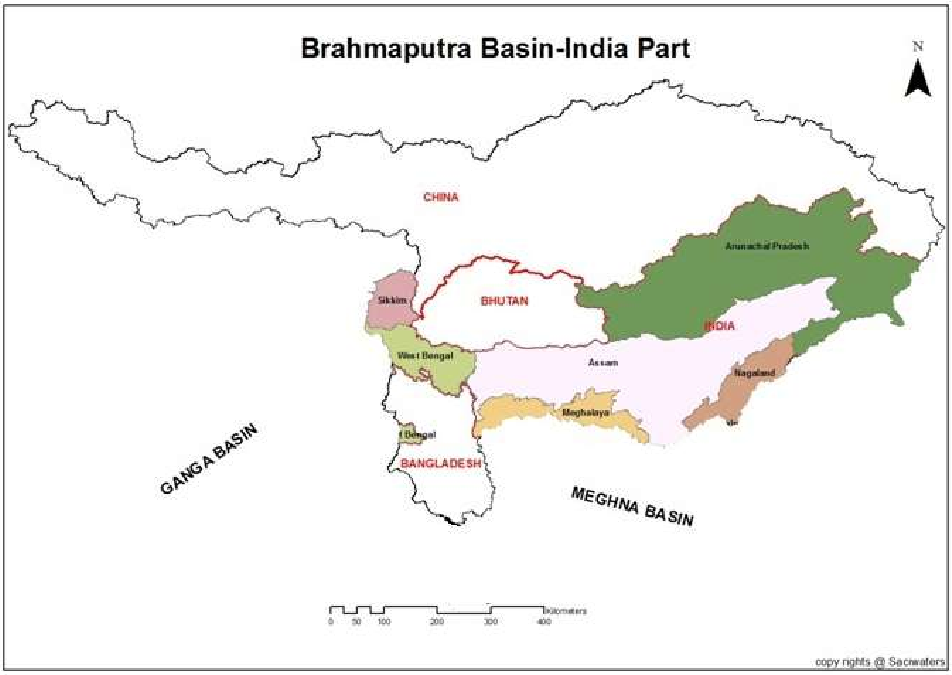


Figure 3.1 Brahmaputra Basin in India

Source: SaciWATERs

3.2 Understanding the Unstable Brahmaputra in India

3.2.1 Physiographic Aspects

The Brahmaputra basin represents a unique physiographic setting in the eastern Himalayas: a powerful monsoon rainfall regime under wet humid conditions with a fragile geological base and active seismicity (Goswami 2006). The Indian Brahmaputra comprises (i) the upper Brahmaputra basin, (ii) the Brahmaputra Valley, (iii) the lower (Assam) mountainous region, and (iv) the plains. These different geo-ecological zones have a distinctive assemblage of topographical, geological, climatological and floral characteristics, which are strongly manifested in the morpho-dynamics of the river downstream.

The Brahmaputra valley, the most significant physiographic unit in India, is sandwiched between the north-east/south-west bound Himalayan Frontal Thrust of Arunachal, and the Naga-Patkai Thrust of Nagaland and the Shillong Plateau (Geological Survey Report 2009; Lahiri & Sinha 2012). It forms part of the upper Assam sub-division.

Administratively, the Brahmaputra valley can be divided into the Western Brahmaputra valley covering the regions of Goalpara and Kamrup; the Central Brahmaputra valley covering Darrang, Nagaon and Sonitpur districts; and the Eastern Brahmaputra valley covering the districts of Lakhimpur, Dibrugarh and Sibsagar. This part of the basin consists of two distinct geomorphic regions, namely a newly formed large alluvial island called Dibru-Saikhoa Island (or 'new Majuli') and old Majuli Island.

The gradient of the Brahmaputra River in the High Himalayan mountain region is very steep – about 4 to 16 m/km (Gorge of Pasighat). After entering into the valley in Assam, the river shows a marked reduction of the gradient, down to 0.1m/km. The dramatic reduction in the slope of the Brahmaputra, as it cascades through one of the world's deepest gorges in the Himalayas before flowing into the Assam plains, explains the sudden dissipation of the enormous energy locked in it and the resultant unloading of large amounts of sediments in the valley downstream. The Majuli, the world's largest inhabited river island, formed within the Brahmaputra valley is a classic example of landform developed in such a lower energy fluvial system (Sarma & Phukan 2004, Singh & Goswami 2011). The island is known for its geomorphic significance and cultural heritage.

The entire belt of the Brahmaputra basin in India is a geo-dynamically very restless region (Singh & Goswami 2011; Sinha 2012). Earthquakes of 8.7 magnitude in 1897 and 1950 are among the most severe in recorded history. They caused the Brahmaputra bed level to rise at Dibrugarh in Assam by three metres, increasing the flood and erosion hazard potential of the river (Goswami 2007). In fact, the region's active seismicity has a significant impact on the hydro-geomorphic regime of the Brahmaputra system, causing landslides. These result in the natural damming of rivers, flash floods due to the bursting of landslide-induced temporary dams, raising of riverbeds by siltation, fissuring and sand venting, elevation of existing river and lake bottoms and margins, and creation of new water bodies and waterfalls (Goswami & Das 2002). The basin in India bears testimony to some major earthquakes (Mukhopadhyay & DasGupta 1988). "Earthquake activity has a great impact on the regime of the Brahmaputra River, particularly on the morphology of channels and sediment transport. Since the river drains through geologically younger, easily erodible formation in the upper reaches of its basin, triggering of an earthquake causes an inflow of an enormous quantity of sediments into the river system, thereby upsetting the regime of the river. The earthquake of 1950 caused devastation on the upper reaches of the Brahmaputra basin." (Singh & Goswami 2011: 5567).

3.2.2 Hydrological Regime

The hydrological regime of the Brahmaputra basin is characterized by an extremely large and variable flow, enormous rates of sediment discharge, rapid channel aggradations, accelerated basin denudation and unique patterns of river morphology. The river appears to be a multi-channel and multi-pattern river with a tendency to generate anabranching frequently (Lane 1957; Leopold & Wolman 1957; Bristow 1987; Latrubesse 2008) in a decadal scale (Lahiri & Sinha 2012). The north bank tributaries generally flow in shallow braided channels, have steep slopes, carry heavy silt, and are flashy in character. The south bank tributaries, in contrast, have a flatter gradient and deep meandering channels with beds and banks composed of fine alluvial soils, marked by a relatively low sediment load.

In Arunachal, the major tributaries of the river are the Ringong Asi, Yang Sang Chhu, Sigong/ Sirapateng, Niyikgong, Angong, Simang, Yamne, Siyom, Yargyap, and Hirit Korong (CWC 2012). In the course of its east-west journey through the Assam valley, some important north bank tributaries are the Lohit, Dibang, Subansiri, Jiabharali, Barnadi, Puthimari, Pagladia, Beki, Manas, Ai, Gabhoru, Chompawati, Sankosh, Raidhak, Torsa, and Teesta. The Burhidihing, Desang, Dikhow, Jamji, Bhogdoi, Kakdonga, Dhansiri, Kopili, Kolong, Sonai, Digaru, Bharalu, Krishnai, Dudhnoi are the major tributaries on the left bank (Sarma & Basumallick 1980; Goswami et al. 1999; Bhakal et al. 2005; Kotoky et al. 2005; Sarma et al. 2007; Das & Saraf 2007; Kumar 2008).

The catchments of the Brahmaputra and its tributaries show significantly high rates of basin erosion and denudation with an average rate reported to be from 72.5 to 80 km2/year (Sarma & Basumallick 1980; Goswami et al. 1999; Bhakal et al. 2005; Kotoky et al. 2005; Das & Saraf 2007; Sarma et al. 2007; Kumar 2008).

The catchments of the Subansiri, Jia Bharali and the Manas along with the Dihang (Siang) are estimated to have experienced an average erosion/denudation of 73-157 cm/1000 years over just 24 years (1955-79). In the Assam valley, bank erosion is severe in Rohmaria near Dibrugarh, Bengena Ati in Majuli, Panikhaity-Khankar near Guwahati, Bhurbandha near Morigaon, besides other areas.

Extensive bank erosion is often followed by disposition of sediment forming sand bars and islands. This phenomenon is particularly observed

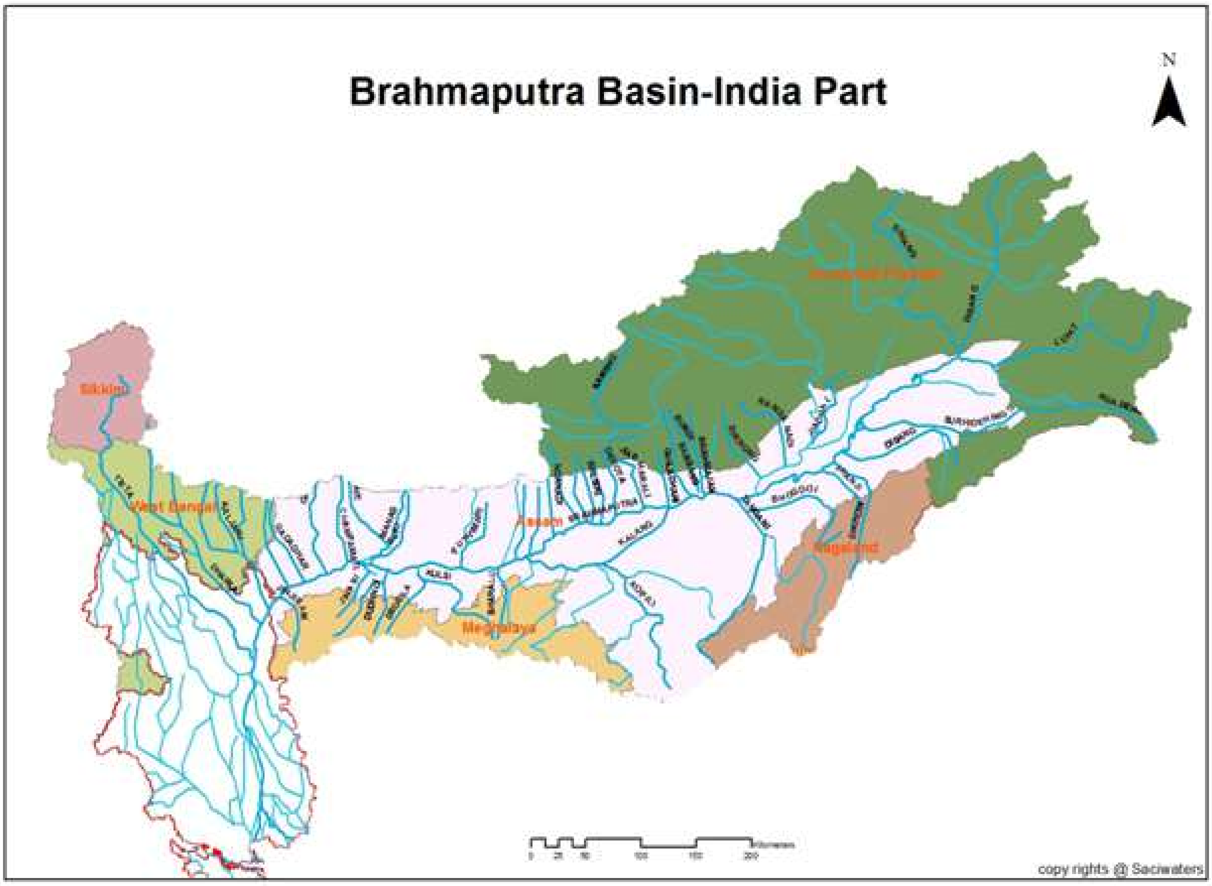


Figure 3.2 Rivers of Brahmaputra Basin in India

source: SaciWATERs

at the lower reaches in Assam and Bangladesh. In spite of being a glacial-fed river, it also has the distinction of being the river with the highest sediment yield - 852.4 t/km2/yr - in the world and the second highest water yield at delta level, next only to the Amazon.

