IRBM for Brahmaputra Sub-basin

Water Governance, Environmental Security and Human Well-being

Jayanta Bandyopadhyay
Nilanjan Ghosh
Chandan Mahanta

IRBM for Brahmaputra Sub-basin

Water Governance, Environmental Security and Human Well-being

Jayanta Bandyopadhyay
Nilanjan Ghosh
Chandan Mahanta

Observer Research Foundation
20, Rouse Avenue Institutional Area,
New Delhi - 110 002, INDIA
Ph. : +91-11-43520020, 30220020
Fax : +91-11-43520003, 23210773
E-mail: contactus@orfonline.org

©2016
Copyright: Observer Research Foundation

ISBN: 978-81-86818-22-0

ALL RIGHTS RESERVED.
No part of this book shall be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright holder (s) and/or the publisher.

Typeset by Vinset Advt., Delhi
Printed and bound in India

Cover: Vaibhav Todi via Flickr.

Table of Contents

About the Authors

Jayanta Bandyopadhyay is a retired Professor from IIM Calcutta. He obtained his PhD in Engineering from IIT Kanpur, and after completing his doctoral work, shifted his research interests to the Himalaya and, in particular, the challenges in sustaining the region's rivers. He was Coordinating Lead Author for the global exercise, *Millennium Ecosystem Assessment*. He was the Chair for the Scientific Advisory Committee of the G B Pant Institute for Himalayan Environment and Development, Almora (2007-12). He serves as adviser to the Water Diplomacy Program at the Fletcher School of Diplomacy, Tufts University, US. His latest publication by Springer (New York) is titled, *Environmental Sustainability from the Himalaya to the Oceans: Struggles and Innovations in China and India*.

Nilanjan Ghosh is Senior Fellow (Professor) and Head of Economy and Development Programme at ORF Kolkata. He is also Senior Economic Adviser at the World Wide Fund for Nature, New Delhi. A natural resource economist and econometrician by training, he obtained his PhD from the Indian Institute of Management in Calcutta. His publications include six books and numerous research papers in various journals like *Water Policy, Conservation and Society, Journal of Industrial Ecology, Journal of Index Investing* and *EPW*. His most recently co-edited book, *Nature, Economy, and Society: Understanding the Linkages*, published by Springer (India) attempts to delineate the evolution and scope of the interdisciplinary framework of ecological economics.

Chandan Mahanta is an alumnus of Delhi University and Jawaharlal Nehru University. He was former Head and Professor at the Centre for the Environment and currently a Professor in the Department of Civil Engineering at IIT Guwahati. He has been an ASCE-EWRI Visiting Fellow at the Utah Water Research Laboratory of the Utah State University, US, and in 2014 attended the Hydro Diplomacy programme jointly hosted by MIT, Harvard University and Tufts University. He has authored more than sixty technical publications in peer-reviewed journals, proceedings and books. One of his major projects on *Digital Brahmaputra* attempted to leverage IT applications in building robust hydrological information systems. His current research engagements are focused on sustainable drinking water and sanitation, and river restoration and management.

Acknowledgements

We would like to acknowledge (deceased) Prof. Pranab Ray, without whose initiative this research project would not have even begun. His untimely demise in April 2015 was a big loss. We appreciate the help of Mr. Mihir Bhonsale, Junior Fellow, ORF Kolkata who provided research assistance for this project. Two anonymous reviewers who commented on this Report provided valuable inputs.

Mr. Ashok Dhar, Director, ORF Kolkata Chapter, was the prime motivator behind the project. While a two-year academic project cannot be expected to be perfectly smooth-sailing, Mr. Dhar's unwavering interest in the Water programme of ORF Kolkata, and his massive support to the Brahmaputra sub-basin management project, provided us tremendous support. Mr. Sunjoy Joshi, Director, ORF, has always been encouraging, and followed the project with keen interest. In the same vein, we acknowledge Dr. Samir Saran and his team at ORF Delhi. We would also like to acknowledge Prof. Rakhahari Chatterji, Adviser, ORF Kolkata, and all the faculty members of ORF-Kolkata for their support and helpful comments at various stages of this research.

Jayanta Bandyopadhyay
Nilanjan Ghosh
Chandan Mahanta

Foreword

Observer Research Foundation (ORF)-Kolkata embarked on its Water Resources Management and Governance programme in 2014, following a lecture delivered by Prof. Pranab Ray on the challenges of Brahmaputra sub-basin management. Held in February 2014 at the ORF-Kolkata campus at Rajarhat, the lecture was commented upon by Prof. Jayanta Bandyopadhyay. A seminar paper was published thereafter, and in discussions with Prof. Ray and Prof. Rakhahari Chatterji, ORF-Kolkata Adviser, we planted the seed of a new research project on IRBM for Brahmaputra. I requested Prof. Jayanta Bandyopadhyay to join in the project. Dr. Nilanjan Ghosh then joined our Chapter, and the "IRBM for Brahmaputra sub-basin" project.

The Water programme got a boost over the last two and half years, with the publication of articles in peer-reviewed journals, as well as the holding of important events at our chapter, the most recent one being the "South Asia Water Dialogue". There have been important policy-relevant publications emerging from this programme. Our scholars have regularly been commenting in the media on critical issues of water sharing over the Ganges-Brahmaputra-Meghna basin, the National Framework Water Bill, the Farakka sedimentation issue, and the Cauvery water conflicts. Nilanjan Ghosh's recent commentary on the Farakka and the Cauvery were critically acclaimed, and resulted in a new debate in the discourse on looking at water conflicts. Similar was the case with a recent paper on India-Bangladesh hydro-political relations by Jayanta Bandyopadhyay and Nilanjan Ghosh, which evoked interest in the policy research community.

Meantime, the untimely demise of Prof. Pranab Ray not only affected us on a personal level, but also triggered a pause in the IRBM research project on Brahmaputra. We were fortunate to eventually get on-board Prof. Chandan Mahanta, and his scholarly contribution helped in completing this important work.

This report is the result of the scholars' hard work over more than two years. One of the most unique findings presented in this report is that unlike other river basins, the overarching challenge of the Brahmaputra does not lie in the neo-Malthusian thinking of physical scarcity of the resource. Rather, the overarching challenge lies in the co-existence of extensive poverty and ample water availability –indeed a developmental paradox. The authors perceive that the explanation of the paradox needs to be related to the lack of an ecosystems perspective in river basin management. To address this, the authors propose an institutional setup in the form of a river basin organisation. This will be of particular interest to the country's policymakers.

This is a rare occasion of the coming together of a multi-disciplinary team consisting of an environment and development expert, an engineer, and an economist. This research will therefore be of interest to policymakers, academics, water-resource managers, institutionalists, research professionals, and also the general public. I congratulate the authors for producing this important and highly relevant piece of research work.

Ashok Dhar
Director, ORF Kolkata

October 13, 2016

Preface

The Brahmaputra sub-basin—spread over Bangladesh, Bhutan, China and India and part of the Ganges-Brahmaputra-Meghna basin—has historically been endowed with abundant water. Yet the populations who live in the region have not benefited from the natural wealth of the sub-basin; the levels of poverty are high. Traditional development theory makes a direct correlation between scarcity of natural resources (like water) and poverty. In the case of the Brahmaputra sub-basin, however, the paradox is clear: "ample water, ample poverty". The situation is not expected to improve in the future, and the governance of the Brahmaputra will continue to be a huge challenge. Environmental security and the promotion of human well-being are two of the most crucial aspects of such difficult task. 'Environmental Security' is defined in this report as "a state of absence of conflicts in the complex and interconnected relations in and between the biological, social, economic and cultural processes of human societies and the natural environment." It depends on various factors such as the dynamics in the natural environment, population change, and degree of access to environmental resources.

It is in this context that this report examines the tenets of Integrated River Basin Management (IRBM), where ecology and ecological economics of water are defined as important cornerstones. This report challenges the notions of "surplus" and "deficit" river basins—concepts that are used often in current literature on India's water resources—and highlights the lack of an ecosystem perspective in the country's river basin management. This absence creates an important void in India's policymaking and practice and is true in the case of the management of the Brahmaputra sub-basin.

The report utilises the Drivers-Pressures-State-Impacts-Response (DPSIR) approach to understand the critical management challenges in the sub-basin. The four-fold management challenges for the Brahmaputra are: floods, bank erosion, and shifting of river flows; hydropower projects within the Indian territory creating situations of conflict, and the hydropower projects in the Tibet region of China; proposed water transfer projects entailing the interlinking of rivers; and the concerns of global warming and climate change. These management challenges are magnified by the lack of an ecosystem perspective, which creates threats at the social-economic-ecological interface of human existence, through the critical ecosystems-livelihoods linkages.

