State of India's Rivers

for

India Rivers Week, 2016

BRAHMAPUTRA

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Contents

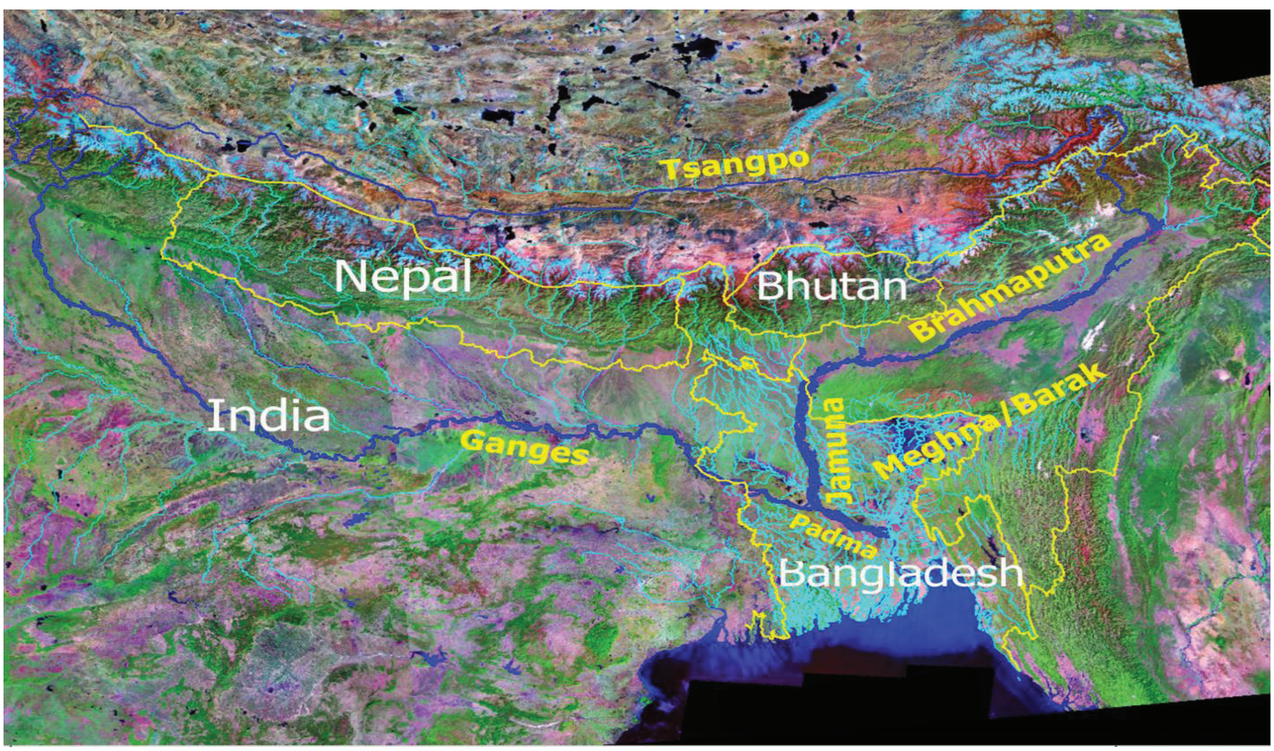
Maps

Tables

Figures

1. Introduction

The profusion of rivers in the northeast India is simply unparalleled (Fig 1). There two major rivers Brahmaputra and Barak have been joined by tributaries in abundance – small and big, the bigger tributaries often surpassing some prime main stem rivers of other states of the country. On the northern side, the great river Brahmaputra, and on the southern side, the Barak River flow across the state of Assam. Both the rivers have been separated by the *Borail* range. Rather ironically, they are well known primarily due to causing havoc through natural disaster like flood and river bank erosion every year. Plentiful tributaries of both the rivers originate from the hills, which are often outside the boundary of the host state. Interestingly, both Brahmaputra and Barak, after flowing through the length of the state, merges with other rivers at Bangladesh, to finally fall into the Bay of Bengal. On the other hands, both the rivers, notwithstanding their accompanying hydro disasters in the corresponding Brahmaputra valley and the Barak valley (also known as Surma valley) during monsoon, makes the floodplains fertile by the endowment of fine nutrient laden silt load.



Map No 1: Rivers in North East India

In the midst of the wilderness of the watersheds and pristine nature over large parts of the catchments, several tributaries flowing through urban and industrial stretches turned into causes of concern due to growing pollution and degradation of water quality.

Northeast India with just five per cent of the country's area has thirty per cent of the national water resource potential. Per capita water availability is 16,589 cubic meters as compared to the national figure of 2,208 cubic meters (CPCB, 2010). The region though rich in natural resources, especially water resources, still endures a sense of isolation from the rest of India, fueled by challenges like ethnic strife, marginalities at political & social front, stagnating economic development and consequent escalation of percentages of people below the poverty line, geographical separation and locational disadvantage with armed insurgencies to act as a major blow.

The Brahmaputra valley is characterized by humid sub-tropical climate with four distinct climatic seasons, pre-monsoon, monsoon, post-monsoon and winter. The region is influenced by the southwest monsoon, which accounts for 90% of the annual precipitation in the range between 2500 and 3200 mm causing severe flooding during the rainy season. Average temperatures vary between 29 °C during summer (month of July–August) and 16 °C during winter (month of December–January) Mahanta et al, 2015). The climate in the Barak valley is warm, humid and tropical. There's definite rainfall pattern in the valley, with the rainfall zone having an east west spread. North western part of the valley bordering Meghalaya falls under high rainfall zone. Northern and southern part of the valley has comparatively less rainfall.

The areas in the northern side of the Brahmaputra River are fed with sediments carried by the northern tributaries draining the geologically younger Himalayan mountain ranges of unconsolidated sedimentary rocks while the sediments deposited in the southern part of the basin are derived from the tributaries draining the hill ranges that are geologically much older (Datta and Singh, 2004). The topographic gradient of the northern tributaries is steeper and the flow rates are generally larger than in the southern tributaries. The steeper gradients, together with more easily eroded bedrock and larger river discharge, result in a higher sediment load from this part of the drainage area (Mahanta et al, 2015)

1.1 The Brahmaputra River System

The Brahmaputra is known in different names along its course. Originating in the east of Kailash Mountain, it flows east of the Mansarovar lake along the Indus Tsangpo sutures known as Tsangpo. Around Namcha Barwa, it changes course to enter India as the Siang. It debouches in the Assam Plain downstream of Pasighat and flows in WWS direction till Dhubri where it turns southward into Bangladesh.The river is known as the Brahmaputra along its traverse from Dibrugarh to Dhubri and as the Jamuna in the Bangladesh. The Brahmaputra receives many tributaries all along its course of about 2800 km. These include the Lhasa He and the Nyang Qu in Tibet; the Parlung Tsangpo in the eastern syntaxis; the Dibang and the Lohit from the Mishmi Hills; the Subansiri, the Ranganadi, the Jia Bhareli, the Puthimari, the Manas and the Tipkai from the southern slope of the Himalaya and the Burhi Dihing, the Dhansiri and the Kopili from the Indo-Burmese Ranges. The total drainage area of the Brahmaputra river system from its origin to its mouth is ~630000 km2, of which about a third,~220000 km^2, lie in Tibet. It drains an area of ~200000 km2 in the Assam and the Bangladesh plains and ~120000 km2 in the Himalaya. The two eastern tributaries, the Lohit and the Dibang flowing through the Mishmi Hills together have a drainage area~50000 km^2 (Goswami, 1985).

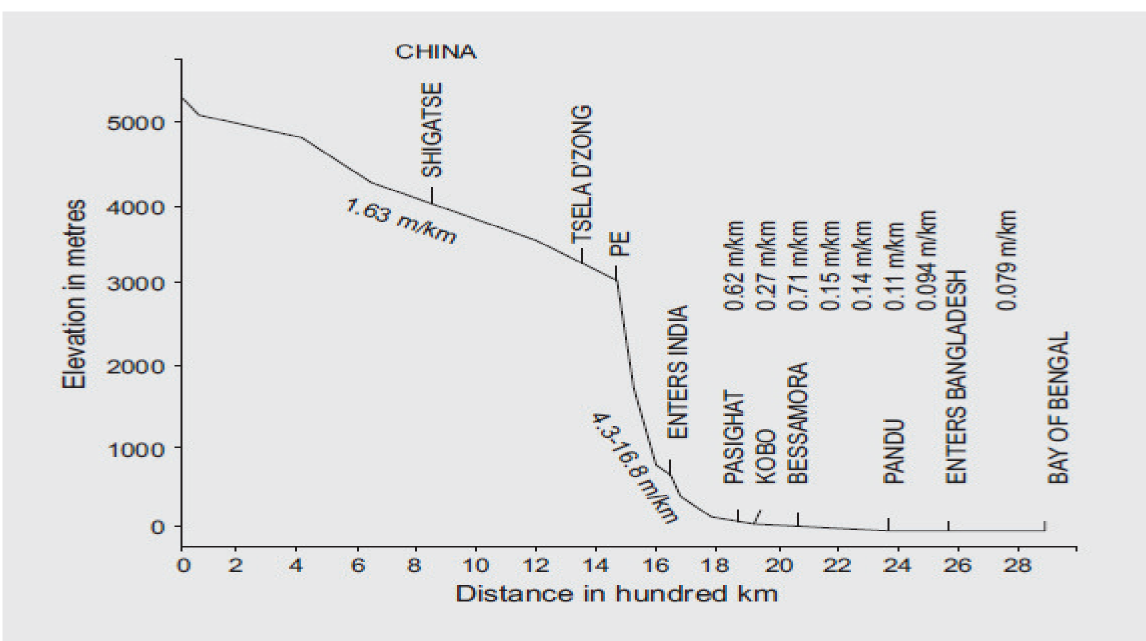


Figure 1 : Long Profile of the Brahmaputra River

1.2 Mythology and History

The name *Brahmaputra* finds its mention in *Kalika Purana*, a mythological text of Hinduism, which is believed to have been written around 10th Century A.D. (Dutta, 2001). The Santanu-Amogha-Parasurama myth finds place here and explains the origin of the river (Dutta, 2001). The famous King Sagar, on seeing the river, summoned a sage, Aubadhya, who used his fecund imagination to enlighten the king with a story tracing the origin of the River to Lord Brahma, the God of creation in Hindu religion. Later, it is believed that sage Parasurama cleaved the bank of the Brahmakunda to cause the Brahmaputra to flow as a river and inundate the region of Kamrupa or present day Assam (Dutta, 2001).

Puranic texts had accounted the Kunda, the origin of the river as somewhere near Mount Kailash. But accounts of the natives, while agreeing that the river originated in the Kunda, recounted the site to be somewhere east-north-east of Assam, in a range of mountains beyond Nara, meaning the boundary of Assam and Burma (Dutta, 2001).

In the padma Purana, there is a mythological story about the birth of river Louhitya. According to one mythology, Amogha, wife of Sage Shantanu, had a child by Brahma, the creator of the Universe. The child took the form of water. Shantanu placed the child right in the middle of the four great mountains – Kailash, Gandhamadana, Jarudhi and Sambwartakka. Susequently the child grew into the lake of Brahmakunda. Later Lord Parashurama, one of the ten incarnations of Lord Vishnu, got rid of his sin of beheading his own mother Renuka on strict order of his father Yamadagni with an axe by taking bath subsequently in Brahmakunda and made a passage for the Kund to come out as the river Brahmaputra by digging the bank of the Kund. It is believed that Parashuram Kunda near Tezu in Arunachal Pradesh is the spot where the axe dropped from the hand of Parashurama.

Investigations of the Indian side of the eastern Himalaya started in 1824 when Lt Wilcox surveyed a number of rivers, including the Dihang and Lohit, which converged and formed the Brahmaputra at Sadiya in Assam. Both he and Pemberton, who had returned from an appointment in Bhutan, had obtained local knowledge that suggested that the Tsangpo and Dihang was the same river.

In the 16th century AD, scripture Kalika Purana, the Brahmaputra river is mentioned as Amogha Garbhasambhuta. During the auspicious occasion of Ashokastami, the mantra recited during the holy dip, amogha garbhasambhuta and louhitya both meant the river Brahmaputra.

Brahmaputra mahabhaga shantanu kulanandana

Amogha garbhasambhuta papang lohitya me hara

(O Brahmaputra, I salute thee! O son of Santanu, I salute thee! O *Lauhitya* form, remove all my sins from previous three births!) (Dutta 2005)

Figure 2: The Brahmaputra can easily boast of its vastness of water landscape, accompanied by some majestic views.

Darjeeling born Sikkimese named Kinthup or K.P. in British records who, spent four years between 1879 and 1882 vidicated these findings (Bulletin of the American Geographical Society, 1915). In 1879, the Survey of India sent a Lama in the Sikkim monastery, known as G.M.N in the official records, to Tibet, to solve the mystery of the Tsangpo i.e. solve the problem of its origin (Bulletin of the American Geographical Society, 1915). They followed the Tsangpo from Arunachal Pradesh eastwards up to the western end of the big gorge through the Himalayas and then returned (Bulletin of the American Geographical Society, 1915). In 1880 a Chinese Lama was employed to continue G.M.N's exploration of the Tsangpo and Kinthup was employed to accompany him. They were instructed to throw logs into the Tsangpo at the lowest point reached in their travels and that watchers have been placed at the point where Dihang debouched into Assam (Bulletin of the American Geographical Society, 1915). The two reached Tibet and travelled further upstream of the Tsangpo to reach Tong-juk Dzong in May 1881. Kinthup returned to India in November 1884.

Until two years from his return, his account was not taken and translated. It was finally Colonel Tanner, who compiled a sketch map of the Dihang basin from Kinthup's narrative. Kinthup was not a trained explorer and in absence of any instruments, notebooks etc., he had to rely on his memory in giving the account of his travel, extending up to four years and covering a large area (Bulletin of the American Geographical Society, 1915). The report 'Explorations of the North-East Frontier during 1911-12-13' by Colonel S.G. Burrand examined Kinthup's work in the light of surveys reported by the Abor expedition, and found Kinthup's accuracy of names striking (Bulletin of the American Geographical Society, 1915). Additional information about the Tsangpo was furnished by Kishen Singh (A.K.) at the end of his memorable four-year journey through Central Asia and his return by the gorge country of south-eastern Tibet (Ward 2000). It was in a volume by Swami Pranavananda that the source of the Brahmaputra or Yarlung was traced as Chema-Yungdung glacier (Pranavananda 1949). Only recently, in 2011 scientists from Chinese Academy of Sciences found that the origin of the Brahmaputra is the Angsi Glacier.