This fluctuating river flow, river bank erosion, and sedimentation have made flooding a regular feature all along its course, from mountainous Tibet to the floodplains of Bangladesh (Bhatt et al. 2013). Statistically, about a quarter of the basin is flooded in an average hydrological year in India (Hofer 1998; Parua 2001; Goswami & Das 2003). The mean annual flood of the river, 48,200 cumecs, has a recurrence interval of 2.2 years, while the maximum recorded flood of 72,726 cumecs is likely to be repeated once in about every 133 years.

From 11 to 12 June 2000, Arunachal Pradesh had experienced flash floods in the Siang (Brahmaputra) River. Nearly 10,000 people were reported to have been affected, 26 persons had died, and 3 bridges - the Sagarm, Dite Dime and Nubo- had been washed away. 4 districts (East, Upper, and West Siang, and Dibang Valley) had been affected by the floods.

From information available, these unprecedented flash floods had not been due to rainfall in the Indian position, i.e. the Arunachal Pradesh catchment of the river, but to failure or breach of a blockade in the upstream portion of the Brahmaputra in Tibet. The middle reaches of the Brahmaputra basin in Assam represent one of the most acutely hazard-prone regions in India, with a total flood-prone area of 3.2 million hectares. The state has experienced major floods in 1954, 1962, 1966, 1972, 1977, 1984, 1986, 1988, 1998 and 2004. The last three floods were the worst in recent history.

The enormously large variation in the river's daily discharge over different seasons is a remarkable feature of its flow regime. Since the time lags and peaking characteristics of flood flows vary in different rivers draining into the Brahmaputra, the tributary inflows generate large and variable perturbations on the Brahmaputra's discharge hydrograph (Sarma 2005, Jain et al. 2007).

3.2.3 The Climate Regime

The climate of the Brahmaputra basin in India lies within the monsoon rainfall regime, with an annual rainfall to the tune of 2,153 mm. The temperature varies from 28° to 33°C and the relative humidity varies from 54% to 86%. A gradual increase in rainfall from the valley bottom towards the lower ranges followed by a decrease towards the higher ranges is evident from the annual rainfall at Dibrugarh (2,850 mm) in the far eastern part of Assam valley, Pasighat (5,070 mm) in the foothills and Tuting (2,740 mm) further up the Himalayas.

Monsoon rains from June to September account for 60-70% of the annual rainfall in the basin as compared to 20-25% in the pre-monsoon season from March through May. These rains contribute a large portion of the run-off in the Brahmaputra and its tributaries. They are primarily controlled by the position of a belt of depressions, called the monsoon trough, extending from north-west India to the head of the Bay of Bengal. In the course of the north-south oscillations in summer, when this axis moves closer to the foothills of the Himalayas, heavy precipitation occurs in Assam and adjoining highlands. The severity of rain storms occasionally reaches as high as 40 cm per day. The years 1998 and 2004 that saw extremely high floods in the region, also recorded an excessively high rainfall, especially in the upper basin areas.

Snowfall is experienced in the Brahmaputra basin in areas with elevations of 1,500 m and above. There are altogether 612 glaciers in the India part of the basin of which 450 are in the Teesta sub-basin of Sikkim, while 162 are in the Kameng River (upper Jia Bharali) sub-basin of Arunachal Pradesh.

3.2.4 Quality of Water Resources in the Basin

Information on groundwater quality of the Brahmaputra basin is relatively scanty. Nevertheless, few studies do point out alarming pictures of degrading water quality of the basin, and the implications for health of the local population. The basin has shown evidences of iron, fluoride and arsenic contamination in several of its pockets in India (Singh 2006). Arsenic contamination has been particularly reported in 21 of the 24 districts of Assam, 6 in Arunachal Pradesh, 1 in Manipur, and 2 in Nagaland. Maximum arsenic contents were observed in Jorhat (Titabor, Dhakgorah, Selenghat and Moriani Blocks), Dhemaji (Sissiborgoan and Dhemaji Blocks), Golaghat (Podumani Block) and Lakhimpur (Boginodi and Lakhimpur Blocks) in Assam, Thuobal in Manipur, in the Dibang valley of Arunachal Pradesh, and Mokokchung and Mon districts of Nagaland (Chowdhury 2001; BGS & DPHE 2001; Chakraborti 2004; Singh 2004).

3.2.5 The Basin Ecology

The Brahmaputra valley in Assam is dotted with innumerable fresh water lakes (locally called 'beel') or ox-bow lakes ('era suti'), marshy tracts and seasonally flooded plains, and hundreds of riverine sandbars and islands. It provides an ideal wetland ecosystem with typical wetland animals like the fresh water dolphin, great Indian one-horned rhino, crocodile and winter monitor lizard, and a few species of turtles (ENVIS 2004). The valley is an important stronghold of the Royal Bengal Tiger (Panthera tigris). Assam contains about 15 per cent of India's wild tiger population (265 wild tigers in 11 protected areas covering 2453 km2). While tigers and the one-horned rhinoceros are still found here, their habitats are restricted to small, isolated populations within protected areas which can further endanger their existence. The area is a meeting point of species of Indian and Malayan origin. The endemic mammals of the valley are the pygmy hog and the hispid hare, both of which inhabit the grasslands of the riverbanks.

The forest cover of the basin in India, as indicated by satellite surveys, is 144,922 km2, which accounts for 59 % of the total geographical area (Myint & Hofer 1997). In contrast, the total basin forest cover accounts for only 14.07 %. The distribution of forest cover in the different states is estimated as: Arunachal Pradesh (82.8%), Nagaland (68.9%), Meghalaya (63.53%), Sikkim (39.52%), West Bengal (21.4%) and Assam (20.56%) (Myint & Hofer 1997). Arunachal Pradesh accounts for about 60% of the forest cover in the Indian part of the basin. The vegetation changes from tropical evergreen and mixed deciduous forests in the Assam valley and the foothills, through temperate coniferous belts in the middle Himalayas to alpine meadows and steppes in the higher ranges. There has been a considerable decline in forest cover due to deforestation, land use conversion and land degradation in the basin. Shifting cultivation, the traditional slash-and-burn technique in agriculture, is widely practised in the hills of north-east India.

It is a major cause of environmental degradation, i.e. deterioration of forest cover, loss of biodiversity, soil erosion, loss of soil fertility and crop yield, reduction in groundwater recharge, increase in surface run-off, lowering of the groundwater table, and acceleration in the rates of sedimentation in rivers and reservoirs downstream.

3.2.6 Socio-Economic Situation

Although the Brahmaputra River is a major backbone of the economy of north-east India, the river basin remains both underdeveloped and sub-optimally managed. Much of the region has undergone a massive transformation under the pressure of human efforts to harness energy and mineral resources, to harvest food and fuel wood, and to create settlements. The population density in the basin in India is very high, averaging more than 143 persons/km2. In the alluvium portion of the basin in Assam, the rural and urban population densities are 257 persons/km2 and 303 persons/km2, respectively (Singh & Goswami 2012). Much of its population lives in the fertile floodplain of the Assam valley. With varied geo-climatic conditions, the region is ideally suited for agriculture, horticulture, floriculture, and other plantation crops. About 90% are small and marginal farmers. Such marginal communities relying on subsistence farming are increasingly settling inside the levied floodplain and are becoming particularly vulnerable to floods.

Rice is the main food crop of the Brahmaputra valley, along with it variety of fruits like pineapple, banana, orange, lemon, mango, and papaya that grow abundantly in the region. It is also famous for the highest number of orchid varieties in the country. Besides, it is richly endowed with varieties of medicinal plants that have a high value in the international market. Vegetable cultivation and horticulture are also practised here. But, due to the lack of a proper infrastructure as well as transport and communication system, and the geo-political condition of the region, these resources largely remain untapped.

Surface irrigation use is low compared to the overall water flow. Severe shortages of irrigation supplies occur in some locations in the dry season. In Assam, the gross irrigated area is estimated at 27 lakh hectares. Of these, 10 lakh is irrigated through major and medium projects. Till 2009, five major and 11 medium projects have been completed.

A total of 1092 minor irrigation schemes have been completed up to March 2008 while the remaining projects and schemes are under construction.

Table 3.2 Agro-Climatic Zones and their features - Assam State

Climatic Zone	Districts	Agricultural Production
North Bank Plain (NBP)	Dhemaji, Lakhimpur, Sonitpur and Darrang.	Rice, rape and mustard and sugarcane.
Upper Brahmaputra Valley (UBV)	Tinsukia, Dibrugarh, Jorhat Sibsagar, and Golaghat.	Rice, rape and mustard and sugarcane.
Central Brahmaputra Valley (CBV)	Nagaon and Morigaon.	Rice, jute, rape, pulses and mustard.
Lower Brahmaputra Valley (LBV)	Kamrup, Goalpara, Dhubri, Kokrajhar, Bongaigaon, Barpeta and Nalbari	Rice, jute, rape and mustard, potato, wheat and pulses.
Hills (H)	Karbi Anglong and North Cachar Hills	Maize and sugarcane.

Source: http://online.assam.gov.in/agricultureandrrigation

Assam produces more than 55% of the country's total tea production and provides livelihood to more than 60 lakh population of the State and to several more in the neighbouring states. The total area under tea cultivation in Assam accounts for more than half of the country's total area under tea. The estimated production of tea in Assam was about 474 thousand tons in 2006-7.

(http://online.assam.gov.in/agricultureandrrigation).