The authors argue that while interlinking of rivers is being proposed without considering the eco-systemic concerns, hydropower projects and other forms of anthropogenic interventions in the upper reaches of the sub-basin are also lacking the same perspective. However, the concerns raised in the Indian press about the impacts of hydropower projects in Tibet appear exaggerated and do not hold much ground from the ecological, social, and economic standpoint. This is because there is little water flow, and equally little sediment load in the upper reaches of the basin to initiate any significant impact on the downstream economy of the sub-basin. As such, the potential impact of the hydro-power projects in the tributaries to the Brahmaputra, need not be distinguished as being in either Chinese or Indian territory. The more important concern is that based on climatic and geophysical knowledge, the distinction will be between hydro-power dams in the northern and southern aspect of the Himalaya. With less water and sediment contribution in the northern aspects of the Himalayas as compared to the southern, even a water transfer project in the northern aspects will have limited impact on the downstream southern aspect.

This present work argues that the present national level institutional structures—like the Brahmaputra Board or the proposed Brahmaputra River Valley Authority—will be inadequate to address present and future challenges. The authors recommend that a better institutional response to the management challenges to promote IRBM in the Brahmaputra sub-basin will be the setting up of a transboundary river basin organisation, considering the lower Brahmaputra for the time being. The lower Brahmaputra sub-basin, in this context, has been delineated by the area within the Brahmaputra sub-basin that falls within the political boundaries of Bhutan, Bangladesh and India. In the initial stages of institutional development, the inclusion of Yarlung-Tsangpo upto the point where it enters India, draining the dry region in the Tibetan Plateau, is deemed to not be of immediate utility for the purposes of this report.

The four-fold management challenges in the Brahmaputra have arisen primarily from the lack of both an ecosystem perspective and a systems approach to basin management. Such fragmented approach to river management has led to the aggravation of floods in the region. There is scarcely any knowledge creation on the eco-hydrology of the floods in the sub-basin, nor are there serious efforts at a broader basin scale on understanding the hydro-geo-morphological foundations of the flood process. Every nation in the sub-basin has attempted to address the problem of floods in their own ways, and that too, through local-level strategies like the building of embankments. Further, the lack of data and weak information dissemination have fractured research efforts on creating better models for the prediction of flood intensity and the setting up of early warning systems. As such, the fundamental relation between flood and sediment load has not been properly established—floods have been viewed as “unmixed” damage, and their role in provisioning services of the ecosystem, for example, by enhancing soil fertility and supporting ecosystem services through soil formation is often not understood. It has often been stated that further downstream in the river Brahmaputra, the main course is carrying more of sand than the nutrient-rich finer sediments. One of the reasons for the same might be the destabilisation of the riverbed from extensive boulder mining in the upper reaches of the sub-basin.

At the same time, there is hardly any systemic approach to learn about the impacts of interventions like the hydropower projects and interlinking of rivers at the scale of the sub-basin. This is another example of a missing ecosystems approach in river management, threatening the environmental security of the region. There needs to be a “bird's eye” approach by looking holistically at the various transitions at the sub-basin scale so that the environmental security is not threatened.

Adding another dimension to the discourse is global warming and climate change. Though there are national-level plans to address climate change, the impacts across the sub-basin as has been documented by the International Centre for Integrated Mountain Development

(ICIMOD) (2015) need particular attention. As such, understanding the impacts of global warming and climate change at the scale of the sub-basin is highly important for creating a sustainable management regime. This is not possible without a broader systemic approach.

Therefore, existing institutional mechanisms at the national level might be inadequate to address regional-level challenges. This necessitates the setting up of a trans-boundary organisation that will have a bird's eye view of the challenges, understand and correlate the micro-level nuances in the cross-section of the sub-basin, and take a systems approach to combat the issues.

It is a fact that complex river basins all over the world, where water is contested bitterly, are getting organised for cooperative governance. An attempt has been made to promote IRBM through a mechanism like the Organisation for Governance of the Lower Brahmaputra Sub-basin (OGLOBS). It has been conceived as a trans-boundary river basin organisation jointly overseen by the concerned governments. Autonomous in character, the OGLOBS will be responsible for providing guidelines for water systems management in the sub-basin as well as guidance in long-term strategy-making for basin-level governance of water. It will be armed with regulatory powers to penalise those who do not adhere to these guidelines. The powers can be vested in this Organisation on the basis of an Agreement by the three nations of the lower Brahmaputra sub-basin, i.e., Bangladesh, Bhutan and India—these three nations can be called the member nations of the OGLOBS.

The report suggests objectives, institutional responsibilities, financing mechanisms, and a broad organisational structure and composition for the OGLOBS. It presents the tentative broad structure that needs to be reviewed, reshaped, and the substance that needs to be rightly placed. Further research is needed for that. In the case of the Brahmaputra sub-basin, the issues are multi-layered not only because of the complex nature of hydro-political relations between the concerned nations, but also because of a complicated and yet not properly understood social-ecological interactive system, and the grave management challenges.

While there is no doubt that a harmonised cooperative regime for the Brahmaputra sub-basin could be achieved through a structure like OGLOBS, trust and political will among the nations is the key to achieve the protocols, agreements, and a legislative arrangement to develop together to fit into the mandate of IRBM. Finally, an organisation like OGLOBS is going to be an important step in helping achieve the Sustainable Development Goals (SDGs). A more informed water management regime that will understand the critical ecosystem processes and services of water in terms of providing sustainable food security in the region, clean water and sanitation, sustenance of aquatic ecosystems, can help in the long run in achieving the SDGs.

1 The Brahmaputra River Sub-basin

1.1. Introduction

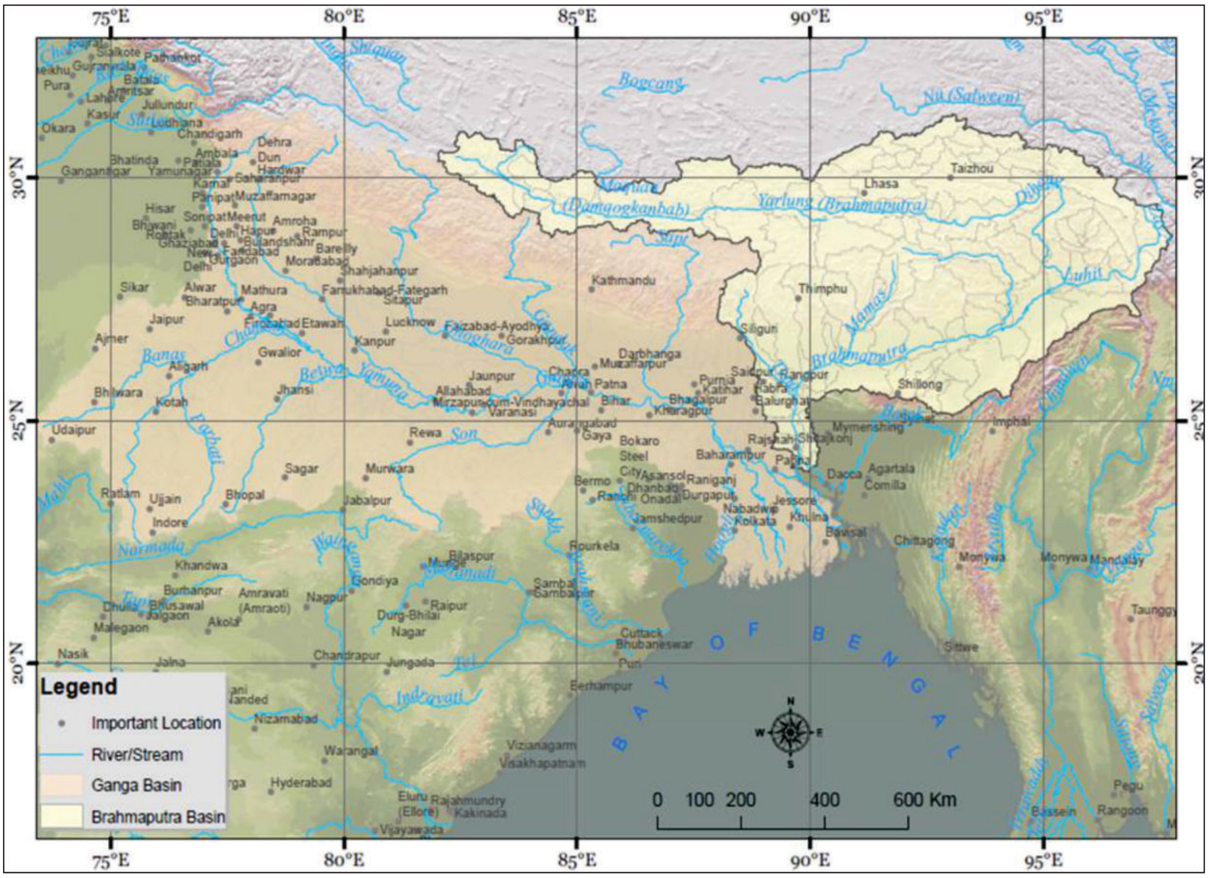
One of the longest and most critical, yet least understood river systems in the world is the Brahmaputra sub-basin in South Asia. Richly endowed in terms of annual availability of water flows, the sub-basin is also afflicted with high levels of poverty. This “ample water, ample poverty” phenomenon, a paradox in development theory, is prevalent across the broader Ganges-Brahmaputra-Meghna basin (of which the Brahmaputra system is a sub-basin), and gets amplified in the Brahmaputra which receives high levels of summer monsoon precipitation, causing floods, land erosion, and changing course of the river.