1.3 Water, People, Literature, Art and Culture

The Tsangpo-Brahmaputra is considered sacred in India, Bhutan and Tibet by the population characterized by multiplicity of cultures. The literal meaning of its Tibetian name, Tsangpo, is the Purifier (Dutta 2001). In Hindu mythology, the river is considered to be sacred and thousands of people take a dip in Brahmaputra during the festival *Ashok Astami*. Though, there are Aryan myths about the creation of the river, the tribes that inhabit in the Himalayan foothills have no such folk-myths regarding the origin of Brahmaputra in their folk-mythology (Dutta 2001). However, there do exist, folk-myths about the fabulous origin of the tributaries like the Kanyak-Bhairavi myth with regards to the Jia Bharali tributary of the Brahmaputra or about Subansiri river among the Mishings who call the river Abanari (Singh 1995; Dutta 2001). Many tribes like the Dimasa also derive their names from river or water. The Dimasa tribe call themselves sons of the big river (Di- river, Ma-big, Sa-son). Similarly, the Hill Miri tribe which inhabits Lower

Subansiri and Upper Subansiri districts of Arunachal Pradesh derives its name from water or river (Singh 1995). Dimasa tribe of Assam consider themselves to be the son of river Brahmaputra, after they settled down in the valley. Dima means big and sa means son. Earlier Dimasa's were known as Badosa, a constituent of the Bodo ethnic tribe. Another community known as Mishing is the amalgamation of two words 'Mi' which means man and 'shing' means water.

Figure 3: A healthy Brahmaputra is critical for supporting the rich agricultural productivity of the floodplain

A frontier region, of bewildering diversity with numerous ethnic tribes residing, speaking different dialects and following diverse cultural practices, they have varied customs, most of which are invariably linked to river and forest. The Mishings claim to have come down to the banks of the Brahmaputra and spread over the banks of Subansiri and Dhansiri. The legend has mentioned their fondness for river banks, as settlement sites. Fishing is indispensible to them (Singh 2003). Further, almost all the tribes in the Arunachal Pradesh relate the river with spirits, natural calamities, and agriculture. Almost all the festivals among the tribes in the Siang-Dihang-Brahmaputra basin have agro-religious significance.

Where fishing is the major occupation, like among the Jhalo-Malo group in Assam who reside in Barpeta and Goalpara districts, dependence on water resources is also reflected in their cultures.

The original word for 'Jhalo' is 'julla' meaning 'water' and 'malo' meaning malla infantry, their original occupation being fishing and infantry (Singh 2003).

The Sonowal Kochari tribe of upper Assam celebrates an agricultural ritual, twice or trices a year known as "Lakhimi Tola Sobah". The ritual is river centred, where through religious procession and music, people gather at river ghat, and specially chosen person delves into the river water to catch fish with a Jakoi (fish catching equipment). If they catch fish, it is considered as Lakshmi's blessings to the village.

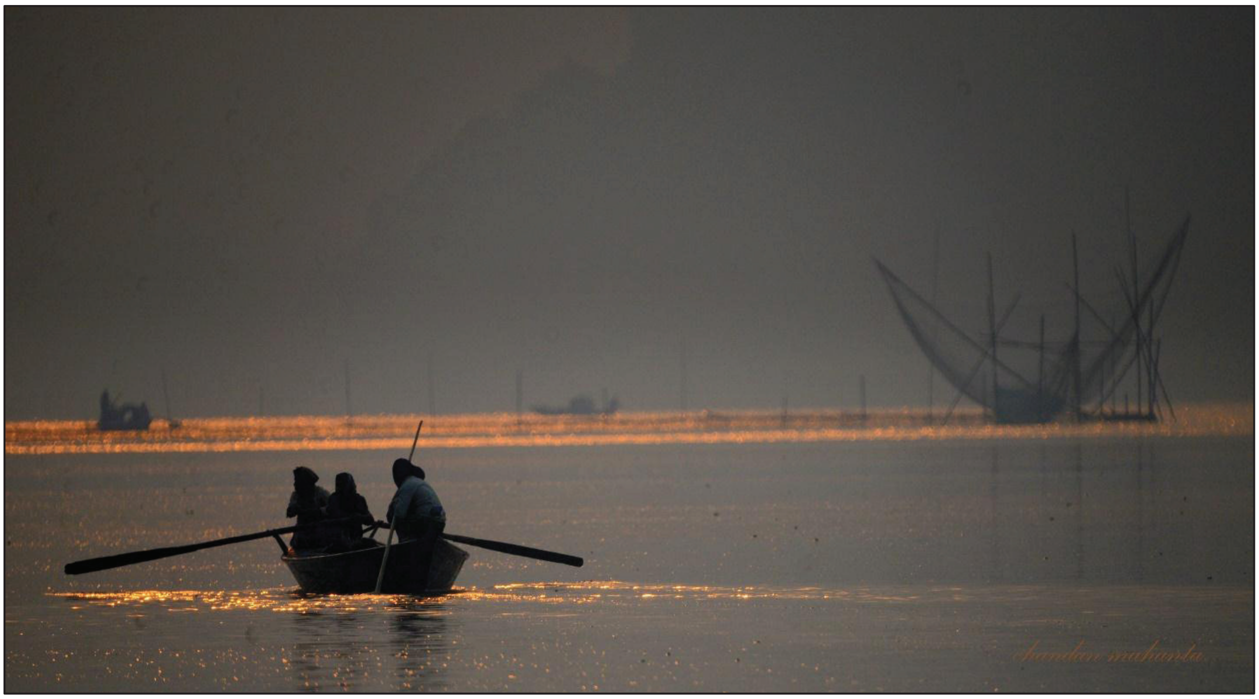


Figure 4: Country boats remain the major mode of local navigation and transport. Fishing nets are all around, yet size of catch leaves much to be desired

Geographical features play an important role as cultural, social and political markers among tribal communities. Settled agriculturists like the Deori of Lohit district of Arunachal Pradesh, have four broad territorial divisions- Dibongiya, Tengapaniya, Borgonia and Patragonia, derived from the different rivers that flow through their region (Singh 2003).

Water also assumes utilitarian significance for the communities inhabiting the region. The Khamba or Kham-Zayu as they call themselves, bury the dead, cremate or immerse them in the river according to Lama's instruction (Singh 1995). In their community, cremation is not allowed if sowing in the field has been done, as it is believed that the smell of the burning body may affect the crop. The Membas, a tribe living in West Siang district of Arunachal Pradesh also dispose of the dead in the water (Singh 1995).

Assamese folk songs, modern songs, Bihu songs are resplendent with river centric theme and is often linked to valour and glory of the Assamese people and also depicts the cultural mosaic of the valley. Reknown Bard of Assam Dr. Bhupen Hazarika wrote numerous poetry and songs centring rivers like the Brahmaputra, Kolong, Kopili, Digaru and many others. One of the epic composition of Dr. Hazarika is the famous song on the river Brahmaputra, which is rendered thus: " Bristirna parore axongkya jonore, hahakar xuniu nixobde nirobe, burha luit tumi, burha luit bua kiyo (Stretched on the two shores where people live in crores, you hear their cries, yet you are silent, O ancient Luit, why you flow in silence!). In patriotic songs, the name of River Luit signifies courage and valour.

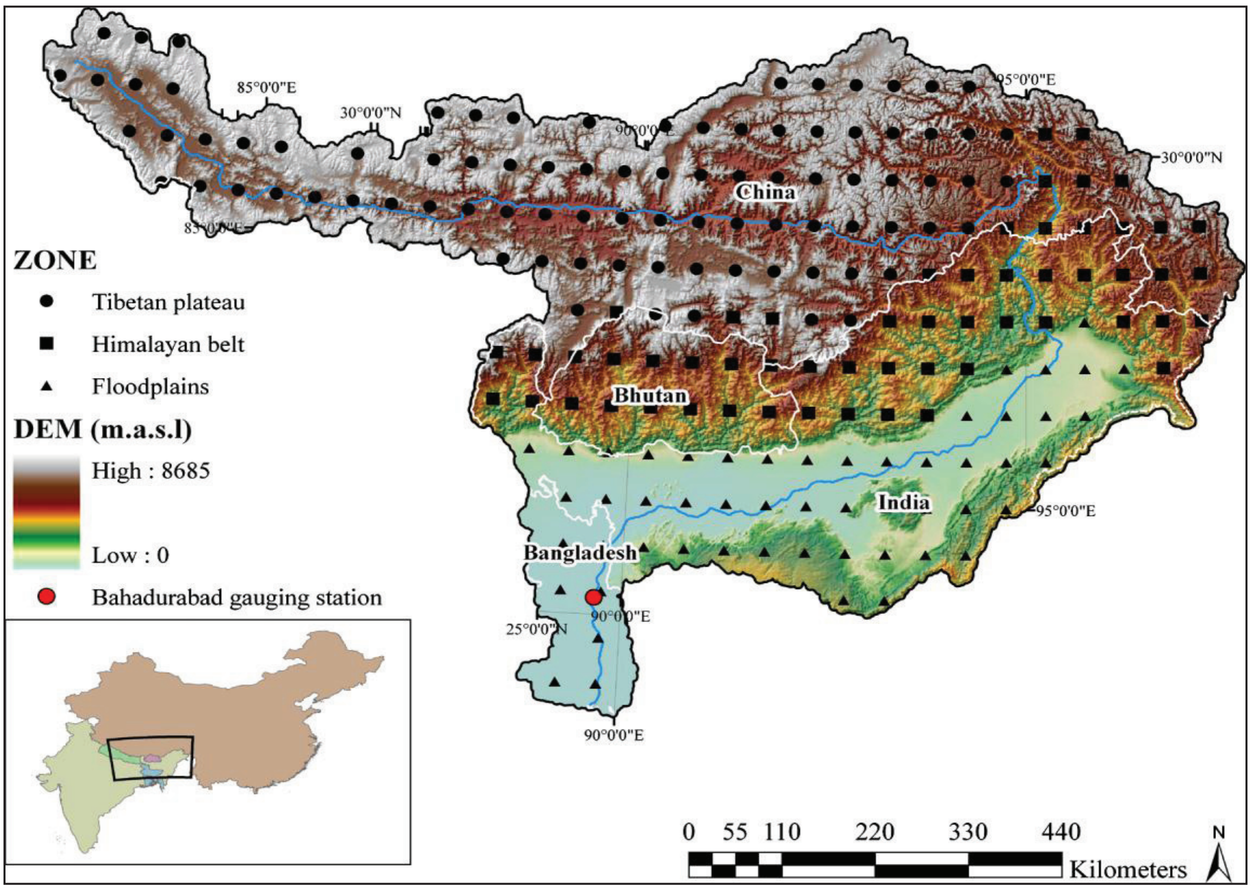
> "Luitor paaror deka bondhu tumar tulona nai, Jiyai thokar jujot naamisa mrityu xopot khai" (Young friends from the bank of river Luit, you are unparalled, you have sworn by death to fight for your motherland)

In the field of fine arts, most of the landscape artists of Assam like Benu Mishra, Nilpaban Barua, have done vast numbers of paintings on river Brahmaputra and life on the river bank. Some of the famous paintings are Shankardeva and Brahmaputra by Mabegum Pasa, Tibetan Painting on Yarlang Tsangpo by Susan Mayclin Stephenson, Brahmaputra by Nicholas Roerich, Bank of River Brahmaputra by Anupam Saikia,

Apart from numerous articles in Newspapers, Magazines and Academic Journals, a number of important books published on the Brahmaputra that are worth mentioning are as follows: Axomor Nod nadi by Jogendra Nath Sharma, Brahmaputra and the Assam Valley by Ranjit Biswas, River Dog, A journey down the Brahmaputra by Mark Shand, Brian on the Brahmaputra by David Fletcher, Water war in South East Asia, Brahmaputra, Dam and Diversion, Colonel Puneet Raina (Retd), The Brahmaputra by Arup Kumar Dutta, The Brahmaputra Basin water resources, Edited by Vijay Singh, Nayan Sharma, C. Shekhar, P. Ojha, Tales from River Brahmaputra by Tiziana Baldizzone and Gianni Baldizzone, The last River:the tragic race for Shangri-La by Todd Balf, Sands of the Brahmaputra River Basin by Zaman Mohammad Nazim, Rahman Aminur and Biswas Pradip Kumar

1.4 Physiography

The basin is categorized into three different physiographic zones respond differently to the anticipated climate change. TP covers 44.4% of the basin, with elevations of 3,500m a.s.l and above, whereas HB covers 28.6% of the basin with elevations ranging from 100m to 3,500m a.s.l. The area with an elevation of less than 100m a.s.l. is considered as FP and comprises about 27% of the entire basin(Immerzeel, 2008).