Aquaculture is the second most important livelihood source in the upper and lower Brahmaputra basin (Singh et al. 1988; Biswas & Michael 1995; Biswas & Boruah 2000a, 2000b). It is essentially practised in ponds or water tanks inside embankments. If there is a breach in the embankment, these culture ponds may get washed off and fish are released into open water. This may also happen during a high intensity flood, when water from outside overtops embankments. Although fish thrive in open water, such situations inflict losses to fish farmers. Studies inferred that large-scale felling of trees in the upper catchment areas and construction of embankments along the

Table 3.3: Class-Size and Source-Wise Area (in ha.) Irrigated in Assam

S.N	Class Size	Area under Operational Holding	Area Receiving Irrigation From Sources					Net Irrigated Area
			Canal	Tanks	Well	Tube well	Others	
1	Below0.5	353051.83	1904.95	1197.90	28.13	1545.57	10486.60	15163.15
2	0.5-1.0	407092.81	2538.38	281.01	80.01	2374.69	9879.69	15153.78
3	1.0-2.0	718383.23	5499.75	331.41	66.71	4146.96	18333.57	28378.40
4	2.0-3.0	496982.96	3862.86	379.48	37.94	2471.65	10661.63	17413.56
5	3.0-4.0	349023.18	3354.49	198.91	25.41	2004.46	9996.45	15579.72
6	4.0-5.0	203932.59	1647.67	125.39	11.04	845.12	6617.06	9246.28
7	5.0-7.5	177267.26	2379.52	135.41	16.60	775.95	6222.10	9529.58
8	7.5-10.0	44203.07	395.95	64.33	0.00	415.22	2237.11	3112.61
9	10.0-20.0	34251.16	80.40	28.02	0.00	252.87	2398.58	2759.87
10	20&above	264354.79	1456.23	400.01	65.06	1863.33	25580.87	29365.50
11	All Classes	3048542.88	23120.20	3141.87	330.90	16695.82	102413.66	145702.45

Source: Economic Survey Assam 2008-9

river bank has altered the riverine ecosystem drastically. As a result, the river has become heavily silted and the connecting channels are also dammed. Consequently, fish and other mega fauna are deprived of adequate water supply, food and breeding grounds. The situation gets further aggravated with increase the extent of monsoon flooding in the context of climate variability and change.

3.2.7 Water Resources Availability and Utilisation

The Brahmaputra basin in India accounts for nearly 30% of the total water resources and about 40% of the total hydropower potential of the country. The total surface water potential is estimated to be 537.2 km3 and groundwater potential 27.9 km3.

Currently, there are no large dams in the Brahmaputra in Indian territory. But the Indian Government has been working on the implementation of a plan to divert water from the Brahmaputra and the Ganges basins by linking both rivers.

The central government, under the 12th Plan (2012-17) for Arunachal Pradesh, has proposed construction of 3 dams with a total capacity of 1610 MW and awarding 23 projects with a total capacity of 7969 MW to the private sector. So, in the next five years, the additional power generated from this State is expected to be 9579 MW. Nevertheless, such a plan does open up new vistas for harnessing such colossal amounts of water resources as this basin brings in (Anand 2013).

With only about 8% of the potential developed, there are arrays of factors that affect the realization of the full potential of the India's hydropower resources. Some are environment and deforestation concerns, other concerns refer to geographical and seismic conditions, but the most critical are the domestic politics between local and national actors (Anand 2013). Interstate cooperation is impeded by the conflicting interests of the different political parties and interest groups. For instance, Arunachal Pradesh's chief concerns include generating revenue through hydropower while avoiding resettlement, whereas Assam's priority is flood management. As a result, Arunachal Pradesh has a strong preference for run-off river projects whereas Assam would benefit most from largely multipurpose dams. Tensions observed between States are replicated within each state, where local communities and tribal populations may have diverging interests, with often little say on the distribution and development of resources their livelihoods depend on.

Various agencies including state, central government, and autonomous institutions engaged in the planning and execution of basin management programmes in the north-eastern region have arguably failed to bring any satisfactory results. Existing institutional arrangements including the Brahmaputra Board are inappropriate and unable to provide an integrated and coherent approach to manage the basin's diverse needs. So, each State continues to pursue its own development agenda. Moreover, policies have a narrowly sectoral focus, looking exclusively at flood control, irrigation or hydro-development, without considering the close

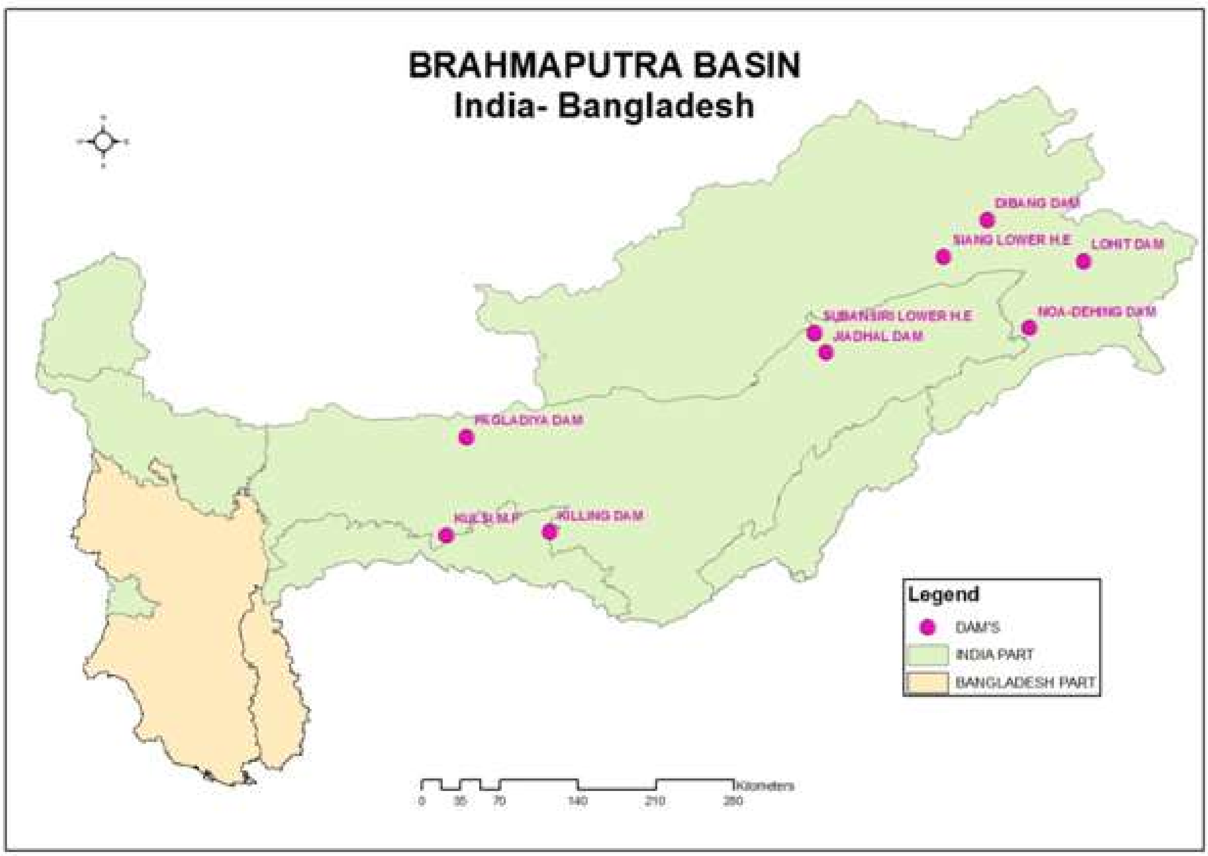


Figure 3.4 Major Dams within Brahmaputra Basin India

source: SaciWATERs

linkages and potential overlapping benefits.

There are real opportunities for the north-east region to harness the Brahmaputra's vast resources effectively and truly transform itself. Considering this situation, it is critical to establish and maintain an appropriate cooperative management structure for sustainable development. What is most needed, of course, is a strong political will, both at the state and national levels, and a sustained popular zeal to convert the water resources of the region into a force for its sustainable development. This should be done through an integrated, multi-disciplinary approach that covers not only technological but also social, economic, and environmental aspects.

Brahmaputra in Bangladesh

4

Brahmaputra in Bangladesh

4.1 Introduction

Bangladesh is located at the lower parts of the basins of the Ganges, the Brahmaputra, and the Meghna with only 7% of the total area lying within the country. There are 57 rivers, which originate outside the boundary of Bangladesh. About 1.18 trillion cubic meters of water flows annually to the sea, of which 1.07 trillion cubic meters or 91 percent enters Bangladesh from upstream basins (principally from the three major basins), and the rest are contributed by total internal rainfall (Rashid 1991). As a result, Bangladesh has been shaped by and is dependent upon these three mighty rivers and their innumerable tributaries and distributaries. The rivers provide fertile soils and a diverse flora and aquaculture to millions of people in their floodplains.

The Brahmaputra enters Bangladesh east of Bhabanipur (India) and northeast of Kuringam district. The river is joined by one of the largest tributaries, the Teesta River (or Tista) at Bahadurabad (Dewanganj upazila of Jamalpur district). After that, the Brahmaputra has a major distributary flowing towards east in the form of the Old Brahmaputra. The eastern branch curves southeast to join the Meghna River near Dhaka. The main river continues southward as the Jamuna, to merge with the lower Ganges at Aricha, and forms the Padma River (Figure 4.1). In the reach within Bangladesh, the Brahmaputra River wanders with a distance of approximately 240 km, out of which as Jamuna for 205 km. It has a mean bank full width of about 11 km. The Padma and Meghna converge near Chandpur and flow out into the Bay of Bengal. This final part of the river is called the Lower Meghna (Best et al. 2007).

In building up their floodplains, the rivers have shifted their courses several times. The most recent major changes were of the Teesta (from the Atrai) and the Brahmaputra (into the Jamuna) in 1787 and of the lower Ganges (from the Arial Khan into the Lower Meghna) in 1840 (Brammer 2002, Sarker et al. 2003, Alam et. al 2007). The Brahmaputra had followed a south-easterly alignment (the present course of the Old Brahmaputra) after flowing past the Shillong Hills in India and thereafter following the eastern edge of the Madhupur Tract. The Upper Meghna thus also carried the flow of the Brahmaputra. Between 1787 and 1830, the Brahmaputra had swung westward by about 60 km to the present course of the Jamuna, leaving the Old Brahmaputra as a distributary of the main Jamuna River.

Different interpretations exist for the avulsion, as summarized by Bristow (1999), including tectonic activity (Winkley et al. 1994), switches in the upstream course of the Teesta River (Morgan and McIntire 1959), the influence of increased discharge (Coleman 1969), catastrophic floods (La Touche 1910), and river capture into an old floodplain channel course (Bristow 1999). The Brahmaputra-Jamuna river-floodplain systems receive utmost importance in Bangladesh because of the dominant role the river plays in flood hydraulics in the country.

The dynamic nature of the river in terms of continuous bank erosion and accretion processes, and the resulting environmental and socio-economic impacts, especially in the char lands within the active river floodplain.