A highly complex river system of South Asia and a narrow stretch of Southern Tibet of China, India's northeast, all of Bhutan, and also large part of Bangladesh, the Brahmaputra flows across unique geo-environmental and bio-physical settings. Through its long course, it has local, regional and international significance and implications. The total drainage catchment of the river is 580,000 km, of which 50.5% is in China, 33.6% is in India, 8.1% is in Bangladesh and 7.8% is in Bhutan (Immerzeel, 2008). In India, the sub-basin is shared by the states of Arunachal Pradesh (41.88%), Assam (36.33%), Nagaland (5.57%), Meghalaya (6.10%), Sikkim (3.75) and West Bengal (6.47%).

Most records point to the Chemayungdung Glacier as the source of the Brahmaputra (as identified by geographer Swami Pranavananda). More recent explorations by Chinese scientists, however, have discovered its origin to be the Angsi Glacier, located on the northern aspect of the Himalaya in Burang County of Tibet (Krishnan 2011). The longest tributary to the Brahmaputra is Yarlung Tsangpo, which originates in the Angsi Glacier at an elevation of 5,300 masl (metres above sea level). The three headstreams that form the Yarlung-Tsangpo are the Kubi, the Angsi, and the Chemayungdung. From its source, the Yarlung river flows for nearly 1,100 km in an easterly direction between the main range of the Himalaya to the south and the Kailas Range to the north. Given its drainage pattern in terms of its main course and tributaries, the Brahmaputra sub-basin's dominion extends over China (Tibet), India, Bhutan and Bangladesh. The total length of the main course in India beginning from Korbo in Arunachal Pradesh to Dhubri is 918 km, while the one from Dhubri in Assam to its confluence with Padma near Goalundo in Bangladesh is 337 km. After this confluence, the channel formed by the joint flow with the Meghna discharges into the Bay of Bengal (Goswami 2001).

This report concerns the stretch of the Brahmaputra sub-basin from Korbo till Goalundo. The series of tributaries and distributaries feeding this channel are considered to be integral components of the basin.

Fig. 1.1: The Brahmaputra sub-basin in South Asia



The river gets the name 'Brahmaputra' after the flows of three major tributaries, Luhit, Dibang and Siang/Dihang meet near the town of Sadiya in Assam. As such, a majority of tributaries constituting this river system are small rivers fed by monsoon rain and spring water, whereas its tributaries in Tibet are primarily fed by snow and ice (Sarma 2004).

1.2. The course of the Brahmaputra

While running from its source for around 1,100 km in a generally easterly direction between the main range of the Himalaya to the south and the Kailas Range to the north, the mainstream is known as Yarlung-Tsangpo in Tibet. This mainstream passes through Pe (Pi) in Tibet, and then after taking a northward turn, it moves towards the northeast. Then it traverses through a series of narrow gorges between the mountainous massifs of Gyala Peri and Namcha Barwa in a succession of rapids and cascades. Thereafter, the river turns southwest through a deep gorge across the eastern extremity of the Himalaya with canyon walls that extend upward for 16,500 ft and more on each side. During that stretch, the river enters northern Arunachal Pradesh state in northeastern India, where it is known as the Siang and turns more southerly. It gets the name Dihang as it enters the State of Assam.]

It makes a rapid descent from its original height in Tibet, and finally appears in the plains in Arunachal Pradesh. The dramatic reduction in the slope of the river as it cascades through one of the world's deepest gorges in the Himalaya before flowing in to 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 wide valley downstream. Two rivers, the Dibang and the Luhit, join the downstream flow of Siang, known as the Dihang, a little south of Pasighat and west of Sadiya town (Goswami 2001). The combined flow, hereafter named Brahmaputra, flows westward through Assam for about 640 km until near Dhubri in Assam, where it abruptly turns south and enters Bangladesh. Below this confluence with Dibang and Luhit, the river is called Brahmaputra. As it enters the state of Assam, the braided channel becomes as wide as 10 km in parts. It is joined in Sonitpur by the Kameng River (or Jia Bhareli).

The Brahmaputra is a mighty river whose stream-flow increases further as it flows downstream. Even during the dry seasons, the distance between the parallel banks are in the area of 8 km (Bora 2004). As the river follows its braided 700-km course through the valley, it receives several rapidly rushing Himalayan streams, including the Subansiri, Kameng/ Jia Bhareli, Dhansiri, Manas, Champamati, Saralbhanga, and Sankosh Rivers. The main tributaries from the hills and from the plateau to the south are the Burhi-Dihing, Dikhu, Kopili,among others.

During its flow between the districts of Dibrugarh and Lakhimpur, the mainstream divides into two channels, the northern Kherkutia channel and the southern Brahmaputra channel. The Majuli island, a river island (known as a *char* in local language), is formed by the southern Brahmaputra channel, the northern Kherkutia channel, and the Subansiri River in the north. The island is about 200 km east from the Assam's largest city, Guwahati.

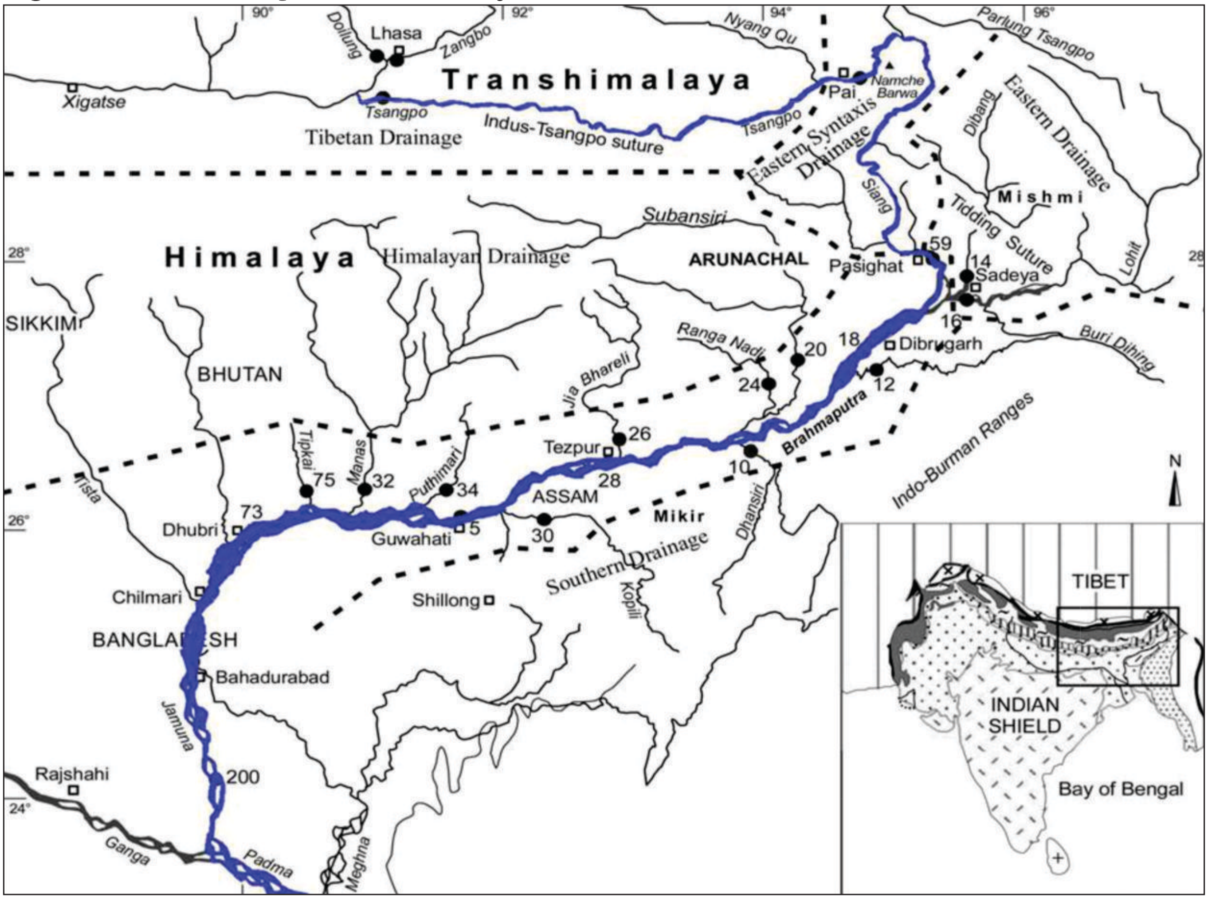
At the head of the Brahmaputra valley at Dibrugarh, the river flows through a gradient of 0.15 m/km which gets further reduced as it reaches the plains near Pandu in Guwahati. From here, the river flows downstream westwards for a distance of around 640 km upto the Bangladesh-India border near Dhubri (Bora 2004). In this stretch, it is joined by numerous tributaries, emerging from both the south aspect of the Himalaya and the north aspect of the Meghalaya hills.