Map No 2 : Physiographic Zones of the Brahmaputra Basin

Further the physiography of Assam is divided into three broad geographic units 1:

1. **The lower and central Assam hills, known as the Shillong Plateau :** The lower and central Assam range which includes, the Garo, Khasi, Jaintia and the outlying Mikir hills are in reality a plateau or table-land. The general height of the plateau ranges between 3,000ft and

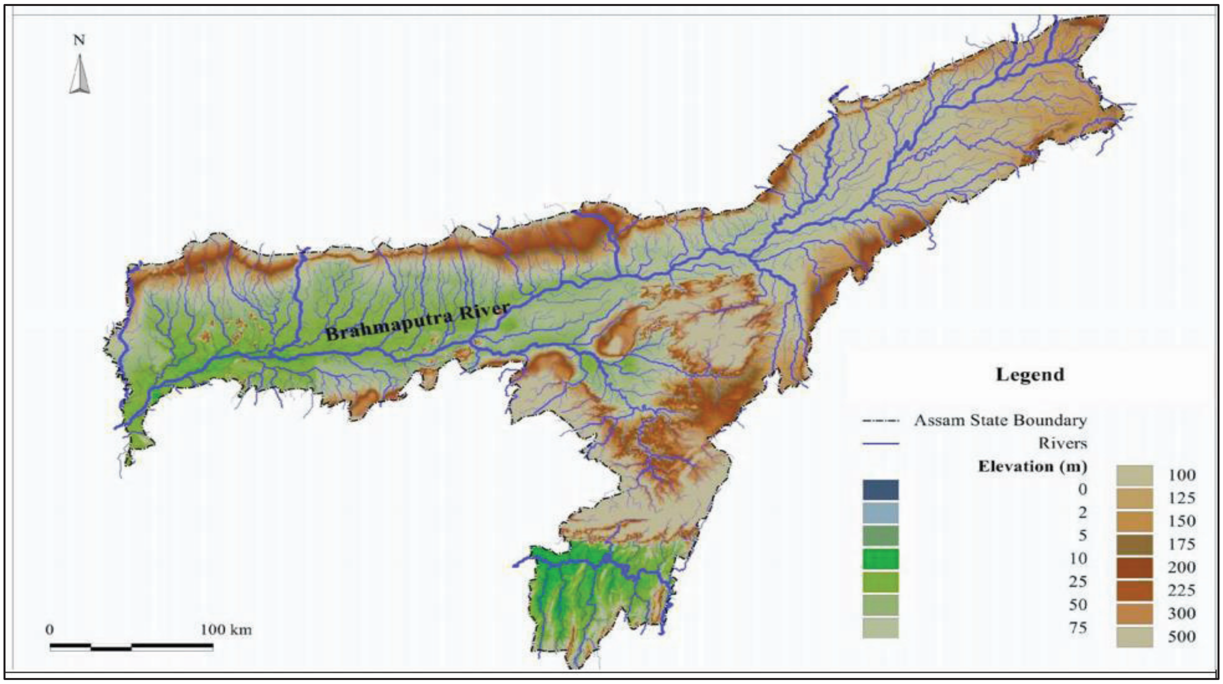
[1] Stare Flood Hazard atlas, Assam 2016

6,000ft. The Khasi and Jaintia hill portion of the plateau are comparatively higher and flatter than the Garo and Mikir hills on the west and northeast. The highest peak of the plateau is the Shillong peak (6450 ft).

2. **The Barail ranges and the low hilly terrains of Mizo hills :** The lofty Barail ranges, also known as the North Cachar hills, are separated from the Shillong plateau on the Northwest by a system of narrow valleys. Tectonically, the Barails form a south westerly extension of the mountain chain of Nagaland and western Burma. It is this chain of mountain that separates the valley of Irrawaddy and Chindwin of Burma from the valley of Brahmaputra and the Meghna. The Patkai, Naga and Manipur hills and the Mizo hills form part of this great mountain system. The Mizo hills consist of a belt of North-South trending ridges with intricate valleys, with an average height of 3,000ft

3. **The Alluvial valley of Brahmaputra, Dhansiri and the Barak River : The** alluvial plains of Assam consist of two distinct parts:
   a) The valley of the Brahmaputra and its tributaries and
   b) The Barak valley.

   These are separated from each other by the watershed of the Shillong plateau and the Barail ranges. The Brahmaputra valley separates the sub-Himalayan foothills from the Shillong plateau and the Patkai-Naga hill ranges. The Mizo hills and the Barail ranges die out towards the west and south west into the plains of Cachar, which is a part of Surma-Kusiyara valley.



Map No 3: Topography of Assam

1.5 Geomorphology

The bank of the Brahmaputra, for the most part, is extremely unstable. Bank failures are rampant and are a result of frequently changing flows, coupled with the fragile geology of the river banks. Moderately high return flows cause large scale slumping of banks. High moisture content and low proportion of clay make the banks highly susceptible to erosion (Goswami, 2010). The drastic channel configuration changes undergone by the river speaks of its dynamics and of the enormous amount of erosion caused by it.

Braiding indices of the Brahmaputra at Dibrugarh and Guwahati are 5.3 and 6.7 respectively. Excessive sediment transport, erratic flows, erosion prone river banks, and long term aggradation of the channel are the primary factors driving the braiding phenomenon. Most of the channel bars in the Brahmaputra are highly transient in nature, being submerged during summer flows, and visible during lean flows in winter months, especially January. Bed forms in the river channel range from small sized ripples to large scale dunes.

Estimation of the amounts of aggradation and degradation in the Brahmaputra with more sound values of average annual sediment load from WAPCOS 1993 report suggests that as a whole, the Assam section of the river registered a net bed-level aggradation of about 6.39 cm, i.e. a difference of about 9.61 cm from the value estimated by Goswami, 1985. This reveals that the net aggradation undergone by the river has decreased in recent times, justifying the tendency of the river to restore itself to its previous state of equilibrium.

The Brahmaputra basin in Assam comprises three major categories of geomorphic units—depositional, denudational and structural. Only the depositional unit, which is of fluvial origin, includes floodplain deposits, younger alluvial plains, older alluvial plains, upper piedmont plain, lower piedmont plain and valley-fill areas. The channel of the river Brahmaputra undergoes changes in response to variations in the flow regime, pattern of sediment transport, and neotectonics. Continuous shifting of the thalweg from one location to another takes place within the bank lines and the river exhibits a braided channel pattern with temporal changes in bank line location as well as channel configuration. The major north-bank tributaries, such as the Subansiri, Jia Brarali, Manas, Sonkosh, exhibit partially braiding character at present but they were meandering rivers prior to the great earthquake of 1950. The characteristic features of the Brahmaputra floodplain are anabranches, locally known as Suti or Sota.

1.6 Climate of the valley

The climate of the Brahmaputra valley cannot perhaps be discussed separately from the climate of NE India. The climate of NE India is distinct from the rest of India due to special features such as orography, the alternating pressure cells of NE India and that of the Bay of Bengal, the predominant maritime tropical air mass from Bay of Bengal followed by south Indian ocean, the roving periodic western disturbances and the local mountain and valley winds (Borthakur 2004). The region belongs to the transition zone of tropic and extra-tropic and as a consequence experiences westerly moving tropical weather systems like lows, depressions and cyclonic storms during pre-monsoon, monsoon and post-monsoon, as well as extra-tropical easterly moving weather systems like western disturbances in winter (Pathak, 2000). Though depression, deep depression and cyclonic circulation are the potent rain bearing weather systems causing widespread rainfall in India, their direct entry during monsoon to NE India is very rare (Pathak 2000). However, re-curvature of monsoon depression after reaching Bihar plateau and adjoining area due to westerly trough is common during monsoon season. On re-curvature, the rain bearing southwest sector of depression gets changed to NE sector (Pathak, 2000). Frequent major floods occur during monsoon season in the Brahmaputra valley caused by heavy rainfall associated with

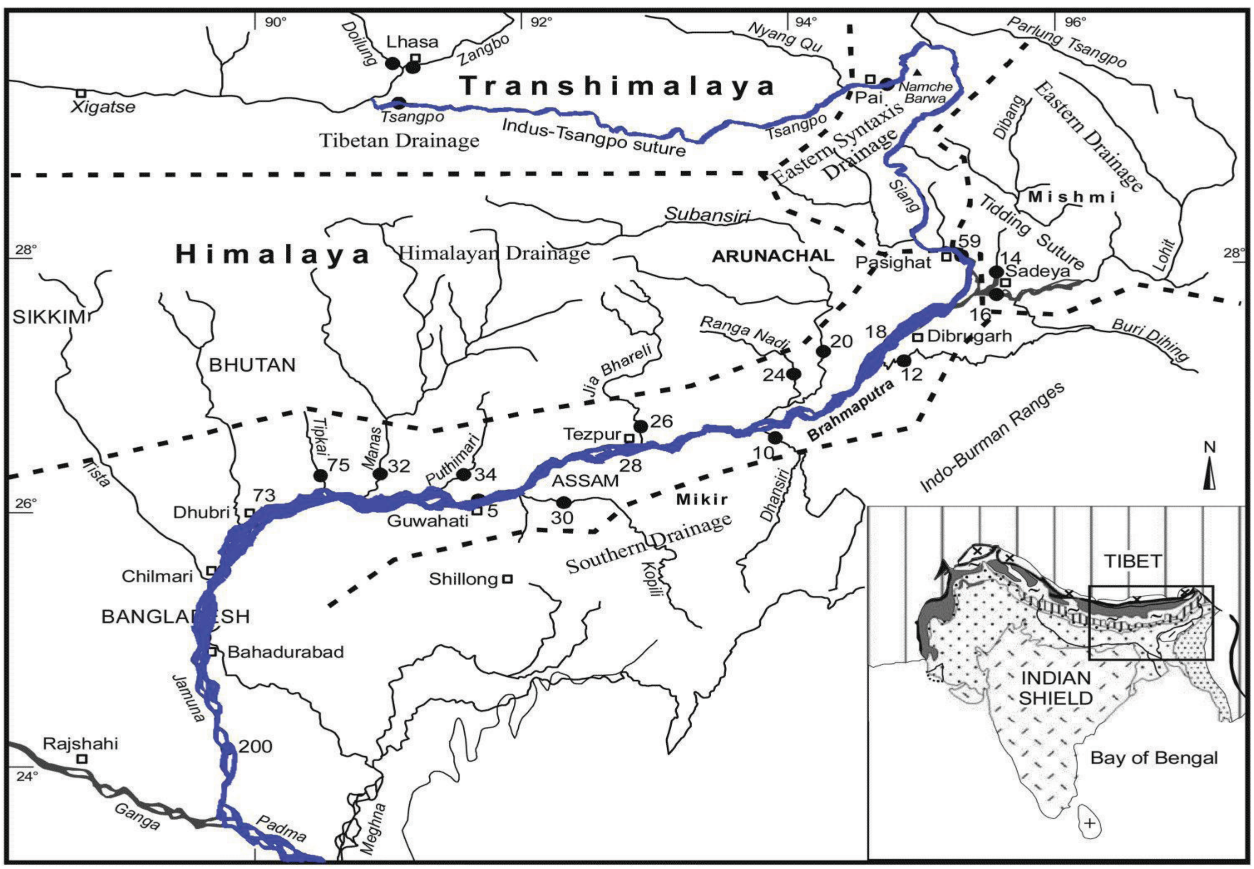
‘Break’ monsoon situations or re-curving monsoon depressions from the Bay of Bengal (Dhar and Nandargi 2000). The break monsoon occurs when the axis of the seasonal monsoon trough shifts northwards from its normal position and lies close to the foothills of the Himalayas (Dhar and Nandargi 2003). These two particular meteorological situations are responsible for causing heavy rainfall on about 65% of occasions over the north eastern and central Himalayas and their adjoining plain areas (Dhar et al. 1984), while the rest of the country reels under drought condition with low or no rain.

The Brahmaputra valley including adjacent eastern Gangetic plains gets affected by severe thunderstorms during pre-monsoon months, in particular during April–May. The valley gets a good amount of rain (about 25% of annual total) falling during this season due to “Nor’westers” which makes the climate cool even during spring. In contrast, there is very little rainfall from March to May in the rest of northern India (Das 1992). This occasional rain in the valley is highly significant for the cultivation of jute, autumn rice and for the budding of tea plants. Thunderstorm activity over the Brahmaputra valley is highest in the country, which produces heavy rain showers, lightening, thunder, hail-storms, dust-storms, surface wind squalls and tornadoes (DST 2005) often causing extensive damage to winter wheat, summer paddy and tea crop. During winter, chilly wind from the Tibetan region is obstructed by the Himalayas and as a result, the valley is protected from unbearable cold. Winter is the driest period in the valley. Local circulations and western disturbances bring some rainfall even during the winter season (Atri and Tyagi 2010).

The Brahmaputra valley receives a mean annual rainfall of 2,293 mm (Deka et al. 2013). Monsoon rains from June to September account for 60 – 70 % of the annual rainfall in the valley while the pre-monsoon season from March to May produces 20 – 25 % of the annual rainfall. Mirza et al. (1998) studied the changes of rainfall over Ganges, Brahmaputra and Meghna basins and found that annual rainfall over the north Assam sub-division (part of the Brahmaputra valley) showed an increasing trend during the study period of 1901–1981. Sen Roy and Balling (2004) found decline in annual precipitation in the NE India. Deka et al (2013) noted a downward trend in rainfall during monsoon and post-monsoon seasons in the Brahmaputra basin in the state of Assam, NE India for the period 1901-2010; this trend was most pronounced in the last 30 years. Poor irrigation coverage and higher degree of probable rainfall fluctuations due to global warming requires better knowledge of spatiotemporal rainfall distribution for planning agricultural operations for optimal yield. However, information of spatiotemporal variations of rainfall over the Brahmaputra valley has been scarce. The present study reports on the outcome of analysis of rainfall data for different parts of the Brahmaputra valley during the last 110 years. This is definitely instrumental in terms of sound understanding of spatial and temporal variations of monthly, seasonal and annual rainfall which will definitely help in evolving new strategies for management of food security and water resource in the valley.