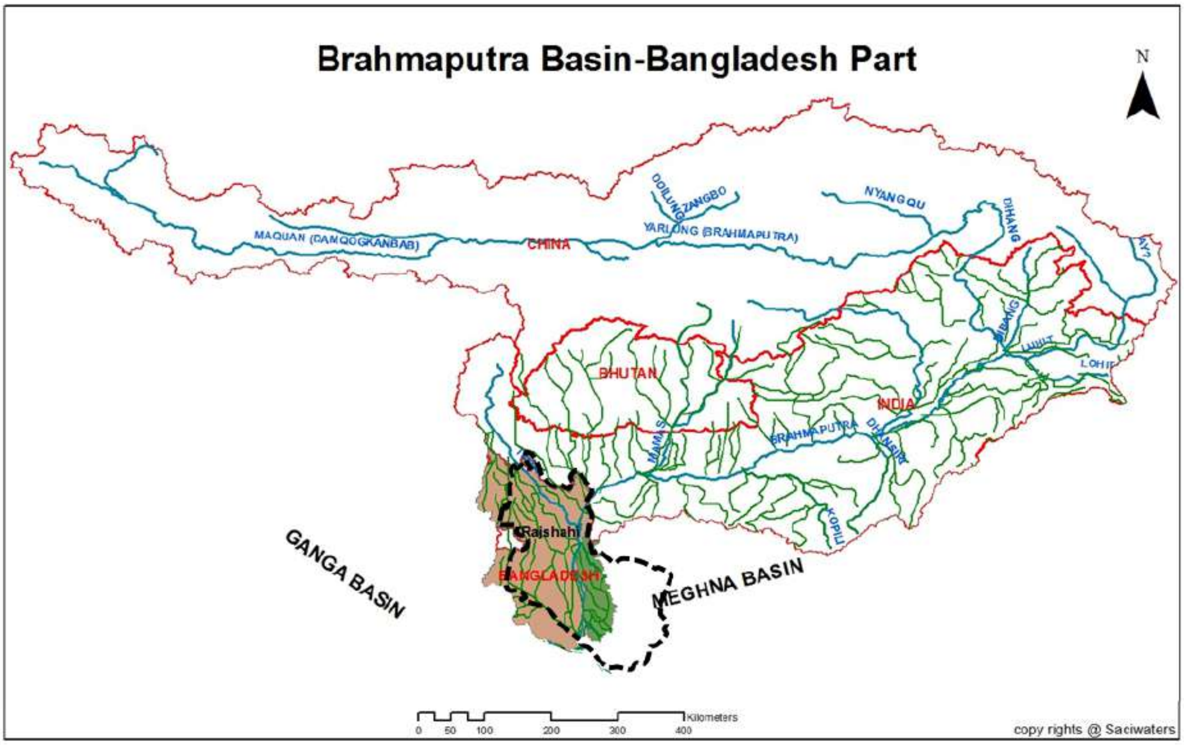


Figure 4.1 Brahmaputra-Jamuna Basin in Bangladesh

Source: SaciWATERs

4.2 Physiographic Features

Physiographically, the Brahmaputra-Jamuna basin is a riverine floodplain, which is particularly diverse, dynamic and complex (Seijmonsbergen 1999, Brammer 2002). Such riverine floodplains in the basin work as a central point for sediment storage. Exchange processes in the zones of transfer and accumulation (Schumm 1977) are built through vertical accretion of flood-borne sediment, coupled with a lateral deposition and re-working driven by channel migration (Leopold et al. 1964, Pickup 1991) and are regulated naturally by the fluvial system.

Agro-ecological zones (AEZs) are characterized by homogeneous agricultural and ecological aspects and identified on the basis of physiography, soils, land levels in relation to flooding, and agro-climatology (Figure 4.2).

Out of the current 30 AEZs, the Brahmaputra-Jamuna basin in Bangladesh includes seven AEZs representing floodplains (Figure 4.3). These consist of: (i) Active Brahmaputra-Jamuna floodplains, (ii) Young Brahmaputra-Jamuna floodplain, (iii) Old Brahmaputra floodplain, (iv) Active Teesta floodplain, (v) Teesta meander floodplain, (vi) Karatoya-Bangali floodplain, and (vii) Lower Atrai basin (FAO 1988, ISPAN 1995, Brammer 2002, Huq & Shoaib 2013).

These constitute about 21% of the entire country. Besides, the basin includes the two uplifted blocks in Barind and Madhupur areas. The seasonal flooding and associated hydrological regime provide the Brahmaputra-Jamuna floodplain with unique characteristics (Islam 2011), making it among the richest and most diverse habitats on earth (Schiemer 2000, Tockner & Stanford 2002).

he course of the Brahmaputra-Jamuna River is alluvial, with shifting, meandering, or braided plan forms that cause massive erosion and deposition, and exhibit changes of course continuously. This affects the adjacent active floodplains. The active floodplains thus represent the youngest alluvial land within and alongside the main river, which is subject to alternate deposition of new sediments and erosion by shifting channels within the main river course. The result is an irregular relief of broad and narrow ridges and depressions, interrupted by cut-off channels and active channels. The temporary alluvial formations (known as chars in Bangladesh) are liable to change in each flood season due to bank erosion and deposition of sands and silts with irregular, stratified thickness.

The young Brahmaputra-Jamuna floodplain occupies a broad band adjoining the active floodplain where bank erosion is seldom active and the landscape is noticeably more stable. It has a complex relief of broad and narrow ridges, inter-ridge depressions, partially in filled cut-off channels and basin. The ridge soils lie above normal flood