From Dhubri, the Brahmaputra turns southwards and enters Bangladesh, where it is called Jamuna. An important transboundary tributary of the Brahmaputra-Jamuna in Bangladesh is the Teesta river, which emerges from Sikkim and the northern parts of West Bengal in India. The Teesta feeds the mainstream with substantial flow. Below the Teesta, the Brahmaputra-Jamuna splits into two branch channels: one moving towards the west and the other moving towards the east. The western branch carrying the lion's share of the streamflow, continues due south as the Jamuna to merge with the lower Ganges flowing from west through India and is known as Padma in Bangladesh. The eastern branch that formerly dominated the flow regime, but is now substantially reduced, is called the lower or old Brahmaputra.

The confluence of the Jamuna with Padma near Goalundo town is considered to be lower (southernmost) limit of the Brahmaputra sub-basin in the context of this study. Prior to reaching this confluence, the Jamuna is fed by the right-bank tributaries like Baral, Atrai, and Hurasagar rivers and Dhaleswari on its left bank. A tributary of the Dhaleswari, the Buriganga ("Old Ganges"), flows past the city of Dhaka, the capital of Bangladesh. It joins the Meghna river above Munshiganj.

Below the confluence, their combined waters flow to the southeast for a distance of about 120 km as the Padma. Near Chandpur, the main body of the Padma reaches its confluence with the Meghna River and then enters the Bay of Bengal through the Meghna estuary and lesser channels flowing and forming the Ganges-Brahmaputra-Meghna delta, the largest delta region of the world. The biodiversity hotspot, the mangrove forests named Sundarbans is located at the southern extremity of this Delta.

Fig. 1.2: The Brahmaputra and its major tributaries



Source: http://www.indiawaterportal.org/articles/coping-floods-and-erosion-brahmaputra-plains

1.3. Mythology and History

The name 'Brahmaputra' finds mention in Kalika Purana, a mythological text of Hindu tradition, which is believed to have been written around 10th Century AD (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 religious tradition. Later, it is believed, sage Parasurama cleaved the bank of the Brahmakunda (on river Luhit) to cause the Brahmaputra to flow as a river and inundate part of 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 locals, 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).

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

The following account is from the *Bulletin of the American Geographical Society*, 1915. Darjeeling-born Sikkimese geographer named Kinthup (or K.P. in British records) spent four years between 1879 and 1882 and vindicated these findings. 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. They moved along the Tsangpo from Arunachal Pradesh eastwards up to the western end of the big gorge through the Himalaya and then returned. In 1880 a Chinese Lama was given the task of continuing G.M.N's exploration of the Tsangpo and Kinthup accompanied 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. 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 Col. C.B. 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, even—he had to rely on his memory in giving the account of his travel, extending up to four years and covering a large area. The report 'Explorations of the North-East Frontier during 1911-12-13' by Col. 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. 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, did scientists from the Chinese Academy of Sciences identify the Angsi Glacier as the origin of Yarlung-Tsangpo.

1.4. Water, People and Culture

The Tsangpo-Brahmaputra is considered sacred in Bhutan, India and Tibet (China) by the local population, characterised by a multiplicity of cultures. The literal meaning of its Tibetan 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 Miri tribe which inhabits Lower Subansiri and Upper Subansiri districts of Arunachal Pradesh derives its name from water or river (Singh 1995).

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 is also reflected in their cultures. For example, the original word for 'Jhalo' is 'julla' meaning 'water' and 'malo' meaning malla, infantry, their original occupation being fishing and infantry (Singh 2003).

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 instructions from the Lama (Singh 1995). In their community, cremation is not allowed if sowing in the field has been done, as it is believed that the scents emanating from a body being burnt may affect the crops. The Membas, a tribe living in West Siang district of Arunachal Pradesh, also dispose of the dead in the water (Singh 1995).

1.5. The Land-use of the Brahmaputra sub-basin

The Brahmaputra sub-basin supports the livelihoods of over 66 million people through subsistence agriculture (Srinivasan et al., 1998) and fishing. Along the upper reaches of the Brahmaputra (Yarlung Tsangpo) in Tibet, the vegetation is mainly drought-resistant shrubs and grasses (Singh et al., 2004). As the river descends from Tibet, increased precipitation supports the growth of forests such as Shorea robusta (sal), a valuable timber tree found in Assam. At lower elevations, tall reed jungles grow in the swamps and depressed, water-filled areas (jheels) of the floodplains. Communities in the Assam Valley primarily grow tea in the upper reaches, and cultivate fruit trees including banana, papaya, mango and jackfruit elsewhere. Bamboo thickets are also prominent throughout Assam and Bangladesh (World Bank, 2007). Most agricultural land in the lower basin is dedicated to paddy. (See Fig. 1.3 for the Map of the Land Use Land Cover in the Brahmaputra sub-basin and Table 1.1 for the summary information including length, area, and land use for the Brahmaputra sub-basin.)