2. Major tributaries and sub-tributaries of the Brahmaputra Basin

Originating from Kailash ranges of the Himalayas at an elevation of about 5150m, river Brahmaputra flows through Tibet (China), India and Bangladesh for about 2900m and joins the Ganga. The river receives a number of tributaries at the north and south banks, in the catchment area within India. The major tributaries and sub tributaries of the Brahmaputra are as follows:



Map No 4: Brahmaputra and its major tributaries

Table 1: Major North and South Bank Tributaries and sub-tributaries of Brahmaputra

South Bank Tributaries
Laikajan, Dibru, Maijan, Burhidihing, Disang, Dikhow, janji, Bhogdoi, Kakodonga, Gelabil, Dhansiri, Dipholu, Kolong, Pokonia, Basistha, Bahini, Kulsi, Krishnai, Jinari, Deosila, Jinjiram
Sub Tributaries
Dumduma ,Dangori ,Dhola,Namsik, Tirap, Namdang, Dirak, Namsang, Tipling, Tingrai, Disam, Sesa, Timon, Taokak, Sofrai, Diroi, Dimou, Mudijan, Kakojan, Teok, Ghiladhari, Kasojan, Dholi, Doiyang, Nambor, Deopani, Rengma, Kolioni, Nanai, Diju, Misa, Haria, Rani, Dudhnoi, Sonai
North Bank Tributaries
Jiabharali, Sadharu, Burigang, Borgang, Jinjia, Brahmajan, Bihali, Puthimari, Champamati, Gaurang, Dhansiri N, Pagladia, Beki, Manas, Jiadhol, Subansiri, Belsiri, Barnadi, Nanoi, Noanadi, Tipkai, Dikrong
Sub Tributaries
Sarikoria, Gai, Moridhol, Kanibeel, Sila, Dangdhora, Ghagor, Kakoi, Bogi nadi, Ranga nai, Singora, Solengi, Kukurajan, Begoti, Sadharu, Bor Dikorai, Mansari, Garhjuli, Digholjuli, Moinajuli, Rangagora, Mora Dhansiri, Beganai

Compiled from Axomor Nod Nodi by Jogendra Nath Sarma, 2014

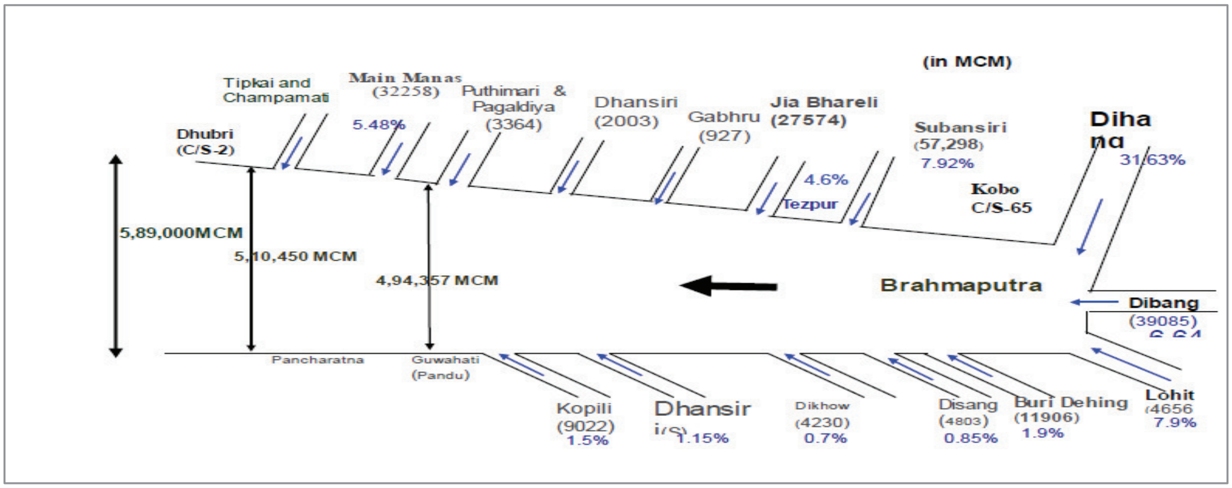


Figure 5 : Average Annual Runoff of the Brahmaputra and its Tributaries (NDMA report, 2012)

The north bank tributaries are flashy in nature, having steep gradients, shallow braided channels and coarse sandy beds, whereas the south bank tributaries have flatter gradients with deep meandering channels, composed of fine alluvium. Most of the north tributaries carry a heavy silt charge. The principal right and left bank tributaries are enlisted in the table below:

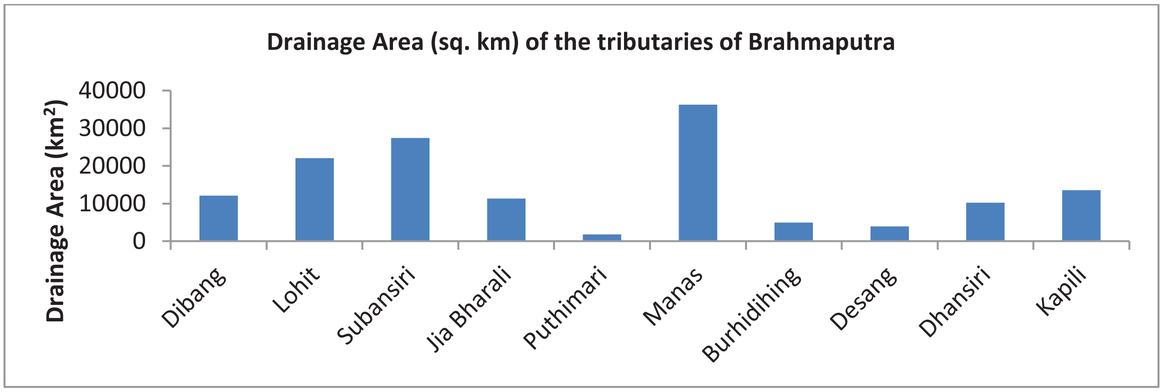


Figure 6: Drainage area (Sq. Km) of the tributaries of Brahmaputra

Table 2 : Percentage contribution of yield by the tributaries of the Brahmaputra River

Tributaries	Average annual yield (in M.cu.m)	Percentage contribution
Dehang (main stream)	1,85,102	37.5
Subansiri	52,705	10.7
Lohit (head stream)	46,964	9.5
Debang (head stream)	37,818	7.6
JiaBharali (Kameng)	28,844	5.8
BurhiDihing	11,906	2.4
KopiliKalang	9,023	1.8
Dhansiri (S)	6,785	1.4
Other tributaries above Pandu	-	23.3
Total of Brahmaputra at Pandu		100%

(Brahmaputra Board 1995)

Table 3: Drainage characteristics of some major tributaries of the Brahmaputra

Tributary	Catchment area (km^2)	Length of river channels (km)	Drainage density
Subansiri	37700	2598	0.07
JiaBhareli	14450	1242	0.09
Dhansiri (N)	1543	268	0.17
Pagladiya	1820	202	0.11
Manas	38176	3177	0.08
Sankosh	17167	1544	0.09
BurhiDihing	8730	821	0.09
Disang	3950	537	0.14
Dikhu	4372	439	0.10
Dhansiri (S)	12584	1392	0.11
Kopili	20068	1819	0.09

Subansiri, JiaBharali and *Manas* are trans-Himalayan rivers. These three tributaries on the north bank have a drainage area of more than 10,000 sq. km each. Similarly two south bank tributaries, the *Dhansiri* and the *Kopili* form basin areas of more than 10,000 sq. km each. The *Manas* River combined with the *Aie* and the *Beki* rivers drains the biggest area of 41,350 sq. km.

3. Wetlands in Assam

The floodplains of the Brahmaputra river is dotted with a large number of wetlands, numbering more than 3,500, covering an area of around 1,01,232 ha.(Singh et al., 2013), which have great significance as unique habitats for exquisite varieties of flora and fauna and also as natural flood water retention rservoirs. These wetlands, home to a variety of fishes and other aquatic fauna, also act as ideal natural habitat for both domestic and migratory birds. The lake-like water bodies are locally known as beels, while the swampy areas are variously called as *Jolah, Pitoni, Doloni, Doba, Hola,* Khal etc. In the Barak valley the beels are called haors. Normally beels represent vast sheet of water with varying shape, size and depth. Some of them are partially or fully infested with floating mats of aquatic plant and water hyacinth. The swampy and marshy areas, are shallower than the beels. The wetlands in Assam are primarily fresh water and riverine in nature. An study by ISRO (National Wetland atlas, ISRO &MoEF , 2010) reports that Assam has wetland of 764372 ha area in the Brahmaputra and the Barak basin. A total of 5097 wetlands along with 6081 small wetlands having area less than 2.25 ha majority of which, are tanks, have been registered during the study. The estimated total wetland area is around 9.74 percent of the geographic area. River/Stream constitutes 84 % of the wetlands (637164 ha), Lake/Ponds (51257 ha), waterlogged (47141 ha) and Ox-bow lakes (14173 ha). There are two reservoir/barrages mapped with 2833 ha area, which is the major man made wetland types. Majority of these wetlands are in the floodplains of the rivers Brahmaputra and Barak and their tributaries and include beels, swamps and marshes. A study carried out by ARSAC revealed that out of the total 3,513 wetlands, 2,378 are low turbidity, 346 with moderate turbidity and 178 wetlands are with high turbidity. High turbidity is prevalent in waterlogged and swampy/marshy areas while low turbidity is prevalent in water-logged wetlands as well as lakes/ponds. Turbidity is high in most of the natural wetlands compared to man-made wetlands.

Figure 7 : The clay and the silt brought as suspended matter by the river, once settled, support a vibrant landscape; but coarse sand deposited in thick layer makes farming field barren and non-arable

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	Inland Wetlands - Natural					
1	1101	Lakes/Ponds	1175	51257	6.71	34408	14526
2	1102	Ox-bow lakes/ Cut-off meanders	873	14173	1.85	7721	5848
3	1103	High altitude wetlands	-	-	-	-	-
4	1104	Riverine wetlands	139	4258	0.56	1669	942
5	1105	Waterlogged	2461	47141	6.17	33660	12630
6	1106	River/Stream	213	637164	83.63	342197	353756
	1200	Inland Wetlands -Man-made					
7	1201	Reservoirs/Barrages	2	2833	0.37	2185	1346
8	1202	Tanks/Ponds	180	921	0.12	892	801
9	1203	Waterlogged	54	544	0.07	336	303
		Sub-Total	**5097**	**758291**	**99.20**	**423068**	**390152**
		Wetlands (<2.25 ha), mainly Tanks	6081	6081	0.80	-	-
		Total	**11178**	**764372**	**100.00**	**423068**	**390152**

Area under Aquatic Vegetation	36817	76036

Area under turbidity levels		
Low	64137	22834
Moderate	358429	366654
High	502	664

Figure 8: Distribution of different types of wetlands in Assam (National Wetland atlas,2010)

4. Major human settlements and structures

The characteristic features of the braided river is numerous amount of big and small sandbars known locally as “Char”, separated by several distributary channels, these char areas are of different sizes and permanency. The braided characteristics of the Brahmapura channel are fully developed during winter. During monsoon, the “chars” are submerged in water, changing their dimension, size and shape. Most of the char areas are endowed with fertile alluvial top soil that are conductive to good agricultural practices and thus inhabited by permanent or semi permanent human settlements, occupied mostly by the migrant Bangladeshi nationals. The sandbars where the cores are relatively high and thus less affected by flood, permanent settlements can be found. Away from the core, and with the river bed becoming shallower, flood havoc is extensive, making permanent settlement impossible. Fringe char areas are prone to high rate of erosion and thus less frequented by settlers (Singh et a).

Table 4: Important Ghats along the Brahmaputra River Bank

Ghats	Locations
Rojaduar, Madhayam Khanda, Silsako	North Guwahati
Kurua, Pandu, Kachomari, Sunsali, Sukleswar, Kachari	Guwahati
Pancharatna, Baghbor—	Goalpara
Kamalabari, Nematighat,	Jorhat
Burhachapori, Laukhowa	Tezpur
Saikhowaghat	Sadiya
Sissi, Sonari	Dibrugarh
Silghat	Panpur
Singri	Dhing

Table 5: Important Temples along the Brahmaputra River

Temple	Location	Importance
Kamakhya	Guwahati	Located at the Nilachal Hill, it is the oldest of the 51 shakti pitha, dedicated to mother goddess Kamakhya
Umananda	Guwahati	Situated in Peacock Island in the middle of the Brahmaputra, is a Shiva temple
Rudreswar Devalay	North Guwahati	The temple is dedicated to lord Shiva. It was built in 1749 CE under the reign of Ahom king Promotta Singha
Dirgheswari	North Guwahati	Situated at Sitachal hills, it was constructed by Ahom king Shiva Singha in 1714CE-1744CE.It is an important Shakti Peetha next to Kamakhya temple.
Aswaklanta	North Guwahati	Built in 1720 by ahom king Shiva Singha, it is an important Hindu temple. There are two temples, one: Kurmayanardan and Anantasayi
Sukreswar	Guwahati	Located at the heart of Guwahati along the river bank, it is a Shiva temple; situatedon a hillock known as Hasti. In Kalika Purana, it is described as the hermitage of sage Sukra.
Mani-Karneswar	North Guwahati	On the north bank of Brahmaputra

Figure 9: Innumerable boats dot the river landscape of Brahmaputra. Sometimes boats are clustered to be used together for specific purposes. These are country boats used for carrying sand in one of the many tributaries of Brahmaputra

5. Structural interventions for flood protection :

Structural Measures: In this approach physical structures are envisaged to prevent the flood waters from reaching potential damage regions. The main structural measures undertaken so far in the Brahmaputra basin are as follows.