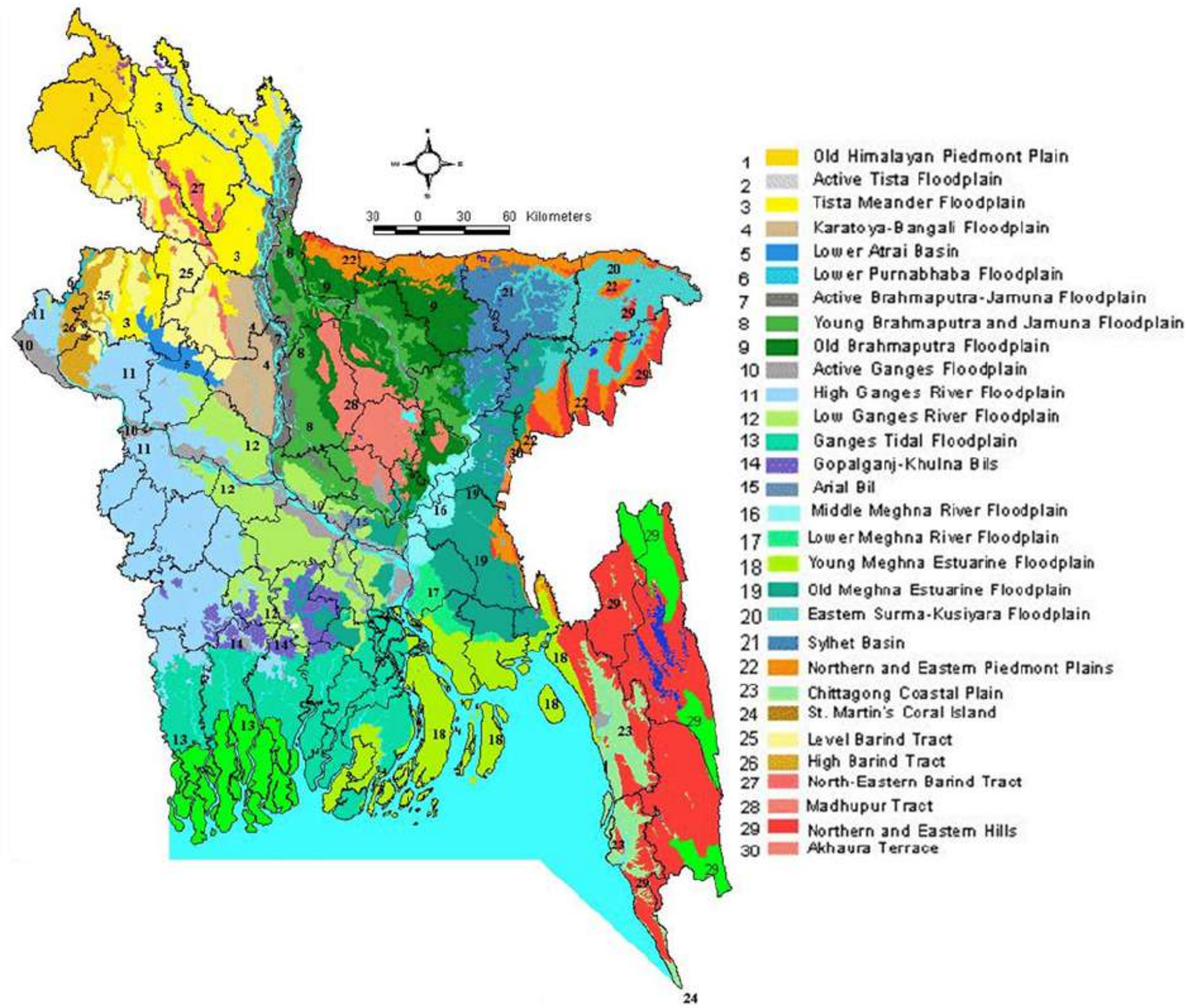


Figure 4.2 Agro-ecological zones of Bangladesh

Source: SaciWATERs

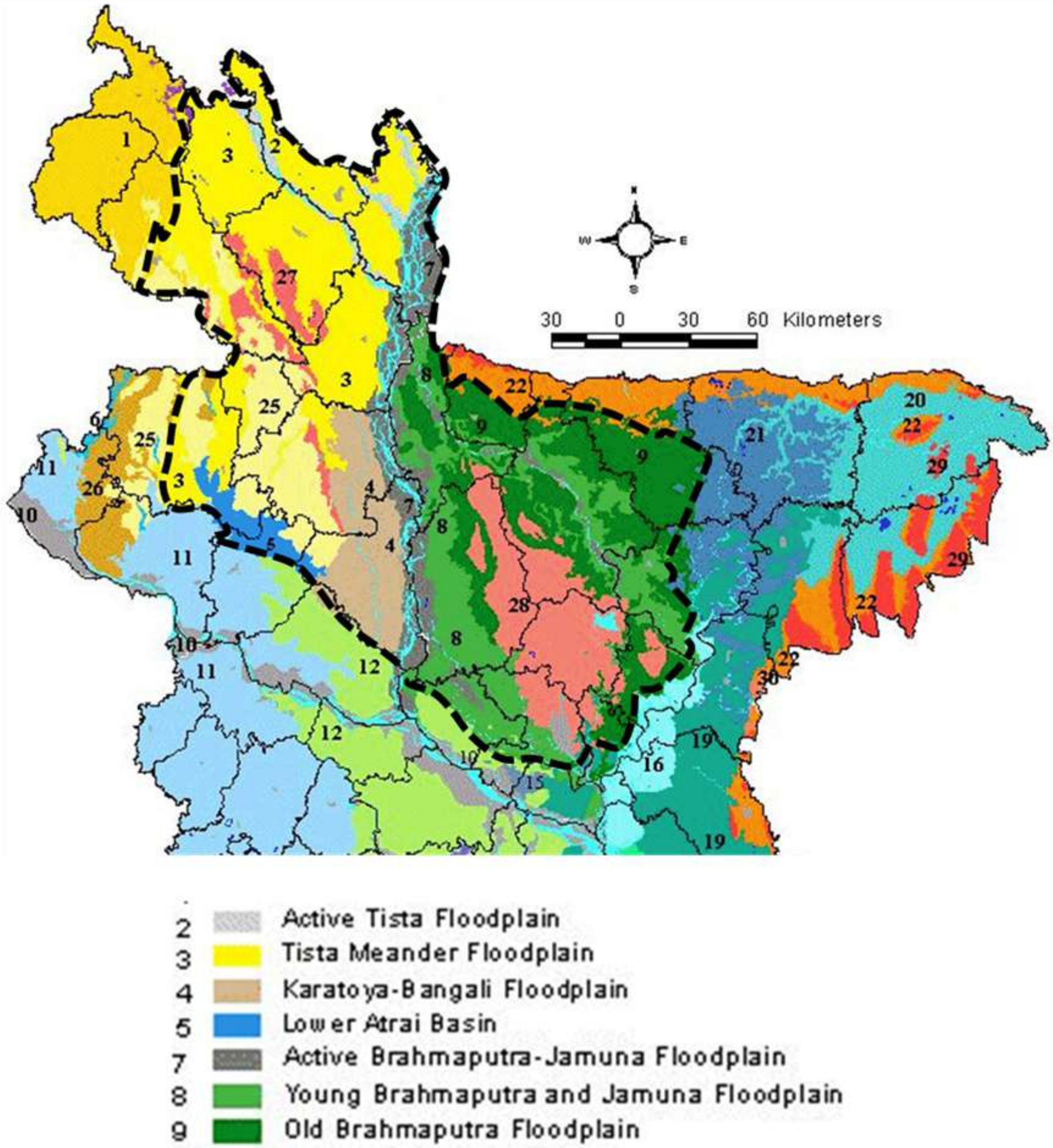


Figure 4.3 Agro-ecological zones in Brahmaputra-Jamuna basin

Source: SaciWATERs

levels, but they are submerged for one to two weeks in years with exceptionally high floods. The middle and lower parts of ridges are mainly subject to shallow flooding, whereas basins are subject to moderate to deep flooding.

The Old Brahmaputra floodplain occupies a large area of Brahmaputra sediments before the river shifted to its present Jamuna channel about 200 years ago. It has an irregular relief of broad and narrow ridges and depressions interrupted by cut-off channels and active channels. Seasonal flooding is shallow on ridges and moderately deep or deep in depressions.

The active Teesta floodplain includes the active floodplains of the Teesta, Dharla and Dhudhkumar rivers, characterized by complex patterns of low, generally smooth ridges, inter-ridge depressions, river channels, and cut-off channels. Most areas are shallowly flooded in the monsoon, with flooding being occasionally deep during flood peaks.

The Teesta meander floodplain occupies the major part of the Teesta floodplain as well as the floodplains of the Atrai, Little Jamuna, Karatoya, Dharla, and Dhudhkumar rivers. Most areas have broad floodplain ridges and almost level basins. The Karatoya-Bangali floodplain is very similar to the Teesta meander floodplain in physiography and soil. The alluvium apparently comprises a mixture of Teesta and Brahmaputra sediments. The lower Atrai basin comprises the low-lying areas between the Barind Tract and the Ganges river floodplain, including the Chalan Beel area. Smooth, low-lying basin land occupies most of the region.

4.3 Hydro-climatology

The basin has been shaped by, and is dependent upon, the Brahmaputra-Jamuna River and its tributaries and distributaries, which provide fertile soils and a diverse flora and aquaculture but also bring significant flood and erosion hazards and risks to the infrastructure for a large and growing population. The basin has always been subject to natural hazards due to climatic anomaly. The disasters are manifested as hydrological events caused by climatic extremes (Khan 2000). The basin's geographical location, high dependence on the overall GBM regional hydrology, and spatial and temporal distribution of water resources – all contribute to the high degree of susceptibility of the Brahmaputra-Jamuna river system to water-related extreme events (Ahmed et al. 1998a).

The entire basin of the Brahmaputra river system is characterized as having a Southeast Asian monsoon climatic regime, except for the areas around the source and the Tibetan plateau. While the upper catchment receives intense precipitation that ranges from 2250 mm to 5000 mm annually (Goswami 1985), the part of the catchment that lies within Bangladesh receives 1750 mm to 2250 mm of rainfall in the summer monsoon (Hossain 1987). Due to the geographical location at the bottom of the catchment of the GBM river systems, the Brahmaputra-Jamuna basin of Bangladesh enjoys a humid, warm, tropical climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations. Besides the monsoon, easterly trade winds are also active, providing warm and relatively drier circulation. The mean annual rainfall of the country is about 2300 mm, but there exists a wide spatial distribution. The average annual rainfall in the basin is much higher than rest of the country (MPO 1991). There is also a highly skewed temporal variation of rainfall, about 80 to 90 percent of the rainfall occurs during the Southwest Monsoon months from May to September.

As a result, unlike other deltas, the seasonal variation in river flow is highly skewed with abundant water during the monsoon and a small flow during the dry season (Chowdhury et al. 1997, Goswami 2008, Rahman & Salehin 2013).

At Bahadurabad on the Brahmaputra, the average annual maximum, mean, and minimum flows are about 66,000 m^3/s, 22,000 m^3/s and 4,000 m^3/s, respectively (Chowdhury et al. 1997). The peak flow at Bahadurabad, however, exceeded 1,00,000 m^3/s in 1998. The difference in water levels between flood and dry season is about 6.5 m at Bahadurabad, which gradually reduces in the downstream direction. The surface water slope of the Jamuna River reduces from 8.5 cm/km upstream to 6.5 cm/km downstream (Sarker et al. 2003). While the reduction of the dry season flow in the Ganges due to the Farakka diversion has caused salinity ingression in the southwest coastal region of the country, the dry season flow in the Brahmaputra plays a dominant role in pushing the salinity front towards the sea in the south-central coastal region.

Being the lowest riparian country, with extensive and very flat floodplain topography, Bangladesh bears the major brunt of floods. The rivers assume a minimum gradient owing to the flatness of the land surface and flood water spreads more evenly and accumulates on the plains. A relatively small increase in flood level results in inundation of a wide area in the floodplains (Rahman & Salehin 2013). Flood hydraulics in Bangladesh is dominated by the three major rivers: the Brahmaputra, the Ganges and the Meghna. These three rivers discharge about 1,42,000 m^3/s into the Bay of Bengal through a single outlet, the Lower Meghna, during high-flow periods (Rahman et al. 1990). The Brahmaputra and Ganges carry about 85% of the flood flow that enters Bangladesh. The Brahmaputra has the largest flood flow followed by the Ganges and the Meghna with a flow ratio of 4.4:2.5:1 (Rahman & Salehin 2013). As far as the area flooded is concerned, the flow in the Brahmaputra has the strongest correlation with the extent of flooding in Bangladesh (Rahman et al. 2005).

Like in upper catchments, 15 major flood events have been recorded from 1954 to date. The important elements that determine the extent of flooding are the magnitude, synchronization of peaks, and duration of floods in the major rivers. The first two elements are directly related to the amount of rainfall in the upstream catchments, while the last element is related, in addition, to the downstream control provided by the coast in the form of the spring tide and the monsoon wind set-up in the Bay of Bengal (Salehin et al. 2007, Rahman & Salehin 2013). Synchronization of flood peaks in the three major rivers has been a common feature associated with the big floods, like those of 1988, 1998 and 2004.

While there are considerable damages to crops and infrastructure, and hence to the socio-economy, in many places of the floodplains, floodplains offer a number of important hydrologic functions. These include moderating the flood flow by acting as a storage during the monsoon, augmenting the post-monsoon river flow (in late October and November) by gradually releasing water from storage during the recession phase of floods, and being a useful source of recharge to groundwater in the shallow unconfined aquifer (Chowdhury et al. 1997, Rahman & Salehin 2013). Bangladesh's rural economy relies upon annual 'normal' floods to bring moisture and fresh sediments to the floodplain soils (Paul 1997). These help cultivation of two of the three seasonal rice varieties (aus and aman) and create favourable conditions for huge fisheries resources in the floodplains and beels (Paul 1997, de Graff 2003, Shankar et al. 2004).

4.4 Hydro-Morphodynamics

As observed by Best et al. (2007), there are variations in estimates of contribution of the water discharge and the sediment yield by the Brahmaputra-Jamuna River to the Padma. E.g. 51% of the water discharge and 38% of the sediment yield estimated by Schumm and Winkley (1994), 66% of the water discharge and 65% of the sediment yield estimated by FAP24 (1996a).

Nevertheless, the Brahmaputra-Jamuna River contributes the higher portion of discharge and sediment load to the Padma River. Sarker's study (1996) presents the annual average sediment load of the Brahmaputra-Jamuna River at 590 Mt per year, with the sand fraction contributing 34% of the total load.

River morphology is the result of mutual interactions of fluid dynamics (velocity, discharge, roughness, etc.), channel configuration (width, depth, slope, pattern, etc.), sediment load, and bed and bank materials (Zhang et al. 2011). The causes of morphological changes of the rivers include rate of supply of water and sediments, water level variations, (near bank) flow velocities, plan form of the river, etc. (Sarker et al. 2003). While in a meandering river bank erosion occurs along the outer bends and accretion occurs at inner bends, in a braided river bank erosion may not be always associated with accretion, and erosion and accretion might occur simultaneously at both its banks.

The process of bank erosion and overbank river flow, the most critical attributes of the hydrological aspects of the basin, get further accentuated during the flooding events. During floods, the concentration of suspended sediment is high and large volumes of sediment are carried through overspill channels and in overbank flow. A percentage of this sediment is deposited and so siltation takes place recurrently on the floodplain. This drives the development of characteristic types of landforms on the floodplains through lateral and vertical accretion. The river is braided with meta-stable island (locally known as chars) and nodal reaches, natural levees, crevasse channels and splays, active and abandoned floodplain channels, alluvial ridges, flood basins, back swamps or marshes, ox-bow lakes (beels) and clay plugs, mobile sandbars, shifting anabranches, and has severe bank erosion (Thorne et al. 1993, Islam 2011).

Following the seminal work done by Coleman (1969), there have been many studies of the geometry, flow, and sedimentary processes, and patterns of erosion and deposition of the sandy Brahmaputra-Jamuna River (Williams & Rust 1969, Rust 1972, Smith 1974, Ashmore 1982,1991, Ferguson & Werritty 1983, Goswami, 1985, Davoren & Mosely, 1986, Bristow 1987, 1993, Bristow et al., 1993, Thorne et al., 1993, Haggart et al. 1994, Thorne & Thiagarajah 1994, Mosselman et al., 1995, FAP24 1996a-h, Richardson et al. 1996, Best & Ashworth 1997, Paul 1997, Richardson & Thorne 1998, McLelland et al. 1999, Ashworth et al., 2000, Best 2003, 2007, Zheng et al. 2011). The focus of many of such studies has been on braided bar (char) and in-channel deposition rather than sediment dynamics in the floodplain proper.