Fig. 1.3: Land Use Land Cover in the Brahmaputra sub-basin

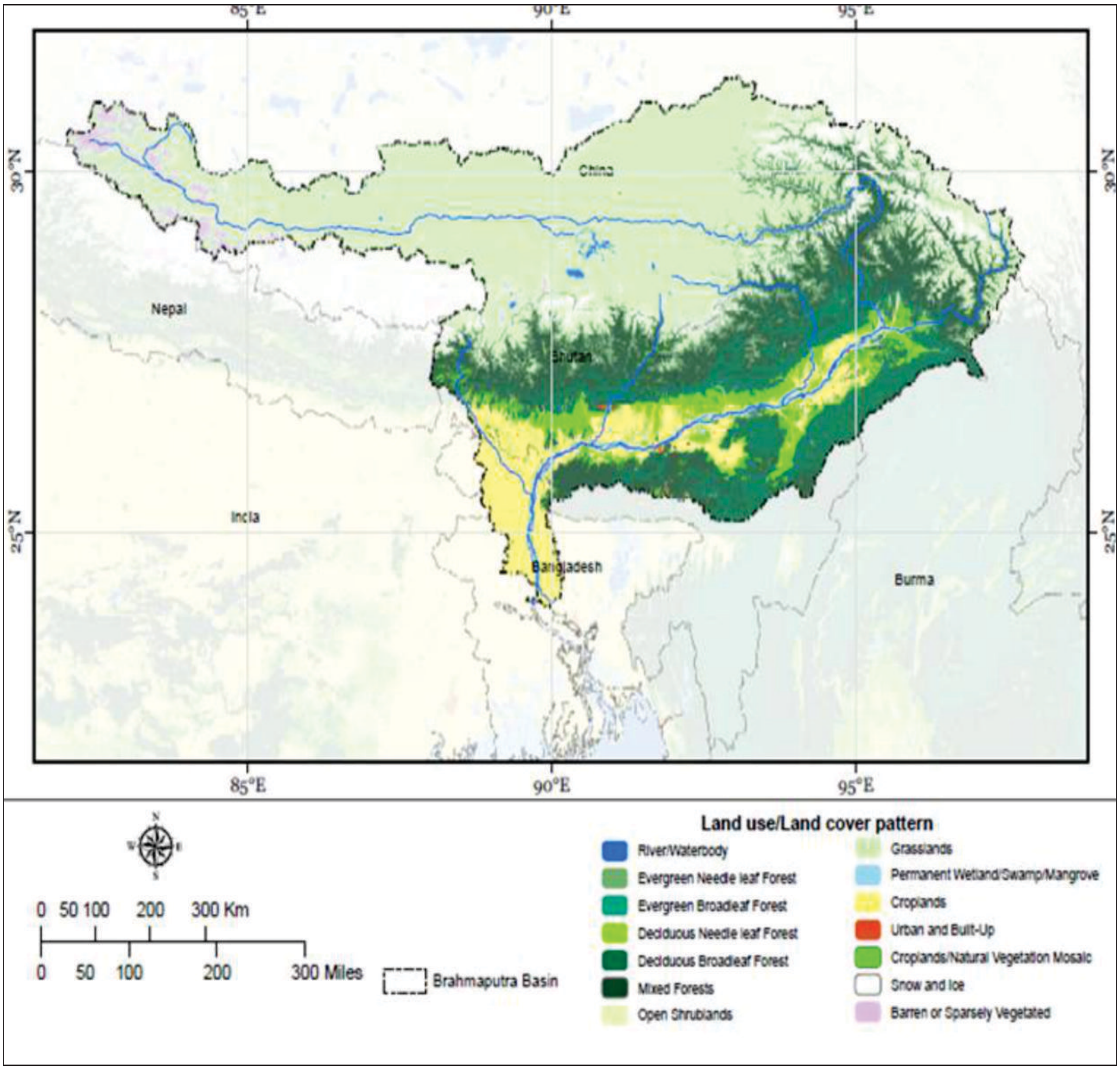


Table 1.1

Summary reach information including length, area and land-use for the Brahmaputra sub-basin								
			Percentage of Land use					
Reach	Length (KM)	Area (KM²)	Snow & Ice	Forest	Grassland	Cropland	Urban	Barren
1	250	22272	0.90	3.5	87.6	0.0	0.0	8.0
2	335	31296	1.20	6.5	88.3	0.0	0.0	4.0
3	350	54912	0.80	0.6	98.6	0.0	0.0	0.0
4	509	61120	4.60	6.0	89.4	0.0	0.0	0.0
5	407	77120	23.80	49.8	23.5	2.8	0.0	1.0
6	224	60160	1.40	59.3	20.1	19.2	0.0	0.0
7	221	40768	1.60	43.5	21.5	33.2	0.2	0.0
8	183	59904	3.40	43.5	34.5	18.5	0.0	0.1
9	77	35840	2.00	19.8	27.1	50.4	0.2	0.5
10	144	9792	1.30	0.0	2.6	96.1	0.0	0.0

Source: Whitehead et al. (2015)

1.6. Precipitation and Hydrographs

The precipitation varies substantially across the Brahmaputra sub-basin. The sub-basin receives primarily two types of precipitation, rainfall and snowfall. Due to variability of climate, altitude, temperature, pressure, latitude, and orography, and variable interactive impacts of different prevailing winds like the monsoon, trade winds, westerly disturbances, and continental cold air., the precipitation pattern is different in different locations.

As such, the Tibetan component of the basin, i.e., the stretch of the Yarlung river, being located on the northern aspect of the Himalaya, receives far less precipitation as compared to the southern aspect, i.e. the stretch in India, Bhutan and Bangladesh. The Tibetan plateau and the higher reaches of the basin above 3000 masl receive snowfall during the winter months from December to February. Further, the southeastern part of Tibet receives the monsoon rains during the months of July and August (Datta and Singh 2004).

Therefore, as a trans-Himalayan tributary, Yarlung is largely fed by snow and glacial melts, with some rainfall. The annual precipitation in the trans-Himalaya averages about 300 mm per year. As the tributaries cross the Himalayan crest line reaching the south aspect, the annual average precipitation (mainly rainfall) reaches about 4000 mm. The mean annual rainfall over the whole catchment excluding the Tibetan part is around 2500 mm (Bandyopadhyay and Ghosh 2016). Within the Assam valley, the average annual rainfall is more towards the northeast and gradually decreases towards the west. In the peak flow periods, the Brahmaputra is fed by the monsoon but during the lean season, the share of its flow from the Yarlung river would be larger, the extent of which needs to be based on flow data. Table 1.2 shows the precipitation across the various stations in the basin, and reveals how the Lhasa in the northern aspect of the Himalayas receives much less rainfall as compared to the regions in the southern aspect of the Himalayas in India, namely, Dibrugarh, Tezpur, and Guwahati, and in Bangladesh, namely, Bahadurabad.

Table 1.2

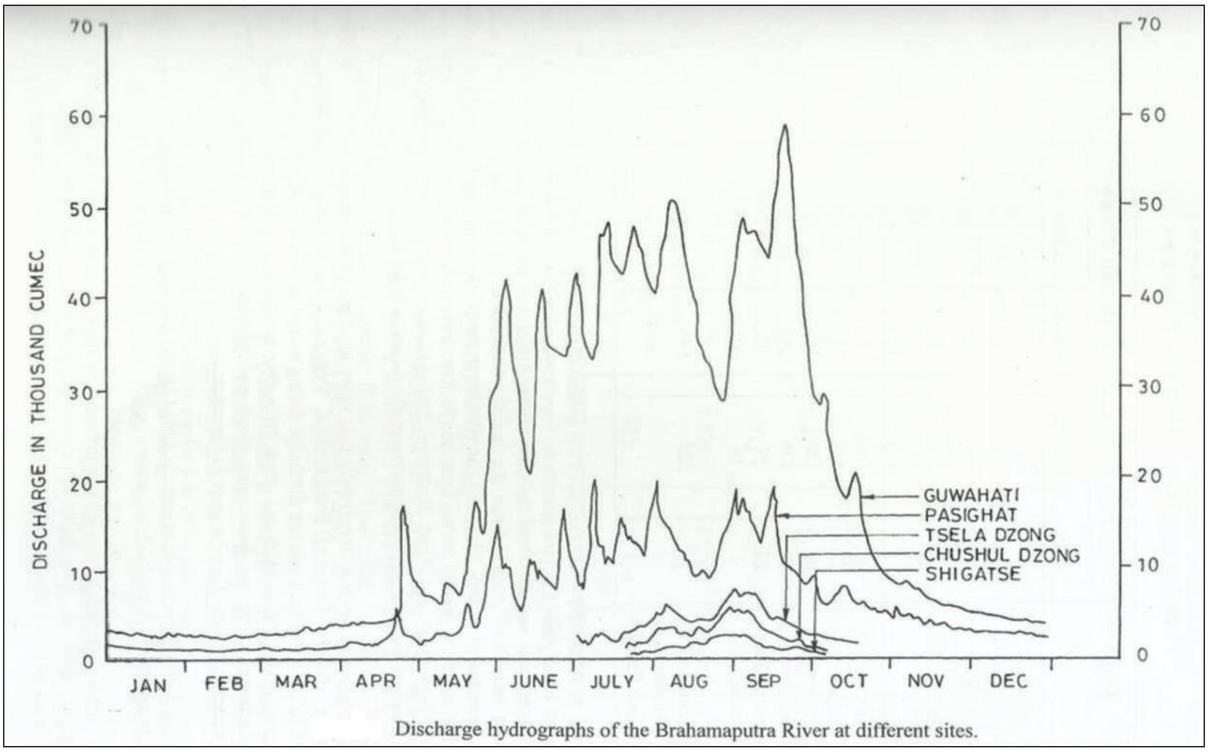
Mean monthly rainfall across five stations within the Brahmaputra sub-basin					
Station	**Lhasa**	**Dibrugarh**	**Tezpur**	**Guwahati**	**Bahadurabad**
Month	**Rainfall (mm)**	**Rainfall (mm)**	**Rainfall (mm)**	**Rainfall (mm)**	**Rainfall (mm)**
January	3	38	15	10	10
February	13	62	27	4	13
March	8	103	48	25	33
April	5	241	153	145	88
May	25	307	271	236	283
June	53	500	308	312	439
July	122	536	348	312	428
August	89	451	331	261	370
September	66	352	210	167	306
October	13	152	104	71	164
November	3	53	23	14	15
December	0	16	6	4	2
Total	**400**	**2811**	**1844**	**1561**	**2151**

Source: (Data compiled by the authors from various sources)

Such differences in precipitation have resulted in huge variations in the flow regimes across the basin. As such, a large component of the total annual flow of Brahmaputra is generated in the southern aspect of the Himalaya in India by tributaries from Buri Dihing in the East to Teesta in the west. As per data published by Jiang et al. (2015), the total annual outflow of the Yarlung river from China is estimated to be about 31 BCM while the annual flow of Brahmaputra-Jamuna at Bahadurabad, the gauging station near the end of the sub-basin in Bangladesh, is about 606 BCM. These figures do not support the linear algebraic thinking that the flow on a river in a country is proportional to its length inside that country. Further, while the peak flows at Nuxia and Tsela Dzong, a gauging station at the great bend in the Tibetan plateau, are about 5,000 and 10,000 cumecs, as presented by Singh et al (2004), the peak flow at Bahadurabad is approximately 50,000 cumecs. The lean season flow in Nuxia, as identified from a hydrograph given in Rivers and Lakes of Xizang (Tibet) (in Chinese), is to the tune of 500 cumecs, while the lean flow at Bahadurabad is about 5000-odd cumecs.