1. Embankments, Floodwalls, Flood levees
2. Dams and Reservoirs
3. Natural Detention Basin
4. Channel Improvement
5. Drainage Improvement
6. Diversion of flood water
7. Catchment area treatment/ afforestation
8. Anti-erosion works

Table 6 : Short-term Flood Control Measures Undertaken by the State of Assam

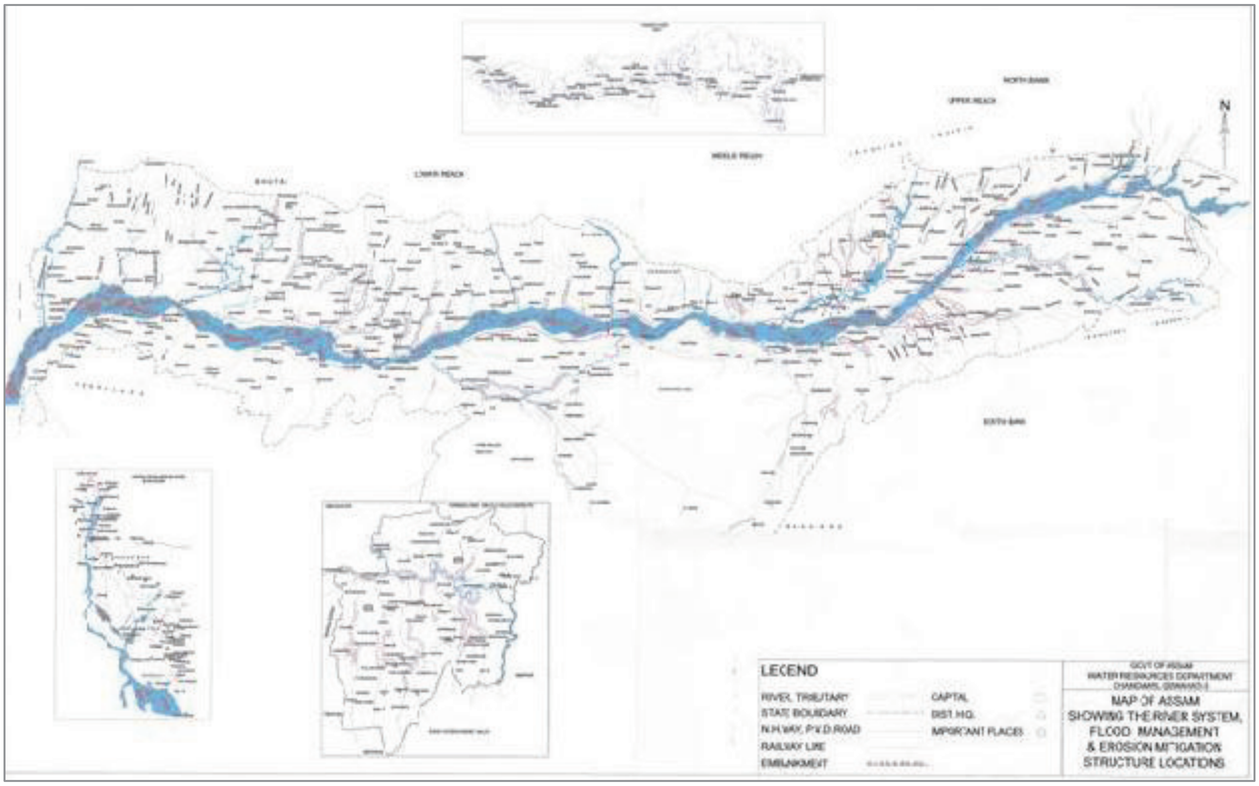
Sl No	Brahmaputra Valley		Barak Valley		
1	**Embankments**		**Embankments**		
	Brahmaputra	1016.187 km	Barak	251 km	**4458.60 km**
	Tributaries	2681.24 km	Tributaries	510.17 km	
2	**Anti-erosion/town protection schemes**	531 nos.	**Anti-erosion/town protection schemes**	156 nos.	**689 nos.**
3	**Drainage Channel**	599 km	**Drainage Channel**	251.69 km	**850.69 km**
4	**Sluices**	56 nos.	**Sluices**	29 nos.	**85 nos.**
5	**Raised Platform**	3 nos.	**Raised Platform**	-	**3 nos.**

(Source: Water resources Department, Assam Flood Hazard Atlas 2016)

- **Short-Term Structural Measures:** The State Government of Assam has suggested Short-term measures like new embankments, gap closure, raising and strengthening of existing embankments, anti-erosion works, drainage development, raised platforms. The total cost of such Short-term works as informed by the State Government is around Rs.2022.01 crore.
- **Long-Term Structural Measures:** The State Government has suggested for early completion of surveys, investigations and DPRs and expediting the 8 major dams (Pagladiya, Tipaimukh, Subansiri, Dehang , Kameng , Lohit , Debang) as under projects.
- **Non- Structural Measures:**

➢ Flood forecasting based on real time data by installation of modern/sophisticated instruments

➢ Flood Plain Management, Flood Proofing, Disaster preparedness and response planning, Flood insurance.



Map No 5 : River System, Flood Management & Erosion Mitigation Structure Locations (Source: ASDMA, Guwahati) Flood Hazard Atlas 2016

Assam has 3 % of total population & less than 1% land mass of India whereas it has 9 % of the total flood prone area of the country. The data shows it has suffered extreme damage due to flood annually both to humans and its rich biodiversity owning to its topographical & climatic setting. An integrated approach in terms of planning and execution of structural and non-structural measures is need of the hour for the sustainable growth and prosperity of its people & biodiversity. .

6. Sediment load in the Basin

In most of these studies the sediment flux of the Brahmaputra River system is consistently estimated to be higher than that of the Ganga River system. This is despite the fact that the Brahmaputra River drains a shorter arc of the Himalaya than that of the Ganga. Based on sediment flux and basin area, the average denudation rate in the Brahmaputra Basin is estimated higher than that of the Ganga Basin. Higher sediment flux from the Brahmaputra Basin than from the Ganga Basin may be related to several processes. The monsoon climate generates higher runoff for the Brahmaputra than for the Ganga. Tectonic uplift may be more active in the eastern side than on the western side of the Himalaya. The erosion in the non-Himalayan parts of the basin, such as the Indo-Burmese Range, the Shillong Plateau and the Tibet-Tsangpo Basin may be important. Finally, the wide floodplain of the Ganga may favour sediment sequestration, whereas Brahmaputra is more channelised between the Himalayan arc and the active Burma arc and Shillong Plateau.

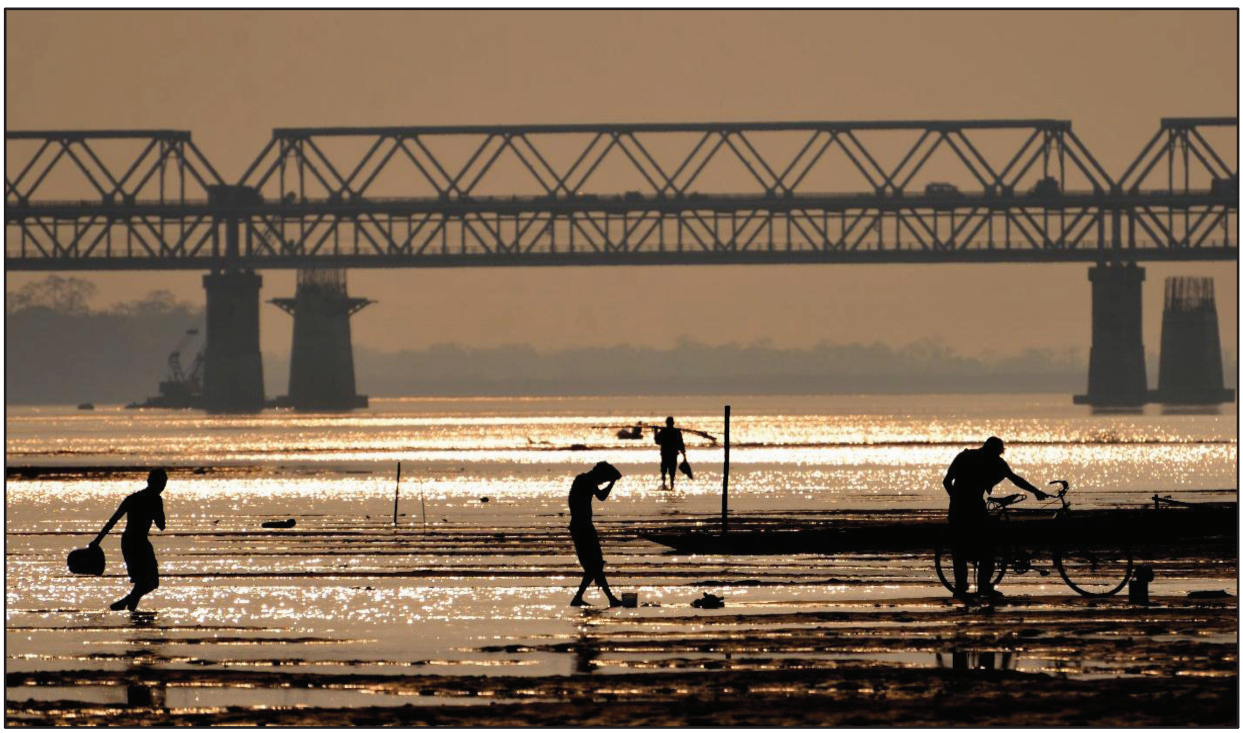


Figure 10 : Today, the river bed is increasingly getting shallower due to constant flux and deposition of sediments during receding flow - thereby inviting multiple activities on the river bed itself, often detrimental to the health of the river

However, geochemical budgets of erosion do not support this hypothesis and suggest that the total erosion rate in the eastern Himalaya is about 1.5 times higher than that in the central and western Himalaya [4]. Nevertheless, little is known about erosion in the eastern Himalaya and it is difficult to analyse the origin of the difference between the two Himalayan basins (Singh and Lanord, 2002).

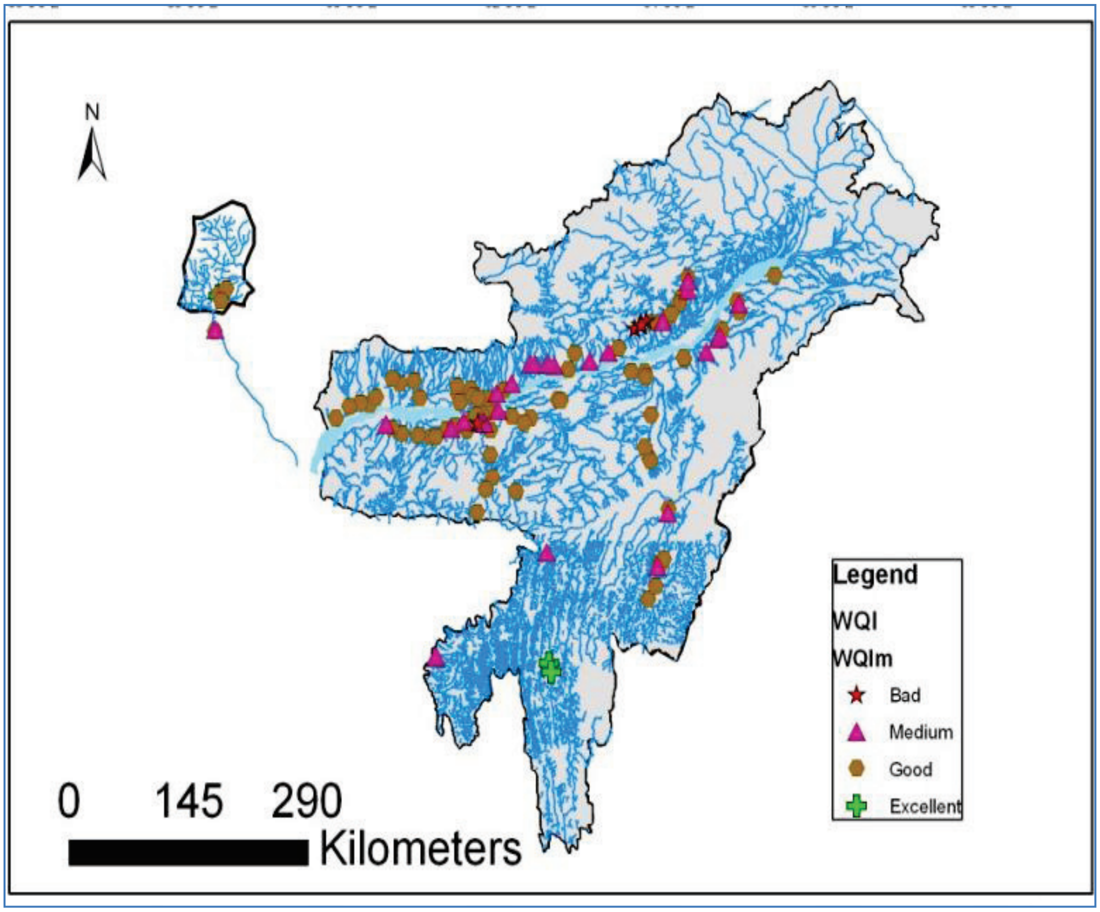
7. Water quality issue of the Brahmaputra

The Brahmaputra basin of North East India is one of the globally focused basins due to its enormous water resource potential and high population, which has lead to the accelerated stress in the river system. Studies (Mahanta et al,) revealed that there is serious threat to some rivers of Brahmaputra basin from pollution due to the rapid industrialization and urbanization. It has been found that river water of the basin is generally alkaline with comparatively high bicarbonate, sulphate and dissolved silica concentration. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Fecal Coliform and turbidity are observed to be the common violating parameters (according to the Indian national guidelines) for most of the rivers of the region. As indicated by the Water Quality Index (WQI_a and WQI_m) values, several urban rivers have medium water quality. However, this medium water quality is also of serious concern comparing to the background pristine status of the rivers in this basin. The high monsoonal flow to the rivers of the basin is very significant in diluting the pollutant almost throughout the year, whereas river water quality scenarios become critical for most of the tributaries in the dry season, particularly in urban areas.

The sediment load is significant for the rivers of the region (Mahanta et al.,2004) leading to high turbidity values. Sediment load in rivers raises the channel bed and thus leads to flood during monsoon, exhibiting a particular water quality profile. Sediments in rivers generally come with the surface runoff from the degraded watersheds. To protect the rivers from high sediment load, conservation and management of watershed is very essential. Proper planning and management need be prioritized for developments in hilly watersheds, to ensure lesser release of sediments to the rivers.

Figure 11: People living close to the river often fill their drinking water bottles directly from the river flow, believing that it is safe to do so, without realising that due to presence of pathogenic bacteria alone - a result of direct discharge of sewer water

Although the rivers have not been worst impacted by pollution so far, rivers flowing through urban areas are highly threatened. The Bharalu river, which is flowing through the Guwahati city of Assam, found to be highly polluted and aesthetically unpleasant (Girija, 2008). According to Girija et. al (2007), BOD, DO and total phosphorus were found to be the sensitive parameters that adversely affected the water quality of Bharalu, and the causes and sources of water quality degradation in the river is due to anthropogenic activities and poor waste management.