Examples of studies that looked specifically into floodplain sedimentation include those by ISPAN (1995), Allison et al. (1998), and Islam et al. (1999). Best et al. (2007), upon reviewing a vast literature on the Brahmaputra, inferred that significant research has been conducted on rivers, including the Brahmaputra, especially in the last 15 years as part of the Bangladesh Flood Action Plan (e.g. Haggart et al. 1994, Thorne & Thiagarajah, 1994, FAP24, 1996a–h, Paul 1997). This has allowed a dramatic increase in the knowledge of the behaviour of the Jamuna River, and major advances in monitoring techniques have resulted in the river being characterized in more detail than ever before (Takagi et al. 2007).

Reasonable success has been achieved in predicting morphological change (EGIS 2002, CEGIS 2003, Mosselman 2006). Together with numerical modelling (Jagers 2003), these offer some hope both to understand and predict river channel movement.

The Brahmaputra-Jamuna River in Bangladesh is braided in plan form, with some anastomosed regions (Sarker & Thorne 2006). Its braiding intensity (the ratio of the total length of the channels in a reach and the corresponding valley length) is about 4 to 5, with an average braid plain width of 11 km. At the beginning of the 19th century, the plan form of the Jamuna River was essentially that of a meandering river, which gradually transformed into a braiding plan form (Sarker et al. 2003). Plan form analysis of the Jamuna using time-series satellite images showed that the braiding intensity of the Jamuna River has been changing spatially and temporally (EGIS 1997, 2000), and the intensity also reduces downstream (Sarker et al. 2003). Changes in the braiding intensity of the Jamuna River were also noted by Klaassen & Vermeer (1988). Sarker & Thorne (2006) have related these changes in plan form parameters, including the braiding intensity in the Jamuna, Padma and Lower Meghna Rivers, to the propagation of a sediment pulse generated from the 1950 Assam earthquake.

Braid-belt widening of the Brahmaputra-Jamuna has gone on since the early twentieth century. The FAP24 (1996a) study estimated an average widening of 50 m/year over 1834–1992. There have been significant fluctuations in the average rate up to 170 m/year, with local erosion rates reaching up to 1 km/year (FAP24 1996a, Khan & Islam 2003). The average rate of widening has decreased more recently (from 150 m/year between 1973 and 1992 to 30 m/year between 1992 and 2000, (EGIS 1997, Sarker & Thorne 2006).

Migration of the Jamuna braid-belt has been predominantly westward, which is likely to have been a product of braid-plain widening as the channel adapts to its new post-avulsion course, and/or a response to underlying tectonic control (Thorne et al. 1993, Sarker 1996, Best et al. 2007). Time series data of dry season satellite imageries, historical documents, and aerial photographs reported westward migration of about 4.3 km since 1983 (CEGIS 2004, 2005, 2006 and 2007). There was, however, a persistent high outward migration rate of both banks over a relatively short time period from 1973-1992, which is believed to have been related to the very high widening phase of the river (Best et al. 2007).

In the last three decades, the Jamuna River has eroded about 82,000 hectares of floodplain, whereas only 12,000 hectares of floodplain have been created through accretion. This net erosion has caused 0.7 million people to become homeless and landless (Sarker et al. 2003).

The islands and accreted lands on the bank are generally known as char. The island chars can only be reached by crossing a channel of the main river, even in the dry season. The attached char is accessible from the mainland without crossing a channel during the dry season, but is inundated or surrounded by water during the flood season. The whole of the braided channel, including subsidiary channels and chars is called the active river floodplain (Brammer 1996). The subsidiary channels have meandering courses which continuously erode their banks and islands, and deposit new materials on existing islands, on other banks to form a point bar or within the channel to form a new island.

The mainland is also eroded and accreted, causing a shift in the main bank of the river. The chars are poorly connected to the mainland and are prone to acute erosion and flooding, which makes the inhabitants feel vulnerable. Historical satellite image analysis has revealed that over 99% of the area within the riverbanks of the Jamuna had been a char at one time or the other in the period from 1973 to 2000. About 75% of the chars persisted between one and nine years, while only about 10% lasted for 18 years or more (Sarker et al. 2003).

4.5 Basin Ecology

The highly variable and dynamic channel processes that changes the shape, size and position of the Brahmaputra-Jamuna River continuously impact the adjacent floodplain areas that constitute about 80% of the total land area of the country and play a vital role in supporting wetland ecosystems (Junk et al. 1989, Goodbred & Kuehl 1998, Paul 1997). The flood plain of this river is the most productive region supporting the life and livelihood of a vast population.

Unlike the floods in the upper and middle reaches of the Brahmaputra basin in India, which are most of the time devastating in nature, floods in Bangladesh many a times are considered highly productive. In fact, the efficiency of diverse wildlife habitats, fisheries, fields, and forests on the floodplain depend critically on the annual flood cycle, with respect to its extent, duration, and association with sedimentation. So, floodplain sedimentation is considered the principal driver of change in the floodplain environment, which is responsible for the existence, productivity, and interaction of the major biota in river-floodplain systems (Junk et al. 1989). Millions of people in Bangladesh rely on the floodplain, and rural economies depend totally on regular monsoonal floods. These floods are regarded as 'normal' and bring potential moisture and fresh sediments to the floodplain to make the land fertile and increase agricultural productivity (Elahi & Rogge 1990, Paul 1997). Floodwater creates favourable conditions for two of the three seasonal rice varieties (aus and aman) and the fish caught both on the floodplain during the flood season and from the many floodplain ponds ('beels') is the main source of protein for many rural people (Chowdhury 1994, Paul 1997, de Graff 2003, Shankar et al. 2004).

Inland fisheries production in Bangladesh is strongly related to the flood sequence. Floodplains inundated during monsoons are nutrient-rich and play a significant role as nurseries for many larvae and juvenile fish species (Welcomme 1985, Bayley 1988, Junk et al. 1989). Further, the growth has been found to vary significantly between years and has been correlated with flooding intensity and duration (Welcomme 1985, Halls 1998, Halls et al. 1999) and hence the formulation of the flood-pulse concept by Junk et al. (1989). The major carp in Bangladesh comprise three stocks, namely that of the Brahmaputra, the Padma, and the Upper Meghna. The first stock is the largest, with spawning grounds located in the southern tributaries of the river in the Assam Hills and the Letha Range, Assam. Adult major carp starts to migrate upstream in the Brahmaputra system in March, coinciding with the gradual rise of the water level. Spawning on the floodplains, on the other hand, begins in May with the onset of southwest monsoon and continues until the end of July (Tsai & Ali 1985, de Graaf et al. 1999). Flood control projects have been one of the main reasons of reduction of floodplain fisheries in Bangladesh, including those in the Brahmaputra-Jamuna floodplains (Sultana & Thompson 1997, Halls et al. 1998, 1999, Siddiqui 1990, ESCAP 2000).

4.6 Socio-economic Situation

The effects of morphological change in the Brahmaputra-Jamuna basin are not limited to the physical environment alone (Hassan et al. 1999). About one million people reside on the islands, attached chars, and mainland along the Brahmaputra-Jamuna River. Their existence is made precarious by erosion that can destroy land and homesteads, by rapid sedimentation that can render land unproductive, or by floods that can destroy home and livestock as well. Each year, a large percentage of chars get flooded. Floods, if they come early, can damage the crops. People in chars build their homesteads on the highest available land and, if they stay there for any length of time, they further elevate their homesteads on built-up plinths to avoid annual inundation. The island chars are found to be flooded more extensively than the attached chars.

In a floodplain, land use practices depend mainly on the depth of flooding due to population pressure, crop variety and intensity. Agricultural productivity, the choice of crops grown, and the cropping pattern in the basin are also largely determined by hydrologic conditions (MPO 1987). Most important of these are flood depth, timing and duration of flooding, rainfall pattern, and the availability of dry season drainage and irrigation. Anywhere from one to three crops a year are grown in the floodplain of the Brahmaputra-Jamuna basin. The old, active and young Jamuna floodplains are predominantly known for subsistence rice farming. About 80% of the available land is used for cultivation with the remaining 20% used for settlements, haats (markets), public buildings, and communications infrastructure. Settlements and infrastructures are mainly located in areas that are, in most years, flood-free.

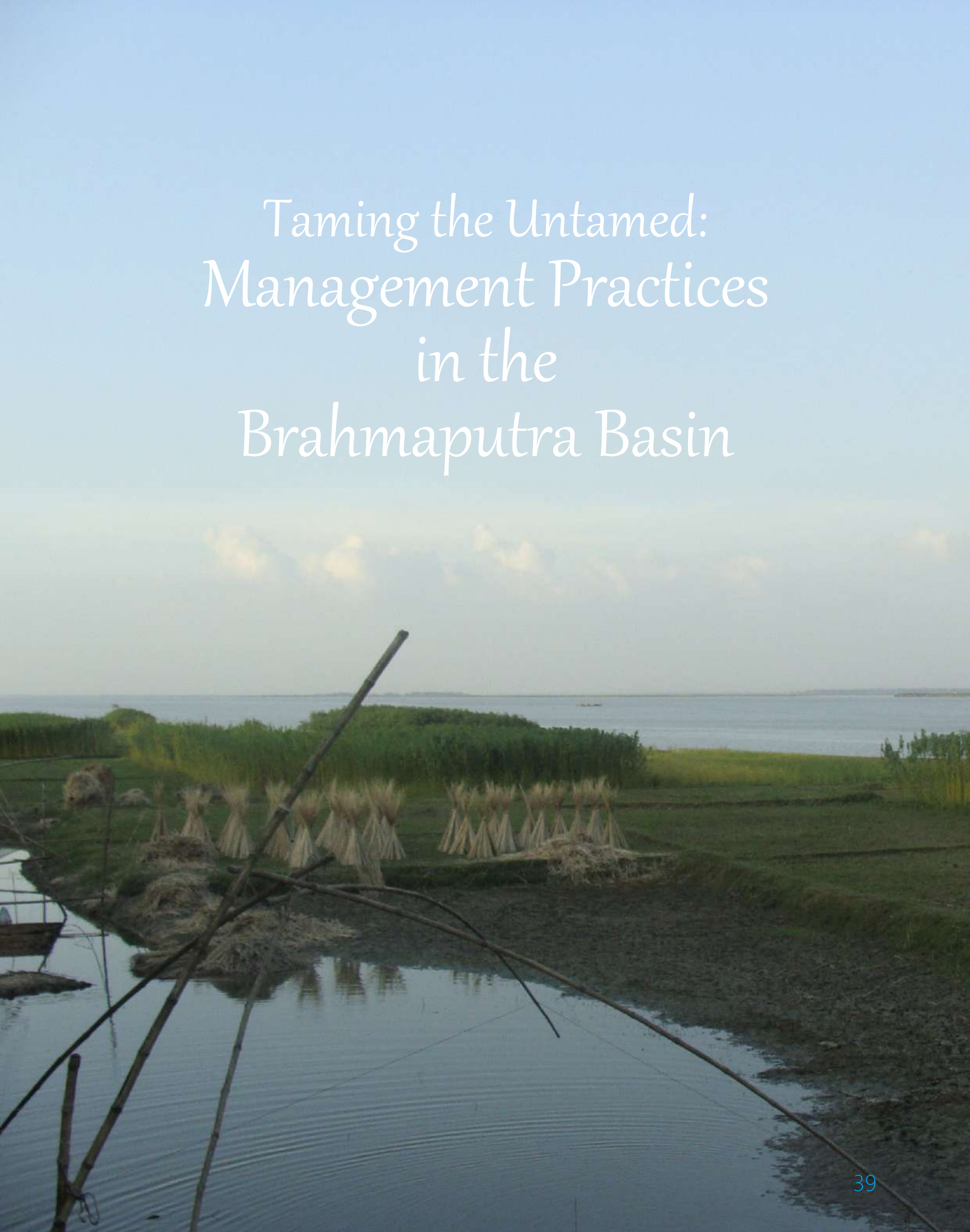
Chars in Bangladesh form an extremely dynamic environment for around 600,000 people, who try to make a living under extreme and hazardous conditions of frequent and intensive flooding and erosion (Sarker at al. 2003).