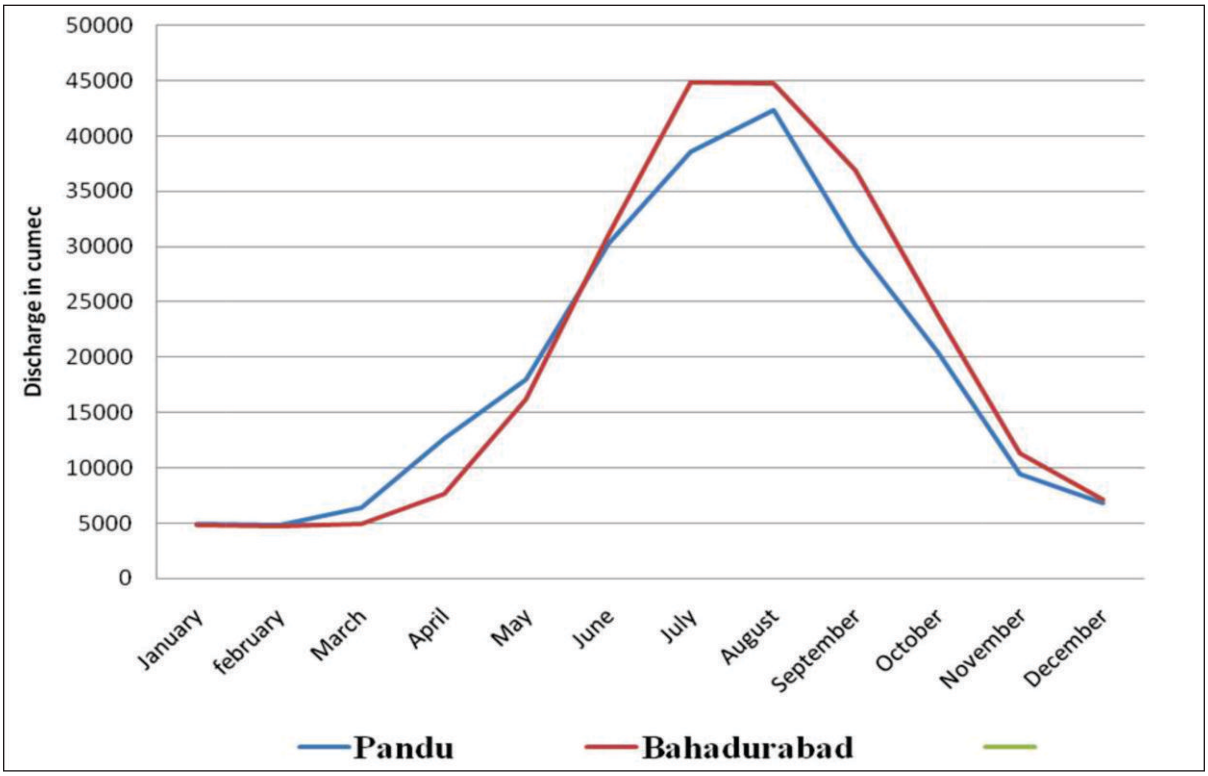
This is particularly due to the intense monsoon precipitation on the southern aspect of the Himalaya. While Nuxia receives around 350 mm of rainfall during monsoon, as the river Siang crosses the Himalayan crest-line and reaches the southern aspect, the annual rainfall in Pasighat may touches about 4000 mm. Such precipitation, flow volume, and discharge in the Yarlung river is not sufficient to generate and transport carry a large sediment load. Further, the annual suspended sediment load near Nuxia has been measured to be around 30 million metric tonnes, (as suggested in a 2016 volume titled *River Morphodynamics and Stream Ecology of the Qinghai-Tibet Plateau* by Wang and colleagues), which is minuscule as compared to same load measured as 735 million metric tonnes at Bahadurabad. However, in case of hydro-power projects in the southern aspect, their role in trapping sediment will be significant.

Fig. 1.4: Relative Hydrographs of Brahmaputra sub-basin



Source: Datta and Singh (2004)

Fig. 1.5: Relative Hydrographs at Pandu and Bahadurabad



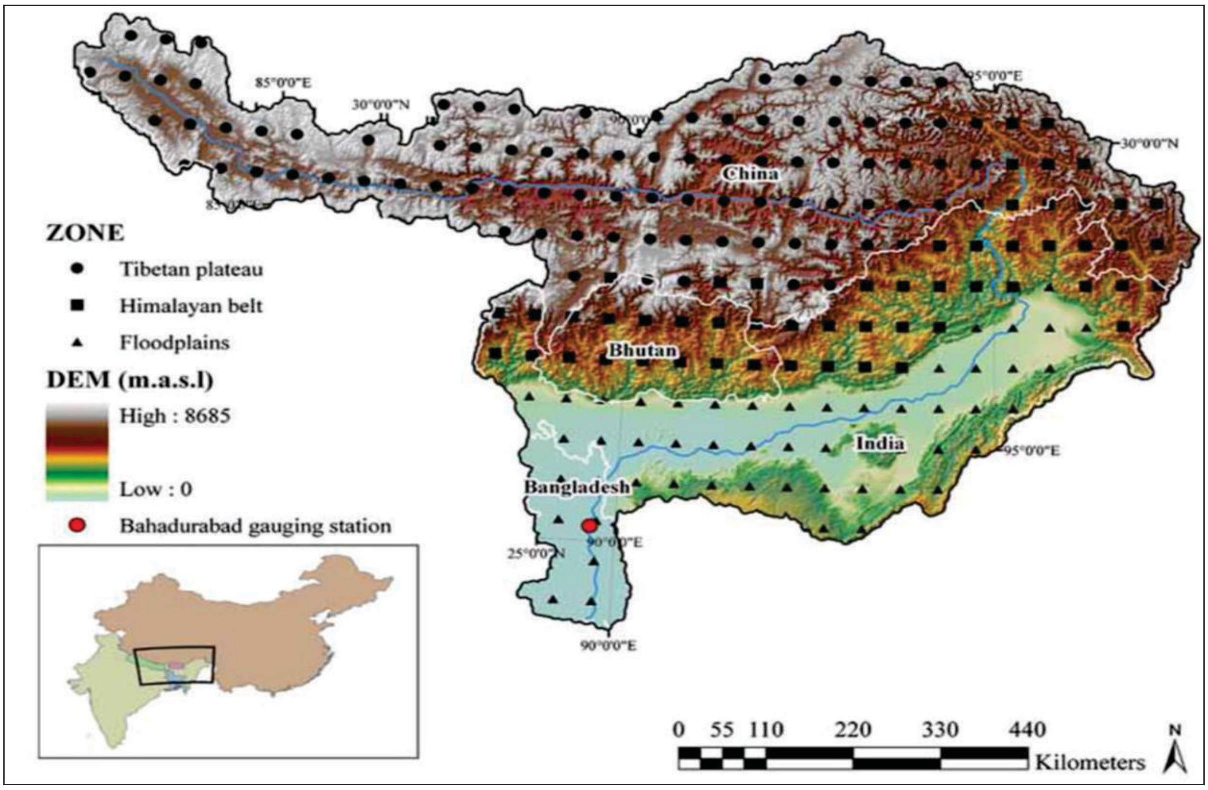
Source: Datta and Singh (2004)

1.7. Physiography

The Brahmaputra sub-basin is physiographically diverse and ecologically rich in natural and crop-related biodiversity. The basin is divided into three distinct physiographic zones: (1) the Tibetan Plateau that covers 44.4 percent of the basin area with elevations above 3500 masl, (2) the Himalayan belt that covers 28.6 percent of the basin area with elevations ranging between 100 and 3500 masl, and (3) the lowland floodplains that cover 27 percent of the basin area with elevations below 100 masl (Gain et al., 2011). The annual average precipitation in the basin is about 1350 mm (Hasson et al., 2013), of which 60–70 percent occurs during the summer monsoon months of June to September when orography plays an important role in the spatial distribution of the precipitation. Approximately 11 percent of the basin area is modified for cropland, of which 20 percent is irrigated (Pervez and Henebry, 2015).

These zones respond differently to the anticipated climate change. TP covers 44.4 percent of the basin, with elevations of 3,500 masl and above, whereas HB covers 28.6 percent of the basin with elevations ranging from 100m to 3,500 masl. The area with an elevation of less than 100 masl is considered as FP and comprises about 27 percent of the entire basin. The Brahmaputra River drains diverse environments such as the cold dry plateau of Tibet, the rain-drenched Himalayan slopes, the alluvial plains of Assam, and the vast deltaic lowlands of Bangladesh.