Map No 6 : Sampling Locations in the rivers showing different levels of water quality based on WQIm value (mahanta et al,)

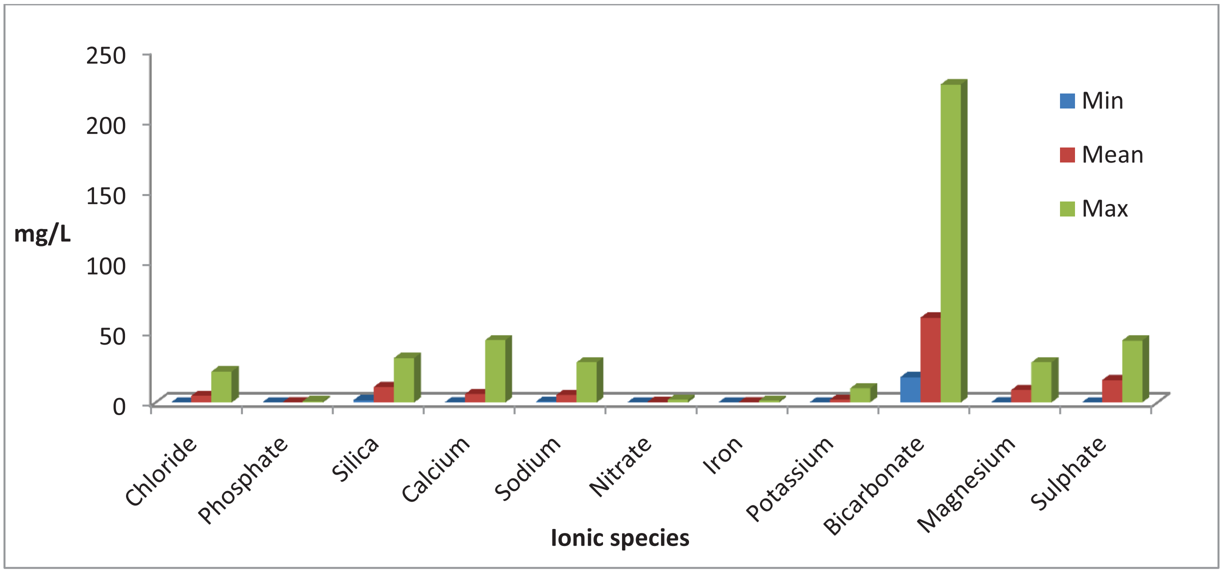


Figure 12 : Distribution of Ionic concentration in the rivers of Brahmaputra Barak Basin

Figure 13: Several tributaries of Brahmaputra like Bharalu, Kolong, Bhogdoi flowing through urban stretches have turned degraded and encroached upon.

Table 7 : Range, mean and standard deviation of the tributaries of Brahmaputra River

Parameter	North bank tributaries			South bank tributaries		
	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation
Temperature (°C)	22.5 -34.4	27.7	3.1	17.3 - 33.8	27.2	4.3
pH	6.6 - 9.2	7.7	0.5	6.1 - 8.2	7.2	0.4
TDS (mg/L)	20 - 290	89.3	59.9	20 - 160	65.4	31.9
EC (µS/cm)	20 - 398	109.2	80.4	25 - 170	75.9	37.1
DO (mg/L)	4.6 - 9.5	7.4	1.2	3.1 - 9.1	7.1	1.6
BOD_5 (mg/L)	0.1 -2.1	0.7	0.4	0.2 - 20	2.1	3.7
Turbidity (NTU)	5 - 914	153.8	219.6	3 - 849	91.8	147.6
Hardness (mg/L)	4 - 218	47.4	39.8	10 - 122	32.2	15.0
Cl (mg/L)	BDL -14.5	4.3	4.6	BDL - 18	5.3	5.4
PO_4 (mg/L)	BDL -0.7	0.2	0.2	0.004 -0.9	0.2	0.3
SiO_2 (mg/L)	3.8 - 30.9	11.6	5.6	2.4 - 31.6	13.6	6.0

Ca (mg/L)	0.1 -44.3	5.6	8.1	0.6 -11.3	4.1	2.8
Mg (mg/L)	1.9 -26.1	8.1	5.8	0.4 - 28.5	5.8	4.8
Na (mg/L)	1.0 -10.5	3.6	2.4	1.8 - 14.3	4.9	2.7
HCO_3 (mg/L)	20 - 226	65.5	44.2	18 - 78	40.6	15.6
NH_3 (mg/L)	0.01 -0.3	0.10	0.1	0.01 -3.9	0.3	0.7
SO_4 (mg/L)	2.1 -23.2	13.1	4.8	0.2 - 23	11.3	6.7
K (mg/L)	0.2 -5.7	1.6	1.4	0.1 -10.0	2.3	1.9
NO_3 (mg/L)	0.01 -1.9	0.3	0.4	0.004 - 0.4	0.2	0.1
Fe (mg/L)	BDL -0.8	0.3	0.2	BDL - 1.2	0.2	0.2
Total Chlorine (mg/L)	BDL -0.3	0.1	0.1	BDL - 0.3	0.1	0.1
Free Chlorine (mg/L)	BDL - 0.3	0.04	0.04	BDL - 0.2	0.1	0.1

Table 8 : Salient features of primary water quality data analysis

Parameters	Mean	St. Deviation	Range
pH	7.5	0.6	4.2-9.6
TDS (mg/L)	87.7	66.1	10-430
EC (µS/cm)	106.0	93.0	16-656
DO (mg/L)	7.0	1.5	3.1-9.5
BOD (mg/L)	1.7	2.6	0.1-20.0
Turbidity (NTU)	95.7	165.1	2-914
Hardness (in mg/L as $CaCO_3$)	51.6	38.6	4-218

Table 9: Rivers facing major quality threats in Assam, India

River	Status	City/Town contributing to water quality degradation
Bharalu River	Highly polluted	Guwahati, Assam
Basistha River	Highly polluted	Guwahati, Assam
Kolong River	Moderately polluted	Nagaon, Assam
Bhogdoi River	Threatened	Jorhat, Assam

Burhi Dihing River	Threatened	Dibrugarh and Margherita, Assam
Pagladiya River	Threatened	Nalbari, Assam
Disang River	Threatened	Namrup, Assam
Barak River	Threatened	Silchar, Assam
Khanajan River	Moderately polluted	Jalukbari, Guwahati, Assam
Boko River	Highly polluted	Boko, South Kamrup, Assam
Kalbhog	Highly polluted	Palashbari, South Kamrup, Assam

8. Strategies to control river pollution of the Brahmaputra Basin

The river water quality conservation and restoration need to be carried out with a systematic approach that can address all issues starting from pollutant generation to the impacts of water pollution on riverine ecology. In the Brahmaptra basin, population explosion is the main reason of degrading river water quality. The rivers that are passing through or in approximate to the urban centers are under threat. Urban centers of the region are lacking in proper waste disposal, sewage or storm water management systems. Besides, watershed degradation due to the growing urbanization has led to increase in yield of non-point pollutants like sediment into the rivers. The following focused approaches to water quality management of the basin may be adopted

8.1 Development of River Water Quality Information System

A water quality information system for the rivers of the region incorporating all information relevant to the rivers can help to assess the existing status regarding physiographic characteristics and water biochemistry of the rivers. This should include records of large numbers of attributes regarding water quality, flow, water velocity, discharge, shape, size, present aquatic community etc of a river system at different temporal and spatial dimension. It is also important to maintain the records of such changing river history for projection of future trends of such variables and management of the river system through appropriate action plan and mitigation measures. The system can facilitate efficient monitoring and management of rivers if updated in a regular basis.

River information systems, if developed in GIS platform can provide easy updating and efficient management of large databases of river systems (Sarma et al., 2010).

8.2 Development of region specific river water quality guidelines

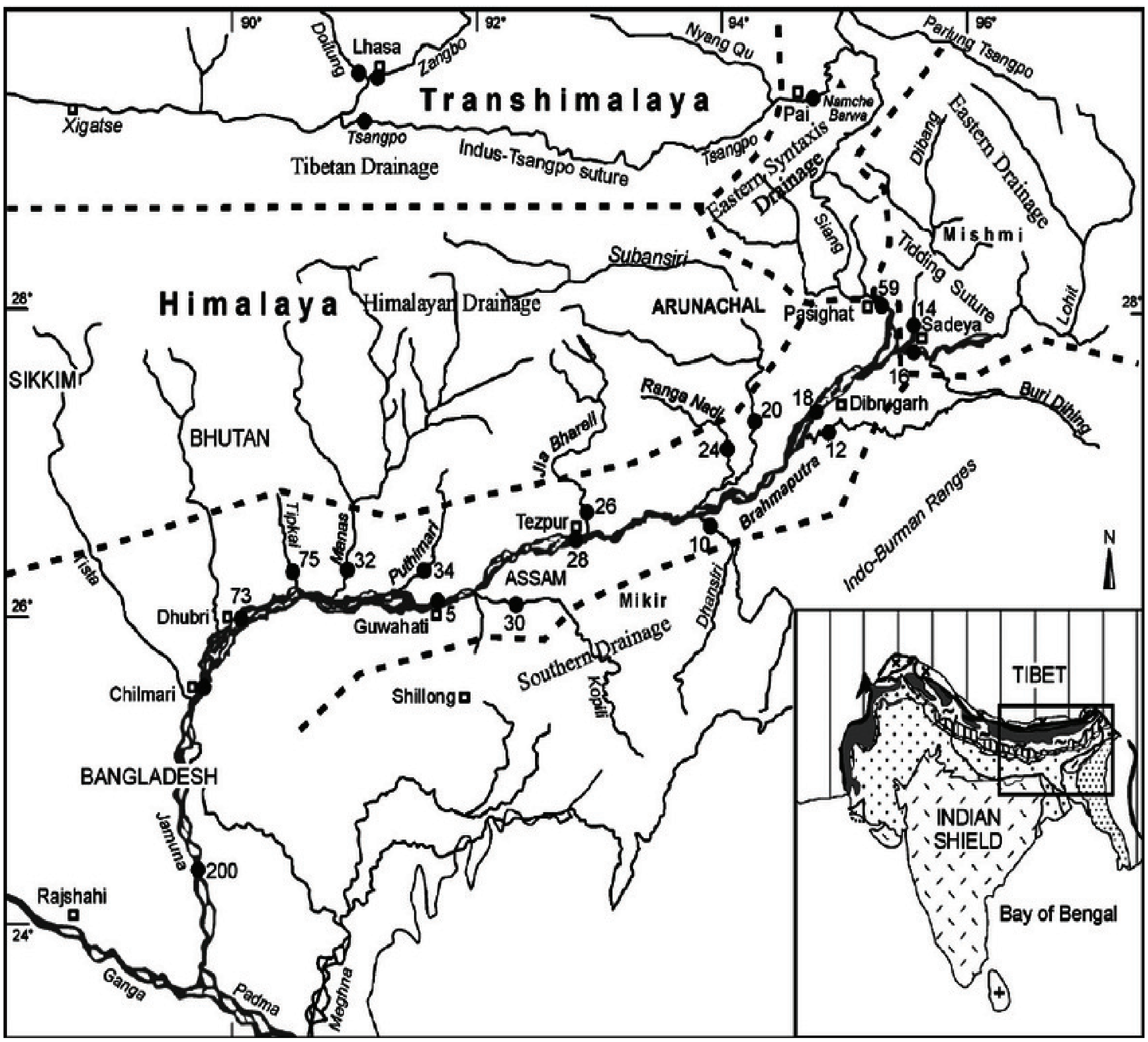
Considering the uniqueness and high discharge of the basin, comparisons of water quality of these rivers against general water quality guidelines may not be adequate enough to evaluate the impact of growing urbanization and the gradually degrading water quality of the rivers. There is a need of developing specific water quality guidelines for the rivers of the region to prescribe allowable effluents discharge to the rivers in the line of Total Maximum Daily Load (TMDL). This can indeed be quite different from the standards maintained for rivers located in highly industrialized areas, where maintaining strict standards can be difficult. Despite urbanization and limited industrialization, most of the rivers of the region are still very much within the Indian National norms and other standards. However, some of the rivers have moved towards the medium water quality, which is also of concern considering the background pristine status of the region. Also, imposing stricter quality standards can be not only practical for these rivers, but also highly desirable and it will help to maintain the river water quality within the self purification capacity of the rivers. The rivers of the region are rich in aquatic biodiversity and so it is necessary to maintain their pristine status for the larger benefit of unique ecosystem. As such, development of the regional river water quality standards should consider the inherent characteristics of the landmasses through which the river passes and the pristine water quality status, which is contributing to the uniqueness of the river ecosystem of the region.

Besides, to maintain healthy ecosystems, maintenance of “environmental flow” or e-flow with respect to the minimum water quality for the rivers of the basin should be a national priority. According to Smakhtin et al . (2004); e-flow required for the Brahmaputra river is 27%, however there are many tributaries with high ecological importance for which determination of e-flow should also be emphasized so that an efficient water quality standard can be developed for the basin.

8.3 Adapting efficient measures to control river water pollution

Several structural and non-structural measures can be adopted to protect the rivers from pollution. Structural measures mainly include solid waste treatment plants and effluent treatment plants which should be made mandatory to every urban centers and effluent generating units. Besides, Ecological Management Practices (EMPs) like river buffer zone with grass and trees, Contour terracing, Mulching, Grass land, Agro forestry, Vegetated waterway and Gully control measures can also tackles problems with non point pollutants. In fact some of such practices like Contour terracing and Mulching are traditionally practiced in hilly agricultural watersheds of NE India and observed to be efficient sediment control measures.

Applicability of such EMPs for watershed management has been studied for different countries oh the world and with prior knowledge of their effectiveness to control different pollutants can be applied to the river systems of Brahmaputra basin, which may provide cost effective and feasible solution in controlling yield of non-point pollutants into the rivers.