The riverine chars offer, on a continuous basis, significant areas of new land for settlement and cultivation. The high demographic pressure in the country forces people to establish their settlements on chars, although the harsh livelihood conditions therein makes them less attractive for living than the mainland.

Almost 4.3 million people (about 4% of the then total population) lived in the active floodplain in 1992-1993, and 22% of them lived on island chars, mostly concentrated in the Jamuna and Meghna (Sarker et al. 2003). An assessment of a 1992 dry season Landsat image showed that the Jamuna contained a total of 56 large chars, each longer than 3.5 km. There were an additional number of 226 small chars, varying in length between 0.35 and 3.5 km, including sandy areas as well as vegetated chars.

The lands in chars are quite fertile since the downstream part of the Brahmaputra River experiences deposits of finer sediment (silt), and this has historically attracted many to exploit the agricultural productivity of many of the chars. Wide expanses of grazing land constitute another economic resource in the chars of the Upper Jamuna, as it has encouraged cattle raizing in many chars, more prominently in those that are less vulnerable to frequent flooding (Sarker et al. 2003). Catkin grass in newly accreted lands accelerates silt deposition on chars and enhances its conversion to agricultural land. Catkin grass is popularly used as housing materials, fuel and fodder. Although the relatively new chars have very few trees, some older ones have a variety of fruit and timber trees, which provide food and cash as well as privacy for the homestead, and act as protection against wind. The people living in the chars enjoy the advantage of being close to fisheries resources. Obviously, the extent of fishing depends on whether the area is close to major fish habitats.

Taming the Untamed: Management Practices in the Brahmaputra Basin



5

Taming the Untamed: Management Practices in the Brahmaputra Basin

5.1 Introduction

The Brahmaputra basin is beset with a multitude of conflicting issues. With a large population dependent on agriculture and natural resources for their livelihood, there is a great need to conserve and co-manage its resources in a sustainable manner. Guided by traditional engineering, quite a large number of structural interventions are being made or planned in the basin.

The reductionist, traditional approach to river engineering, as initiated by the British, continued to guide interventions in the post-colonial era. It provided limited space for the expression of legitimate civil-society voices and stakeholder interests. Without addressing the complex and largely unexplored relationship between water and economic development, these initiatives remained cursory, thereby creating water related political tensions in the basin (Verghese 1990; Ahmad et al. 2001). Broader stakeholder perspectives through an effective combination of cooperative non-structural (like sharing or exchange of information) and structural (such as dams or reservoirs at 'suitable' locations) measures are considered vital to the sustainable management of one of the world's most resource-rich but impoverished basins.

5.2 Structural Measures for Effective Basin Management

5.2.1 Flood control measures

Dikes and embankments are important structural measures adopted by the Government of India towards effective flood control in the Brahmaputra basin. According to Tiwari (2004), of a total of 15,675 kilometres of embankments along various rivers in India, nearly 5,027 kilometeres are on the Brahmaputra and its tributaries alone. According to one estimate, some 14 lakh hectares (nearly half of the flood-prone area in the Brahmaputra valley) have been protected as a result of the embankments (Bhave et al. 2012).

Although these embankments did serve their purpose and protect the area reasonably well till the 1990s, they failed to stand the test of time as a sustainable long term solution for the basin. Critics pointed out that with the construction of around 5,027 kilometres of embankments on the Brahmaputra and its tributaries in the past 50 years, a large amount of sediment got confined between the embankments on both sides of the river system. The silt had led to rise in the riverbed resulting in breaching of the embankments and severe flooding. Due to floods, heavy deposits of sediments on cropland are now turning land useless for cultivation.

The Ministry of Home Affairs realized that structural interventions will need to be evaluated in terms of technical, social, and environmental considerations. These would refer to seismic activity, submergence, population displacement, impact on land and ecosystem, physical impact downstream, and the equity issue in sharing costs and benefits.

So, in collaboration with UNDP, they introduced initiatives aimed at building community-level awareness and strengthening its capacity to address disaster risks. Also, a high-level National Disaster Management Authority was set up in India to coordinate actions by all concerned agencies with respect to warnings, evacuation measures, and disaster management.

The Government of Bangladesh's 'Water and Flood Management Strategy', an integrated approach, is based on the concept of 'controlled flooding', where emphasis has been given to the implementation of large-scale water control projects. During the 1980s, about 1,963 kilometres of embankments, 8000 hydraulic structures, and 1000 river closures were put in place (Hughes et al. 1994; WSIP 2000). The National Water Management Plan and the National Water Policy of 2000 gave new vigour to the overall water-resource management strategies of the country through the institutional strengthening of the Water Resource Planning Organization and the revival of the dormant National Water Resources Council.

5.2.2 Hydropower

Long-term energy security is at the heart of the Brahmaputra basin development considering its huge, untapped hydropower potential. Run of the river dams and multipurpose reservoirs thus remained critical structural measures in the development and management of the Brahmaputra basin in India. The idea is to use these storage reservoirs to generate energy, mitigate floods, augment dry season irrigation potential, and facilitate the possibility of river navigation. The Union Power Ministry identified 220 potential sites (2001) for large muti-purpose dams on the Brahmaputra and its tributaries. The Government of India set up the Brahmaputra Board to take care of various tasks. In 2003, the Government of India launched the 50,000 MW national hydro-electric initiative, identifying 42 projects with an installed capacity of 27,293 MW in Arunachal alone. The Cabinet Committee on Economic Affairs approved the Rs 6,285-crore Lower Subansiri hydro-electric project in Arunachal Pradesh. The Subansiri and Dehang hydel power projects in Assam are other significant projects proposed in the Brahmaputra valley. Between February 2006 and October 2010, Arunachal allotted 132 projects -38 of these are above 100 MW- of a combined installed capacity of 40,140.5 MW. Around 120 of these projects involved private companies. Since then, at least another 15 MoUs have been signed. Till December 2012, 17 of these projects had been given environmental clearance while another 70 got Terms of Reference or Stage I clearance. The combined generation capacity of these projects is nearly 40,000 MW.

Such a desperate rush has triggered angry protests in Assam where people fear drastic flow fluctuation between trickling rivers and floods will threaten their livelihood and lives.

In the sparsely populated, fragile mountains of Arunachal, the tribes fear that so many dams will further unsettle this high-seismic zone and the influx of lakhs of construction workers will destroy their cultural identity.

Environmentalists, on their part, have raised serious doubts over the viability and sustainability of these projects and their environmental impact in the region. According to one assessment, such projects would either submerge or lead to the destruction of about 28,000 hectares of rich forestland. For instance, the entire area of Subansiri, that would be submerged, covers the forests areas of Kakoi, Dilung and the Subansiri Reserve area in Assam as well as the Tale Valley Sanctuary, and Tale and Panir Reserve forests of Arunachal Pradesh (Tiwari 2004).

There are also controversies over issues like the inappropriate assessment of environmental and social effects, and lack of transparency and public participation in the decision-making processes, displacement of local communities, and loss of their lands and livelihoods. In many places, local people are already demanding a review of all projects for a fresh cost-benefit analysis and, in some cases, demanding decommissioning of projects.

5.2.3 Agriculture

With the basin comprising 8% of India's total geographical area, agricultural growth has been uneven. Production from this area contributes only 1.5 per cent of the nation's food grains. Though agriculture, horticulture, animal husbandry and fisheries are the major livelihood options, the low levels of productivity have not been successfully addressed by government policies and programmes.

The basin has not benefited from the 'Green Revolution' that has seen other states increase their food grain production by leaps and bounds. Poor market links have compounded the existing constraints of logistics, preservation and distribution of perishable produce. This makes it imperative to promote investments in food processing industries, marketing, storage facilities, and improved technologies and seeds within the region. This is with the realisation that, to achieve the economic potential of the region, it is imperative to utilise the demographic advantages and parameters leading to market-linked skill development and livelihood options in the future.

Policymakers are now also creating a framework investment and inviting private investors to set up higher education facilities. This would be filling a glaring shortage that caused students in the region to migrate to other parts of the country in the past (ICC 2012). An Indian Chamber of Commerce (ICC) study on the development and employment generation potential of the North-East has estimated that between 2011 and 2021, the region will offer over 2 million jobs. Half of these jobs will be located in Assam alone. Job seekers emerging in this period are estimated at 17 million. This will result in an excess of 15 million job seekers.

So it is essential to channel available manpower by developing skills for local employment but also for those who seek to migrate.

The Government of India's investment in region-specific research through agricultural universities on improved cropping and productivity, and establishment of institutes to impart training on the use of innovative technologies and food processing units testifies to a paradigm shift in management strategies for the basin.

It is further expressed with the preparation of a white paper called 'Vision 2020' by The North-Eastern Council and the Ministry of Development of the North-Eastern Region focusing on building capacities and competencies in critical sectors in the basin, working with existing institutions and organizations to impart training and build capacities, and setting up new institutions where the need is felt.

Water-sector development in the Brahmaputra basin in Bangladesh has been exclusively aimed at increasing agricultural production to achieve national self-sufficiency. This resulted in solutions tending to focus on irrigation projects. In 1992, the National Minor Irrigation Development Project (NMIDP) was launched by the Ministry of Agriculture. Its principal objective was to consolidate the transition of minor irrigation from a supply-driven public sector to a demand-driven private sector. It has been successful in identifying affordable options. There has been widespread growth of minor irrigation in Bangladesh thanks to privatization and technology developments as well as by reducing government taxes on equipment. But this has been captured by big and middle-level farmers who are able to take the risk and have the resources to invest.