Fig 1.6: Physiographic Zones of the Brahmaputra Basin



1.8. Topography

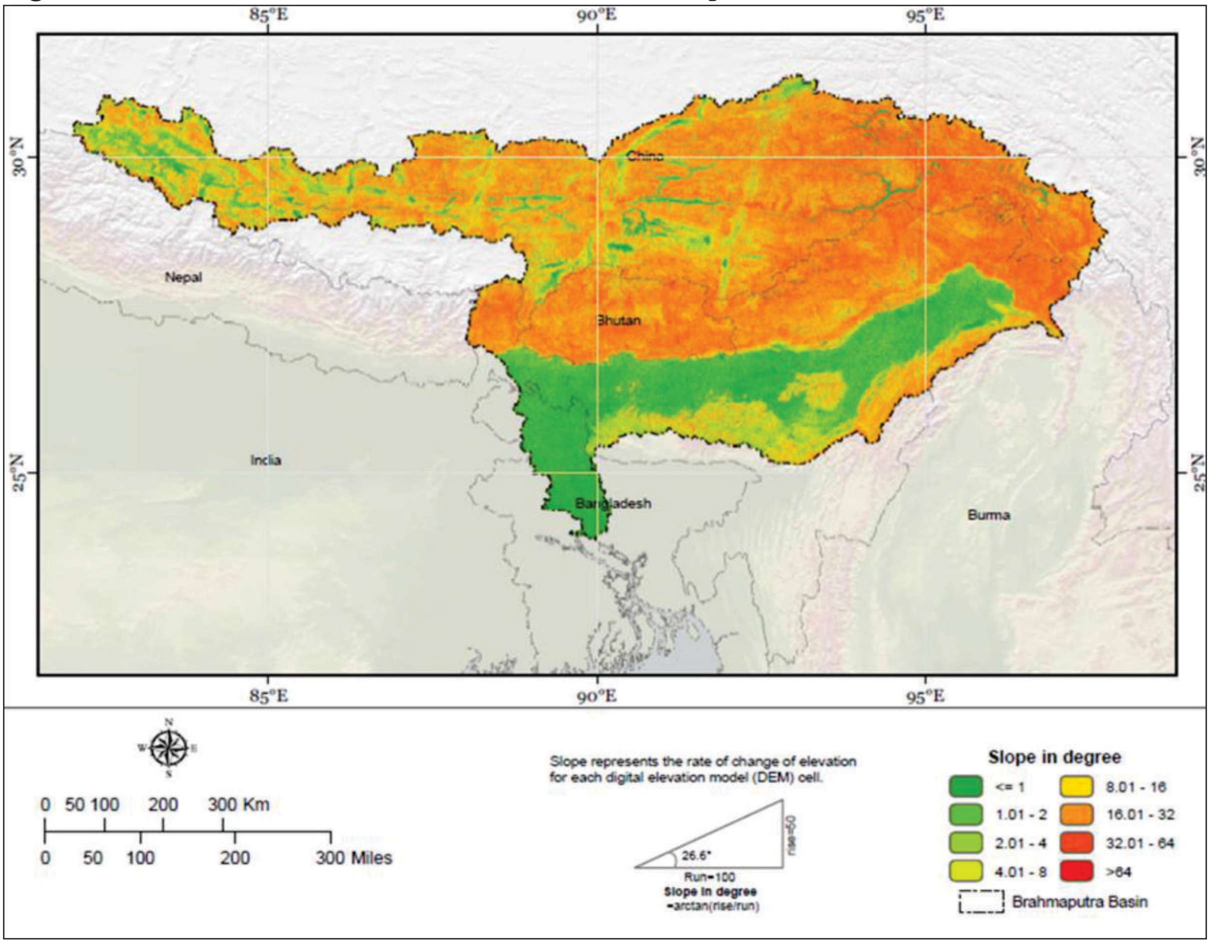
The basin is of irregular shape: the maximum east-west length is 1,540 km and the maximum north-south width is 682 km. The basin lies between 23°N to 32°N latitude and 82°E to 97°50'E longitude. The part of the Tibetan plateau falling under the basin has an elevation varying from 3,000-5,000 masl and is dotted with numerous glaciers (Singh et al 2004). The basin covers five topographic regions falling in four countries.

Table 1.3 Topographic Regions of the Brahmaputra River Basin

Topographical region	Area (Sq km)	Geographical location
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 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 West Bengal (India) and part of Bangladesh

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

Fig. 1.7: Gradients at various locations of the Brahmaputra sub-basin



The water resources of the Brahmaputra river basin are huge and are the highest among all the rivers in the Indian subcontinent. Human interventions have been limited till date, as shown in Table 1.4.

Table: 1.4: Water resources: availability and utilisation in India

Total water resources potential	537.2 km^3 (30% of the country's total)
Per capita water availability	17, 855 cu m as against 2,200 cu m of the country
Hydropower potential	44% of the country's total (66,065 MW out of country's total of 1,48,701 MW) as per NHPC
Hydropower Potential developed so far	Only about 3% as against 16% of the country
Irrigation potential	4.26 million hectare (m. ha)
Present coverage of irrigation	0.85 m.ha (20% of the existing potential against the national average of 56.4%)
Total replenishable Groundwater potential	26.55 km^3/year against 431.42 km^3 /year of the country (6% of country's total)
Groundwater Potential developed so far	4.3% (against the national average of 32%)

Source: Authors' estimates, Goswami (2001), NHPC

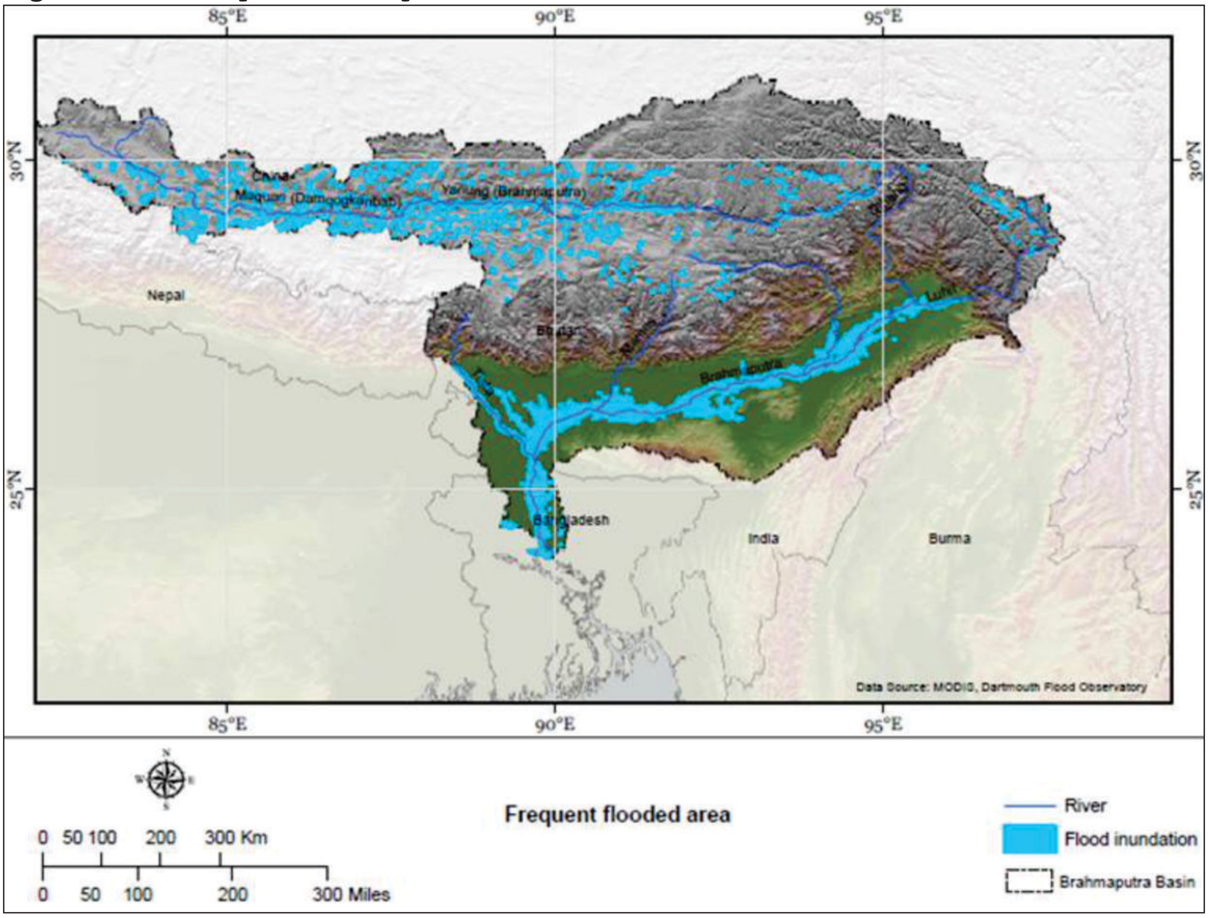
1.9. Ecosystems-livelihood Linkage

The Brahmaputra sub-basin is ecologically valued because of the mosaics of aquatic and terrestrial habitats. Large riverine ecosystems like Brahmaputra provide a wide range of ecosystem services that contribute to human well-being, such as fish and fiber, water supply, water purification, climate regulation, flood regulation, bank protection, recreational opportunities, and, increasingly, tourism (Immerzeel 2007). The biotic and abiotic components in such ecosystems are strongly connected. The change in level and quality of water and soil affect the biological components that, in turn, affect the ecosystem services. The value of ecological resources may be determined from basically two approaches—the value to humans and the value to ecological entities.