Map No 7 : Drainage Map of the Brahmaputra Basin(Singh et al, 2006)

Fish are invariably one of the most important biotic components of an aquatic ecosystem, which apart from forming protein rich food source for human beings, also act as a good bio indicators of a water body. The Brahmaputra and its tributaries are endowed with huge varieties of freshwater fish biodiversity. Among the several kinds of inland freshwater bodies, the riverine system holds a unique position in terms of ecosystem, which generally covers different types of climatic zones, landscapes and bio-geographic regions. However, the cleanliness of rivers is one of the primary factors required for sustenance of aquatic life. So far, there are no specific records and systematic study on the hydrobiology and fish inventory. Biswas and Borua (2000) in a study highlights the hydrobiological features and the ichthyofauna of selected waterbodies of northeastern Himalayas with special reference to the Brahmaputra river. The study found alarming siltation of the Brahmaputra and shrinkage of 'beels' through weed infestation and eutrophication, which adversely affect the habitat and thereby the fish fauna. The degradation of river basins, particularly through shifting cultivation (*jhum*), a widely practised method throughout the hilly areas of the region, and also large-scale felling of trees in the catchment areas lead to increased suspended sediment load. Indiscriminate killing of brood and juveniles, destruction of aquatic biota by careless application of pesticides in the paddy fields and tea gardens, and fishing pressure were responsible for the gradual depletion of major fisheries in the Brahmaputra system. But the most shocking feature is the unscrupulous use of poison and explosives in the highlands of northeastern region that resulted not only in the depletion of carp fishery but also wiped out many rare varieties of ornamental fish. Implementation of all fisheries and conservational acts are suggested to check the rapid depletion of aquatic fauna from the Brahmaputra drainage system.

Map No 8: Local fishing by small nets on the Brahmaputra is a favourite pastime particularly for those living by the bank of the river

Table 10 : Significant aquatic and riparian biodiversity (plants and animals)

The 30 most important fish species present in the Brahmaputra Drainage System				
Family and species	Habitat	Frequency	Distributional status	
Notopteridae				
1	Notopterus chitala (Ham.)	Riverine	Occasional	Indian sub-continent and South-East Asia
Anguillidae				
2	Anguilla bengalensis (Gray)	Riverine	Rare	Indo-Burmese
Clupeidae				
3	Hilsa (Tenualosa) ilisha (Ham-Buch)	Riverine	Rare	Ganga Brahmaputra and the Far East
Cyprinidae				
4	Catla catla (Ham.)	River and beels	Common	Indo-Burmese
5	Cirrhinus mrigala (Ham.)	River and beels	Common	Indo-Burmese

6	Labeo calbasu (Ham.)	River and beels	common	Indo-Burmese
7	L. gonius (Ham.)	River and beels	Common	Indo-Burmese
8	L. pangusia (Ham.)	Streams and river	Occasional	Hindukush Himalayan region
9	L. rohita (Ham.)	River<comma> beels<comma> ponds	Abundant	Indian sub-continent
10	Neolissocheilus hexagonolepis	Rivers and upland waters	Occasional	Himalayan region
11	Puntius sarana (Ham.)	Almost all lentic and lotic systems	Occasional	Indo-Burma and the Far-East
12	Riamas bola (McClelland)	Streams and rivers	Rare	Indo-Burmese
13	Schizothorax richardsoni (Ham.)	Hill-streams	Occasional	Eastern Himalayan streams
14	Tor putitora (Ham.)	Sluggish streams	Rare	Himalayan region
15	T. tor (Ham.)	Sluggish streams	Rare	Himalayan region
Bagridae				
16	Aorichthys aor (Ham.)	Rivers and beels	Common	Indo-Burma and the Far-East
17	A. seenghala (Sykes)	Rivers and beels	Common	Indo-Burma and the Far-East
18	Mystus menoda (Ham.)	Riverine	Occasional	Indo-Burmese
19	Rita rita (Ham.)	Riverine	Occasional	Indo-Burmese
Siluridae				
20	Ompok bimaculatus (Bloch)	Riverine and beels	Occasional	Indo-Malayan
21	O. pabda (Ham.)	Riverine and beels	Occasional	Indo-Malayan
22	Wallago attu (Schneider)	River<comma> beel and tanks	Very common	Indian sub-continent and the Far-East
Schilbeidae				
23	Clupisoma garua (Ham.)	Riverine	Occasional	Indo-Burmese
24	Eutropiichthys vacha (Ham.)	Riverine	Occasional	Indo-Burma and the Far-East
25	Silonia silondia (Ham.)	Riverine	Occasional	Indo-Burmese
Pangasiidae				
26	Pangasius	Riverine	Occasional	Indo-Burma and the Far-

	pangasius (Ham.)			East
Sisoridae				
27	Bagarius yarrellii Sykes	Riverine	Occasional	Indo-Burma and the Far-East
Clariidae				
28	Clarius batrachus (Linn.)	All types of water bodies in the plains	Common	South Asia and Africa
Channidae				
29	Channa marulius (Ham.)	Muddy sluggish shallow waters	Common	Indo-Burma and the Far-East
30	C. striatus (Bloch)	Muddy sluggish shallow waters	Common	Indo-Burma and the Far-East

Source: Boura and Biswas, 2000

9. Conflicts over rivers

The management challenges have emerged and loomed large, especially because of the lack of the ecosystems perspective. While interlinking of rivers have been thought without considering the ecosystem concerns, hydropower projects and other forms of anthropogenic interventions in upper reaches of the sub-basin are also devoid of the same. However, the concerns raised by India about the hydropower project in the Tibetan boundary does not hold much ground from the ecological, social, and economic standpoint, as there is neither much water flow, nor much sediment load in the upper reaches of the basin to really affect the downstream economy. As such, the impacts of hydro-power projects in the tributaries to Brahmaputra, upstream of Sadiya, need not be seen whether the project is Chinese or Indian. Based on climatic and geophysical knowledge, the distinction will be between hydro-power dams in the northern and southern aspect of the Himalaya. With small water and sediment contribution in the northern aspects of the Himalayas as compared to the southern aspects, even a water transfer project in the northern aspects will have limited impact on the downstream southern aspect.

10. River restoration Plan in the Brahmaputra Basin

Bharalu River restoration project: The Bharalu River suffers from severe degradation as it flows through the city of Guwahati. The DPR for conservation of *Bharalu* River was prepared for Government of Assam, to be submitted to the National River Conservation Directorate of Ministry of Environment and Forest of Government of India for consideration for funding. These include restoration of fresh water flow from upstream, diversion of drains from falling into the river, maintenance of water quality, ensuring augmentation of natural flow and prevention from solid and liquid waste dumping. Since Guwahati city is yet to have a sewerage system, the problem has become intensified. However, under JNNURM, provision of a sewerage system coupled with sewerage treatment plant has been assigned a high priority by GMDA and this should result in significant improvement in the water quality of Bharalu due to prevention of freely flowing sewage from numerous drains. Thus, an important complementary component of the project will be to integrate with the trunk sewer facility currently under consideration within JNNURM initiative to carry waste water flows generated by the growing population. These short and medium term solutions provided to relieve the pollution problems in the drains and sub-drains should integrate well with the planned long term solutions for Bharalu. The long term goal is to improve not only the water quality of the river, but to conserve the Bharalu River as a healthy urban fluvial ecosystem.

The DPR provides a plan and cost estimates of undertaking restoration and conservation activities for the Bharalu River to be protected and improved, to evaluate the alternatives of re-establishing upstream freshwater flow for improving the quality of water in the river and to carry out a techno – economic study of simpler options for recommendation of the most feasible project. Based on preliminary field observations, secondary data and primary data from field, easily accomplishable options have been suggested, instead of sophisticated technologies that have been already found to be unsustainable in other rivers of the country, primarily due to O&M issue.

10.1 Primarily the following key steps are proposed:

1. Physically securing the river along with a buffer zone on both banks all along the longitudinal profile of the channel. Fencing of all accessible section of the river is

recommended considering that unabated discharge and dumping of liquid and solid waste is almost unstoppable by any other means. A typical cross section is suggested as below along with corresponding cost estimate in the DPR. Simultaneously, all drains flowing to Bharalu will require screens to retain solid waste and the liquid waste to be diverted by an interceptor drain to be treated separately.

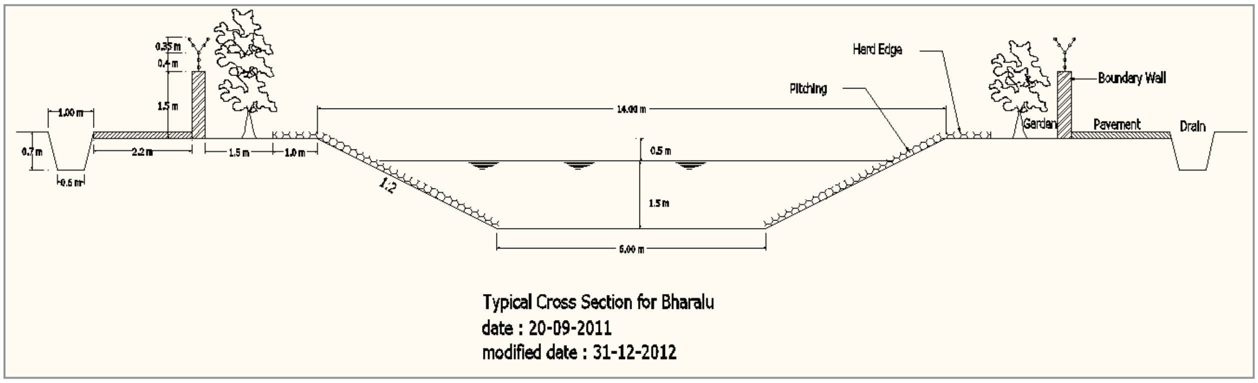


Figure 14 : Cross section of Bharalu River

2. Restoration of flow of Bahini from upstream to downstream beyond the current sluice to rejoin with the (now) dead channel of Bahini across National Highway bypass and then to further downstream to Bharalu so that fresh water from Basistha to Bharalu is reconnected (with the provision of stopping the flow by operating the sluice during flood season so that no additional water logging hazard is created by the additional monsoon flow) and augmented to flush out the waste-water from the Bharalu channel and normal flow for river sustainability be restored. A complete planning is possible only after a confirmed political decision to remove encroachment and restore the connecting channel of Bahini with Bharalu so that continuous flow from the catchment is restored. Continuous fresh water flow is a necessary condition for future water quality conservation of the entire Bahini-Bharalu system.
3. Ensuring sustainable source for continuous and available flow during dry season and adequate widening and de-congestion of the Bahini- Bharalu channel from source to confluence with Brahmaputra, so that sufficient continuous flow is available for water and sediment flushing and any unavoidable debris. While stopping sediment transport from the rock quarries and other hill cuttings and erosion particularly from the Basistha hill catchment and Meghalaya hills is a mandatory necessity, in order to maintain and

conserve the health of the river bed, it has to be ensured that sediment deposition in Bharalu river bed is within threshold. If the ecological integrity of the river bed is to be maintained, deposition must be stopped and only selective dredging of bottom should be necessary to be carried out carefully, maintaining the gradient of the river bed and ensuring continuous flow of water along with sustaining river ecology.

4. Installation of a decentralized wastewater treatment system with STP. This will need to be implemented by a sewerage network and intercepting sewer drains. Sewerage network is to be separated from storm water drainage system and measures to be taken to protect the STPs from risk of entry of storm water laden with heavy sediment load due to erosion from the city hills during monsoon. This called for a separate DPR preparation considering the technical challenges of a seasonally changing river varying between and heavy flood and very low flow. As it was not within the scope of this DPR, the relevant aspects from the Sewerage DPR prepared separately by GMDA has been integrated suitably so that a complete river management and conservation can be envisaged.
5. De-encroachment of river front areas is to be ensured so that these river fronts can be developed as integral part of the basin. As has been indicated, where space is available, identified areas can be converted into parks, gardens, memorials and rest can be used for parking lot and playground for children and senior citizens. For instance, the area currently occupied by the Bharalumukh police station can be considered to be cleared up and a river front garden with memorials can be established for children and senior citizens.
6. A complete plan is possible only after a confirmed decision to remove encroachment and restore the connecting channel of Bahini with Bharalu so that continuous flow from the catchment is restored. This is a necessary condition for future water quality conservation of the entire Bahini-Bharalu system. The exact space available after de-encroachment and eviction of illegal occupancy will provide scope for further planning the river front.
7. The possibility of reclaiming a part of the river bank in proximity of Sankardev Udyan without compromising the flow in the river channel can be explored so that this additional land at the junction of Bharalu and Brahmaputra can be used for locating a memorial (eg: for Bhupen Hazarika). The other option could be to locate a waste water treatment plant at such a location after all other necessary considerations. Relocation of

the Bharalu bridge, the police station and the narrow corridor to ease future traffic problems may also require consideration. This will call for further detail survey of the location including the river front which has to be carried out independently. We did not keep this provision in the DPR proposal as of now.

10.2 Conservation of Kolong River

River *Kolong*, originating in the eastern part of Nagaon District of Assam(India) from River Brahmaputra at Hatimura near Jakhalabandha (about 50 kms east of Nagaon town and to the west of the Kaziranga National Park) as a tributary of the river Brahmaputra, flows through Nagaon, Morigaon and Kamrup Districts before discharging into Brahmaputra in *Kolongpar* near Guwahati. During the 1960s, when there was devastation caused by flood from *Kolong* River, the government closed the entry point of *Kolong* from Brahmaputra by erecting a dyke. This made the *Kolong* water stagnant and degraded. Kopili, a major tributary of *Kolong*, merges with *Kolong* near Dharamtul. Between the point near Hatimura (now sealed) which is the point of origin of *Kolong* river and to the point of its confluence with Kopili, the stretches of nearly 187 km is degraded and choked with silt and water hyacinths and the water is murky and polluted.

Public concern and initiative for restoration and conservation of Kolong is a welcome move that was long due. The purpose of restoration and conservation is for physical, chemical, and biological upkeep of the river as a healthy environmental system, preferably through simple, easy-to-implement yet dependable, means. These may include possible restoration of fresh water flow from upstream, diversion and treatment of waste water drains from falling into the river, maintenance of water quality, ensuring augmentation of natural flow and prevention of encroachment and solid and liquid waste dumping. The Kolong River today suffers from major degradation as it flows through the Nagaon town. Since Nagaon town is yet to have a sewerage system, the river water degradation has become intensified. However, provision of sewerage system coupled with sewage treatment plants has been assigned a high priority by urban development ministry and ministry of environment and forest and this should result in opportunity for prevention of freely flowing sewage from numerous drains. An important complementary component of a Kolong conservation project will be to integrate it with a trunk sewer facility to carry waste water flows generated by a growing population. Meanwhile, any short and medium term solutions provided to relieve the pollution problems in the drains and sub-drains should integrate well with planned long term solutions for Kolong. The long term goal is to improve not only the water quality of the river, but to conserve the Kolong River as a healthy urban fluvial ecosystem.