5.2.4 Climate Change

Climate change effects are already visible in the Brahmaputra basin, on both the Indian and Bangladesh sides, with temperature increases and increase in the frequency of extreme events such as floods and cyclones. The United Nations Framework Convention on Climate Change (UNFCCC) made it mandatory for all Least Developed Countries (LDCs) to identify their 'urgent and immediate' adaptation needs, giving prominence to participatory approaches and community-level inputs. This provided an enabling environment to formulate several climate adaptation programmes in the Brahmaputra basin in India.

Climate-change adaptation programmes in India are being implemented in a target-oriented manner, such as the North East Climate Change Adaptation Programme by the Ministry of Development of the North-Eastern Region and the Governments of Assam, Nagaland, Meghalaya and Sikkim. The State

Action Plan on Climate Change, an initiative by the Ministry of Environment and Forests, is another important programme to tackle increasing climatic variability in the basin.

Adaptation programmes in the Brahmaputra basin of Bangladesh started with participatory National Adaptation Programmes of Action.

The participatory approach that went into the preparation of such a plan brought in contributions from policymakers, local government representatives, academicians, lawyers, doctors, ethnic groups, the media, non-governmental organizations (NGOs) and community representatives, and women. The government established an inter-ministerial committee on climate change headed by the Minister for Environment and Forest. It has representation from relevant government ministries and departments as well as key NGOs and research institutions.

The Department of Environment under the Ministry of Environment and Forest has set up a Climate Change Cell to act as Secretariat for climate-change related work within the government.

There is also a National Environment Committee to determine environmental policies. It is chaired by the Prime Minister and contains Members of Parliament as well representatives from government institutes and civil society. It has been observed that the institutional capacity, including human resource quality, in most such organizations is weak. It needs substantial improvement if the challenges of climate change are to be faced adequately (NAPA 2005).

5.3 Non-Structural Measures for Effective Basin Management

It is increasingly recognized that skills other than technical engineering expertise are required to facilitate and enable the transboundary water negotiation process. Diplomatic and negotiation skills are needed together with an understanding of the technicalities. The official discussion on water management of the Brahmaputra basin between Bangladesh and India on tract I diplomatic mode was initiated with the Joint River Commission that came into being in 1972. Under the Indo-Bangladeshi Treaty of Friendship, Cooperation and Peace, the two nations established the commission to work for the common interests and sharing of water resources, irrigation, floods, and cyclones control. The studies and reports of the commission contributed directly to the efforts of both nations to resolve the dispute over the sharing of the Ganges-Brahmaputra river waters, facilitating bilateral agreements in 1975, 1978 and finally in 1996. The countries exchanged official proposals in 1978 for augmenting the dry season flow of the Ganges. These were subsequently updated in 1983 with no major change.

In 1983, they reached an agreement on ad-hoc sharing of the Teesta waters, one of the important tributaries of the Brahmaputra. Accordingly, 36% of the water was allocated to Bangladesh, 39% to India. The agreement was extended up to 31 December 1987, though never implemented nor extended further. Till today, the sharing of the Teesta water is a source of tension between Bangladesh and India, also because of unilateral actions. For instance, both constructed two barrages along the river (Rahaman & Varis 2009). Also, 4 hydropower projects on the river are under construction in India. These projects are going ahead without any formal agreement with its lower riparian Bangladesh, so they have a potential of conflict (Rahaman & Varis 2009).

After the disastrous floods in Bangladesh in 1988, the Indian Government showed interest in regional co-operation for flood mitigation in both the countries through a joint action plan. Through bilateral cooperation, Bangladesh receives water level and rainfall data from a number of stations (Ahmad & Ahmed 2003).

Such tract-I and tract-II diplomatic efforts have been pursued so far between the two co-riparian countries. Although they did provide some opportunities for an effective and sustainable management of the Brahmaputra basin, there is still significant scope for the strengthening of the existing cooperation and extending it further in a regional perspective. In view of the growing complexities of water sharing issues and the highly politicized nature of discussions between the co-riparian countries, it seems that a Track-III diplomacy approach is warranted.

Here, dialogue and advocacy efforts will be led by civil society organizations, with the aim to stimulate progress at more formal levels (Track I and Track II). The Track-III approach will result in an open environment that enables listening to each other and understanding each other's viewpoints, not hampered by political or other power-oriented positions.

Conclusion and Policy Implications

6

Conclusion and Policy Implications

6.1 Conclusion

The Brahmaputra River basin presents a picture of an economically prized, politically charged, and environmentally dynamic fluvial system. Spanning over vast expanses of diverse topographical and climatic regimes, the basin is often perceived as an important engine of regional economic development, a crucial base of livelihood resources, and a site of biodiversity conservation. Although there is huge potential, water resource development within the basin has remained particularly challenging. Structural measures in the form of embankments, run of the river dams, or multipurpose reservoirs, constructed so far, have proved to be inadequate to manage the water resources of the co-riparian countries effectively. Some non-structural measures like flood forecasting and data sharing are in place between China-India and India-Bangladesh, but they are far from satisfactory to usher in a holistic development of the basin.

Critics pointed to the unique physical features, combined with a lack of cooperation as well as political tensions and armed conflicts across the riparian countries, as major factors hampering regional development. Efforts to resolve these conflicts have largely remained bilateral with the power hegemony being determined by positional considerations. In this context, India and China, considered strong riparian countries, have always dictated terms and conditions on water-sharing strategies and policies. The geographical position of China in the upstream has made it a major stakeholder, thereby preventing an effective power balance in the hydro-politics of the basin. Bangladesh as the lower-most riparian state has always remained dependent on the benevolence of the upstream countries. Inter-country cooperation is further impeded by the conflicting interests of the different political parties and interest groups within each of the riparian countries.

As a long-term strategy for resource utilization and hazard management, a judicious mix of structural and non-structural measures with a greater emphasis on the latter should form the core of a regional plan. State-centric, technocratic policy practices should give way to create space for a more holistic and inclusionary approach. Such approaches have to be mindful of a potential resistance to reform within national institutions and the private sector, and be able to mobilize political, legal, and knowledge tools for change effectively. More importantly, resource planning needs a type of assessment that is transparent, can effectively engage the community, reduce vulnerability, empower local populations, ensure food, health and ecological security, and strengthen existing institutions.

6.2 Policy Implications

- The basin's huge hydropower potential (around 206,000 MW) could be developed and utilized by coordinated efforts among India, China and Bhutan to meet the growing energy demands of Bangladesh, north-eastern India, and China. Water regulation upstream by coordinating plans between China, India and Bangladesh would reduce the threat of flooding in the monsoon. It would also provide irrigation water during the non-monsoon period in downstream

India and Bangladesh. Coordinating would ensure that the existing and future plans of India and China supplement each other. E.g., after meeting the water requirements of India and Bangladesh, excess water from the Brahmaputra basin might be diverted to other water-short regions in India, China and Bangladesh through mutual cooperation agreements.

- Sharing hydro-meteorological, physical, and environmental data among riparian countries is very important. Although China controls over 50% of the Brahmaputra basin, studies have left out in-depth discussion of the concerned development plans in China due to lack of data and information. This is true for India as well where key data regarding the Brahmaputra and Ganges basin water resources are classified.

- An integrated basin-wide approach, including the concerns of upstream and downstream, is seen as an opportunity to improve water quality, sustain biodiversity, maintain river flow characteristics, sediment management, and salinity control, increase fisheries, and reduce industrial pollution of the river. There is an urgent research need to adopt an eco-hydrological approach integrating physical, social and ecological aspects of the Brahmaputra basin. Research should emphasize river ecology, biota, and livelihood sustenance of the marginalized who are depending intricately on this basin. Indicator species like dolphin and hilsa need to be selected to understand the ecological health of the river as well as the lives of the people depending on it.

- For the Brahmaputra River, both water quantity in terms of flow and sediment transport and quality in terms of nutrient transport are important. Compared to the Ganges River, there is a great dearth of data on the Brahmaputra. This is with respect to flow, sediment transport and budget, nutrient transport, and river ecology, with country level researchers knowing very little about the river reaches in another country. As a result, it has been difficult to prove or disprove many of the assumptions. This warrants joint research to have a common understanding of the biophysical processes.

- A joint dialogue on transboundary river management is one of the best practices to bring together diverse stakeholders into one single platform. Such a dialogue must continue and should not be a one-off initiative.

  Co-management practices can yield significant results if the dialogue is multilateral in nature as well. In the case of the Brahmaputra, utmost emphasis should be given to both inter-state and inter-country dialogue, facilitating horizontal and vertical interaction within and between riparian countries. The involvement of Bhutan and China in this kind of joint dialogue is extremely vital. This could be achieved through the continuous sharing of declarations from dialogue meetings and leveraging the benefits of Information Technology (e.g., getting mass media and social networks involved).

- Most of the dialogues on joint management of the Brahmaputra basin are through track-III diplomacy. Lifting the status of the joint dialogue from track III to track II or even track I-I/II, and bringing government representatives into the fold will be a significant step in multilateral advocacy. Because of so much diversity in people's views both within and across the basin countries, moving to an integrated co-management of the Brahmaputra River will take time. Here lies the importance of dialogue meetings: dialogues should lead to consultation and then move to an integrated co-basin management ultimately.

- In-depth research on policy implications is necessary as much as review of the work of regional economic forums like Bangladesh–China–India–Myanmar Forum for Regional Cooperation (BCIM), the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), and SAARC (working on regional cooperation across South and South-East Asia). Efforts must be put in to bring water onto the main agenda of these forums.

- More systematic, structured and innovative ideas require involving bureaucrats and politicians in the dialogue and consultation process. As a first step, workshop proceedings and reports can be translated into key summary notes, to be shared with policymakers. Summary notes should also be shared with sub-regional (multi-country) groups that have been working on different sectoral issues including water and energy.

- There should be a knowledge management hub and data sharing portal (like the Wikipedia / Brahmaputra portal) that can be shared by co-riparian countries and can be accessed by public and researchers alike. Efforts should be made to use social, electronic and print media to campaign multilateralism. Youth should be actively involved to undertake a sustained campaign in effective river management.

- Based on what is already scientifically known about the Brahmaputra river, a "Brahmaputra protocol: do's and don'ts" should be developed, focusing on different sectoral issues in a holistic way.

- Disaster management (flood and bank erosion) of the Brahmaputra basin is a critical area that needs urgent attention and mutual cooperation from the co-riparian countries. Such cooperation can go beyond political considerations.

- Research and dialogue initiatives in the co-management of the river should be gender-sensitive. It is imperative to integrate the perspective of female professionals, bureaucrats, media personnel, academicians, community representatives, etc., while designing a sharing mechanism.

All interventions should be based on requirements of society, and for the ecology and economy of the region. They must be initiated on a modest scale, with the least possible impact on the environment and society living in the downstream. Adoption of judicious mitigation measures arrived upon through dialogue and discussion is a must. Since this is an international river of immense size with a huge resource base and high hazard potential, only effective cooperation and coordination among the basin countries together with persistent efforts at national and regional levels will be able to create an effective response mechanism to the problems of flood and erosion, and usher in an era of progress and prosperity to the region.

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