A technological strategy and cost estimates of undertaking restoration and conservation activities for the Kolong River should include evaluation of alternatives for re-establishing upstream freshwater flow for improving the quality of water in the river and to carry out a techno – economic study of simpler options for recommendation of the most feasible immediate steps. Based on preliminary field observations, secondary data and primary data from field, easily accomplishable options can be suggested, instead of sophisticated technologies that have been often found to be unsustainable in other rivers of the country, primarily due to O&M issues.

While the river must be kept safe from untreated waste water, it is the most urgent need that natural flow is restored through Kolong by allowing fresh water flow from upstream particularly during the dry season through the possible installation and operation of a series of sluice gates at its origin from Brahmaputra, which is currently lying permanently closed in order to provide safety from potential flood risk during rainy season to save the downstream towns from flooding. This possibility however must be investigated and examined carefully in order to have a foolproof mechanism. Since the current lift irrigation infrastructure at Hatimura is under performing due to eroding infrastructure, and power requirement is a major limitation, this mechanism is not suitable to augment water in Kolong. Water from tributaries Dizu and Misa is not adequate for Kolong. Upstream flow augmentation has to be integrated with the maintenance of physical features of the river through careful channel dredging maintaining required gradient, river front development, and other environmentally sound river management practices. If limitation of data availability can be overcome, design outline and financial requirement can be laid out in a DPR for achieving these objectives. The history of degradation and pollution of Kolong river is decades old now, so intervention of suitable scale and resources are essential for its complete restoration and conservation. Particularly in the face of continuing urban onslaught, this remains a constant and continuous challenge and should be undertaken gradually in the increments of solid steps, even if it is going to take some time.

11. Climate change impacts in the Brahmaputra Basin

The effect of climate change on the Brahmaputra basin is expected to be strong due to three major reasons[2] i.e. Influence of snow and ice melt on stream flow, increased monsoon rain intensity, increase in sea level rise hampering the drainage of rivers. Bolch et al., (2010) found that the glaciers in this area have been retreating at a rate of around 10 m/year for the period 1976 to 2009. The increased rates of snow and glacial melt are likely to increase summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear and snowfall diminishes (Immerzeel 2008). This is particularly true for the dry season when water availability is crucial for the irrigation systems. Immerzeel et al., (2010) stated that the Brahmaputra is most susceptible to reductions of flow. The basin is extremely sensitive to intense southwest precipitation and subsequent flooding and if any climate change event even slightly results in variability in the intensity and reliability of the monsoon, it will affect both high and low flows, leading not only to increased flooding but possibly also to increased variability of available water, Gain et al., (2011) found that climate change is likely to lead to reduced frequency of extreme low flow conditions and also an increase in peak flows. Ghosh and Datta (2011) also found that the impact of climate change is likely to be greater compared to changes in land use/land cover in the basin. A study by IWM and CCC (2008) found that the frequency of flood flows in the Brahmaputra River at Bahadurabad has already increased compared to earlier flow records. As a result, the modeling study found that with climate change, the frequency, extent and depths of floods would increase further in flood plains of Assam.

Another report[3] notes that in the North- Eastern Region the increase with respect to 1970's is by 0.3% to 3%. The north-east also show a substantial decrease in rainfall in the winter months of January and February in 2030's with respect to 1970's with no additional rain projected to be available during the period March to May and October to December. However, the average monsoon rainfall during June, July and August is likely to increase by 5 mm per day in 2030's with reference to 1970's, a rise of 0.6%.All regions are projected to have an enhanced rainfall in 2030's with respect to 1970's. The increase in rainfall in 2030's with respect to 1970's varies 5

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[2] (Mahanta et. al.2014)Ecosystems for Life: A Bangladesh-India Initiative IUCN, International Union for Conservation of Nature December 2014

[3] Climate change and India,INCAA report, 2010 MOEF

% in all the simulations carried out. Surface air temperature is projected to rise by 25.8 to 26.8 °C in 2030's with a standard deviation ranging from 0.8 to 0.9. The rise in temperature with respect to 1970's is ranging from 1.8 to 2.1 °C. Minimum temperatures are likely to rise from 1 to 2.5 °C and maximum temperatures may rise by 1 to 3.5°C. The number of rainy days is likely to decrease by 1–10 days. The intensity of rainfall in the region is likely to increase by 1–6mm/day.

A study by (Mahanta et.al, 2014) infers a gradual increase of temperature in the Brahmaputra basin. The increase of temperature ranges from 0°C to 4.5°C by 2050 & from 0°C to 6°C. The average increase of monthly temperature ranges from 1.3°C to 2.4°C by 2050 & 2°C to 4.5°C by 2100, with the increase more in dry and winter months than in monsoon. The average increase of monthly evapotranspiration ranges from 5% to 18% by 2050 and from 7 to 36 % by 2100 and likewise temperature the variation is more likely to be in the dry and winter season. The results show that large increase in monsoon flows tends to lead to an increase in the lean season (base) flows with the change of monthly average flow due to climate change more prominent in summer months (Mar, Apr, May) compared to wet (Jun, Jul, Aug, Sep) and winter (Dec, Jan, Feb) months.

Table 11 : Projected changes in climate

Item	2021-2050 wrt BL	Remarks
Mean Temperature	1.7-2.0º C	All across Assam
Annual Rainfall	-5 to 5%	North western districts
	5-10%	North Eastern districts
	10-25%	Central, SouthEastern Districts
Extreme rainfall days	5-38%	Rainfall >25 to 150 mm
Drought weeks	-25% to >75%	Southern districts show marginal reduction in drought weeks but rest of the district show an increase by more than 75% wrt BL

Floods	Stream flow <10% to >25%	Min in NE and Max in Southern part of the State

District level climate projections are available across Assam driven by A1B scenario15 for the period 2021–2050 using regional climate model PRECIS, a model developed by the Hadley Centre, UK Met office. Temperatures continue to rise and may increase by 1.7-2 °C wrt to base line. Only the western part of the State will experience slight decrease in rainfall but the rest of Assam is projected to have increase in rainfall. There is likely to be increase in extreme rain fall event by 5 to 38% w.r.t to base line. Drought weeks are going to rise, with Southern districts showing marginal reduction in drought weeks but rest of the district show an increase by more than 75% wrt BL. As regards floods, they are going to rise by more than 25% in the southern parts of Assam. Ravindranath et al., (2004, 2006) concluded that under the climate projection for the year 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types under different scenario.

12. Conclusion

From qualitative aspects, futuristic scenario of the northeast rivers indicate their chance of survival as productive ecosystems because anthropogenic interventions has still not reached gargantuan proportion as in case of other important river systems of India such as the Ganges, and the Yamuna or rivers of the south like the Cauvery, the Krishna or the Mahanadi. Although flood has negative implications to public life and property, ironically annual flooding also acts as a cleansing mechanism by taking all the physical and chemical contaminants of the entire Brahmaputra floodplain, starting a new cycle every year. Most of the solid, municipal and industrial wastes actually get diluted and diffused by the heavy monsoonal surge in the river. While some rivers of the northeast are severely polluted, most rivers have moderate or low pollution mainly due to their rejuvenated life every year during monsoon season. By and large, the rivers of northeast are mostly flowing rivers. It has been particularly ensured by generous monsoon and large amount of flow from Bhutan or the Himalayas. As the rivers get ample amount of fresh water and monsoon contribution, simple management practices like not allowing waste water to drain into them and not allowing them to coming in contact with untreated sewage and human excreta would be good enough for their general health.

Evaluating the status of a large unique alluvial river like Brahmaputra with respect to hydrology, morphology, water quality and biodiversity is almost of impossible proportion – particularly when future scenarios due to enhanced pollution load compounded by less understood phenomenon like climate change impact is considered. The role of annual seasonal flooding in terms of rejuvenating the grassland ecology and supply of particulate nutrients to the floodplain is undeniable and needs to be continued. Yet, unusually high flood and lack of adequate treatment during dry season are two extreme annual challenges. The condition of urban tributaries receiving municipal pollution load is inexplicable. The dry season conditions are challenging to water quality, also due to potentially enhanced water depletion – although it has not yet assumed the alarming proportion in non-urban tributaries. What is clear is that if ongoing practices are to continue, without an improved treatment and rather prevention arrangement with a forward looking solution seeking exigency, may not help to reverse the trend of degradation. As such, average per capita water availability in Brahmaputra is much higher during monsoon than global average, although it is lower than in dry winter. Various sectors of water quality management reflect: (a) Lack of adequate appreciation of harm caused to the river by water quality degradation and absence of remediation efforts; (b) complex and unknown discharges from upstream oil fields, coal fields and other urban and industrial sources; (c) incomplete and only partly accessible hydrological or water quality data base; and (d) disillusionment by public and communities of past pollution mitigation efforts due to their failure to deliver.

This can possibly be changed with a pragmatic hydrological governance and pollution prevention through local government with the help from local communities and stakeholders. Key among these changes are (a) utilization of key data, technology and best management practices to develop strategy for water quality, social and environmental security of the affected river stretches; (b) increased accountability by the pollution control authorities to examine and accommodate the water quality management and sustainability aspects; and (c) thoughtful consideration for decision making vis-à-vis steps to be taken for countering detrimental water degradation impacts and ensuring safe water flow within available and possible hydrological units judiciously, focusing not only on wider, long-term sustainability aspects, but also on those corresponding activities that have immediate impact on hydrological and environmental security at the river stretches. River management authorities must be able to create and manage an environment of scientific understanding of the hydrological and water quality challenges and their mitigation that encourages initiatives consistent with sound water safe guards of the tributaries and the main stem, and discourages activities that pose threat while inflicting social and environmental loss to the water quality as a fall out of abuse and exploitation of rivers.

The following have clearly emerged:

1. The entire Brahmaputra floodplain, including the landforms and water bodies contained within it are almost entirely defined by the extremely fluctuating flow conditions governed by its contrasting hydrological and environmental conditions influenced both by water flow and sediment transport in an unique way. Extremes in flow and sediment transport also make it an ideal fluvial system where climate change impacts can have pronounced implications. In this backdrop, ensuring and maintaining excellent water quality in the river is an utmost necessity.
2. Flooding as a natural phenomenon has provided a spontaneous cleansing system in all the tributaries of the Brahmaputra River and in predominantly pristine conditions has a set of positive roles to play in all the river stretches including urban parts. However, spells of pollution do take place at urban and industrial locations, and particularly the widespread discharge of untreated sewage that often happens on continuous spells in all the seasons inflicts negative consequences particularly to water quality, often accompanied by further casualties due to accidental spills and industrial effluents.
3. During the flood season, bank failure of sediments and selective deposition are too a regular phenomenon, invariably leading to turbidity and siltation in undesirable locations including wetlands and fertile farm areas, thereby causing distress to human and other life forms alike. A major handicap is the lack of scientific knowledge base that should help adopting pragmatic policy regarding taking up proper preventive and remediation steps, invariably in multiple spells. Prima facie it appears logical to reduce both frequency and intensity of pollutant loading by regulating waste water discharge through appropriate technology to be chosen carefully. This may range from in situ treatment to ecological engineering options like phyto-remediation. Vegetation based bioengineering applications should be better alternative, to be designed and implemented carefully.

All above responses should be done keeping in mind the enhanced intensity of water quality degradation as well as industrial pollution threat due to often unregulated impact on Brahmaputra hydrology and hence ecology.

The role of sediment both as source and sink of contaminants must be kept in mind due to combined impact of physical and chemical perturbations on main Brahmaputra and tributary inflows from upstream transport and erosion. Brahmaputra is an obvious case in point where water quality degradation is greatly influenced by only few intensely polluted urban tributaries like Bharalu, Kolong, Bhogdoi with immediate outfall to main Brahmaputra before being treated. Stagnation of flow at river mouth often compounds the problem and hence solutions must take into account aspects other than conventional approaches like waste water treatment alone.

However, there are rivers on the verge of extinction which is the cause of greater concern. It is an entirely different story for rivers which are flowing through intensively urbanized areas like Guwahati, Jorhat, Nagaon. There are concerns about some relatively smaller but highly polluted rivers flowing through densely populated region which are facing death as a pristine ecosystem or some of the rivers can be described as dead rivers. Examples of highly polluted rivers which are mainly flowing through the urban areas are the Bharalu in Guwahati city, the *Bhogdoi* in Jorhat, and *Kolong* in Nagaon,. These rivers have been observed to be having very poor quality of water, full of sludge even during the rainy season. Although contaminants in the rivers are diluted during rain and flooding, but as soon as the monsoon is over, they become extremely polluted once more as the rivers mostly drain city and urban drainage. So the greater focus of the polluted northeast rivers pertains to those urban rivers which not only have been deprived from natural fresh water flow from upstream, but they have essentially turned into urban drainages. These polluted rivers needs special attention, strong policy intervention as well as stringent measures for their restoration as well as conservation keeping in mind future urban population increase, industrial effluents and solid waste dumping. Specific scientific intervention including waste water treatment plants, bank development practices and other best management practices are essential for these dying rivers. These rivers needs initiatives of greater dimensions like structural measures to treat waste water, to develop river front and to maintain both freshwater flow and quality. There is also urgent need of mass awareness campaign to sensitize people about river restoration and rejuvenation, to involve local youths and school children in cleaning river banks under NSS schemes and keeping an eye on the river to prevent dumping of wastes in a rivers and for quality monitoring. The threatened rivers obviously cannot be restored in their entirety in a short span but at least should be maintained in reasonably good health so that it should not become a perpetual source of disease burden to the people living on the bank of the rivers For the polluted rivers, adoption of a strategic approach to control river water pollution may be suggested to ensure sustainability of the river ecosystems of the basin. Several practices generally followed elsewhere such as vegetative strips, forest buffer zones, detention pond and retention basins seems to have good potential for the rivers of Brahmaputra basin, particularly if complemented with sustainable structural measures such as waste water treatment plants and solid waste management system, that can save one of the few most pristine large alluvial rivers left on the face of the earth.

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