1.10. Floods and Bank Erosion

Heavy bank erosion by the Brahmaputra river, especially in its middle reaches in Assam, take place owing to its velocity and volume of flow during the peak season, erodible nature of bank materials, and consequent development of side channels and varying width. Active bank erosion is generally observed to take place both upstream and downstream of the nodal points and also in the downstream reaches of the confluence of the major tributaries. The instability of the Brahmaputra River coupled with silt and sand strata of its banks is also responsible for considerable bank erosion in its valley reach. There is a tendency of the Brahmaputra river to shift southward within the valley reach. This southward thrust in the south bank near the Dibrugarh town has initiated widespread erosion, which is still continuing at different reaches even after construction of anti-erosion schemes.

Fig. 1.8: Flood Map of Brahmaputra sub-basin



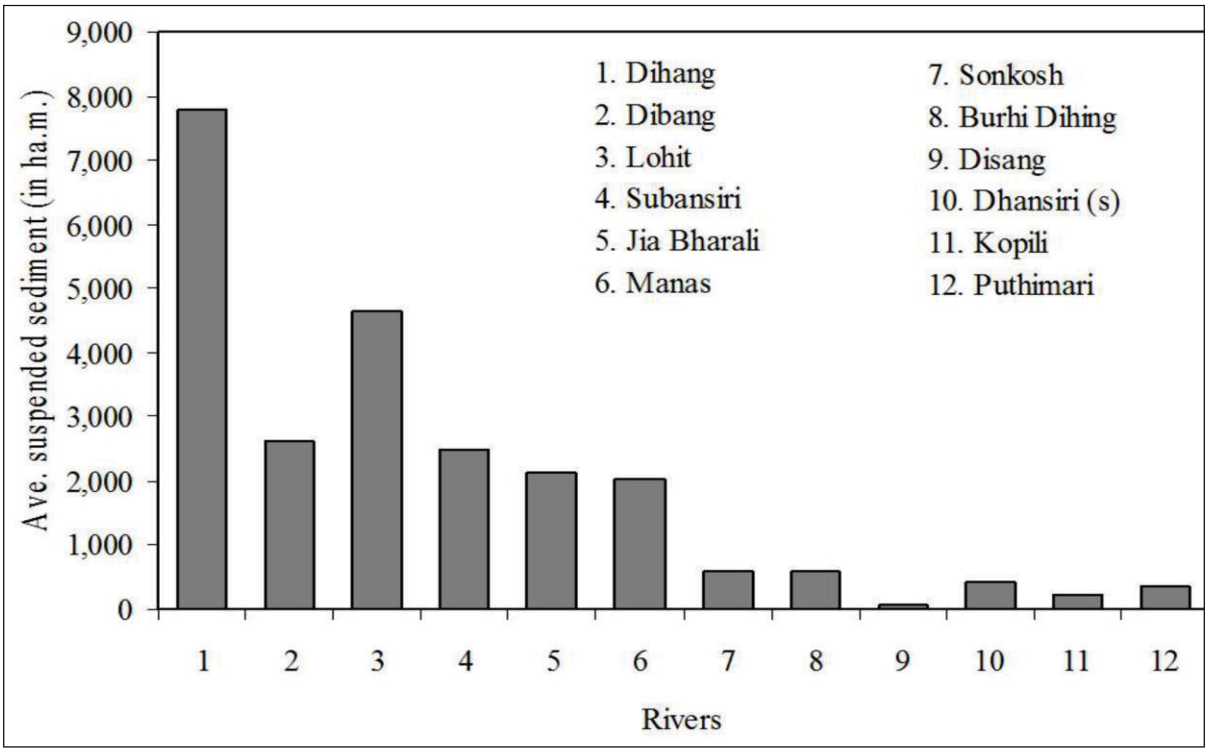
A few km downstream of the nodal point near Guwahati, the river is observed to have a northern migration since 1920 and active bank erosion is observed to take place in the Nalbari and Barpeta districts of Assam. The situation is different further downstream of the next nodal point near Jogighopa, where the river shows a tendency of migration towards the south. The south bank in this reach is facing active bank erosion. A more detailed description of floods is presented in subsequent chapters.

1.11. Sediment Dynamics

The Brahmaputra sub-basin is one of the highest sediment-laden river systems of the world, second only to the Yellow River in China. High sediment flux from the Brahmaputra sub-basin can be attributed to several processes. The monsoon climate generates a high runoff for the Brahmaputra than any of the other river systems in the Himalayan region. 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 more prominent. Finally, though wide floodplain of the Ganges (another sediment-laden Himalayan river of the GBM basin) may favour sediment sequestration, Brahmaputra is more channelised between the Himalayan arc and the active Burma arc and Shillong Plateau. Further, geochemical budgets of erosion suggest that the total erosion rate in the eastern Himalaya is about 1.5 times higher than that in the central and western Himalaya (Galy and Lanord 2001). 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) studied erosion in the Brahmaputra watershed by collecting bank sediments and suspended loads of the Brahmaputra River and its important tributaries from the Himalayan front to Bangladesh along with most of the important tributaries. Chemical and isotopic compositions of the sediments are used to trace sediment provenance and to understand erosion patterns in the basin. Overall isotopic compositions range from 0.7053 to 0.8250 for Sr and ϵ_{Nd} from −20.5 to −6.9. This large range derives from the variable proportions of sediments from Himalayan formations with high Sr isotopic ratios and low ϵ_{Nd}, and Transhimalayan plutonic belt with lower Sr isotopic ratios and higher ϵ_{Nd}. The latter are exposed to erosion in the Tsangpo and in the eastern tributary drainages. Overall erosion of the Himalayan rocks is dominant, representing ca 70% of the detrital influx. Compositions of the Brahmaputra main channel are rather stable between 0.7177 and 0.7284 for Sr and between −14.4 and −12.5 for ϵ_{Nd} throughout its course in the plain from the Siang-Tsangpo at the foot of the Himalayan range down to the delta. This stability, despite the input of large Himalayan rivers suggests that the Siang-Tsangpo River represents the major source of sediment to the whole Brahmaputra. Geochemical budget implies that erosion of the Namche Barwa zone represents about 45 percent of the total flux at its outflow before confluence with the Ganga from only 20 percent of the mountain area. Higher erosion rates in the eastern syntaxis compared to the other Himalayan ranges is related to the rapid exhumation rates of this region, possibly triggered by higher precipitation over the far-eastern Himalaya and the high incision potential of the Tsangpo River due to its high water discharge.

Fig. 1.9 Average annual suspended sediment load of some important tributaries of the Brahmaputra river within its valley reach (middle reach)



Source: Datta and Singh (2004)

Further, a large component of the sediment is created in the upper Brahmaputra valley in India. The sediments have traditionally offered immense ecosystem services for the downstream agrarian economies, including in Bangladesh.

Table 1.5: A Few Salient Features of the Brahmaputra Basin

1.	Total Catchment area	580,000 km2
	i. Catchment area within China	293,000 km2
	ii. Catchment area within India	195,000 km2
	iii. Catchment area within Bhutan	45,000 km2
	iv. Catchment area within Bangladesh	47,000 km2
2.	Length from its source to confluence with the Ganga	2,880 km
	i. Length within Tibet (China)	1,625 km
	ii. Length within India	918 km
	iii. Length within Bangladesh till the confluence with Padma	337 km
3.	Gradient	
	i. Reach within Tibet	0.00260
	ii. Reach between Indo-China border and Kobo in India	0.00190
	iii. Reach between Kobo and Dhubri	0.00014
	iv. Reach within Bangladesh first 60 km from India border	0.00009
	Next 106 km reach	0.00008
	Next 92 km reach	0.00004
	Next 79 km reach	0.00003
4.	Discharge characteristics	
	i. Maximum discharge at Pandu (Assam) on 23-08-62	72794 m3s-1
	ii. Minimum discharge at Pandu on 20-02-68	1757 m3s-1
	iii. Mean annual flood discharge at Pandu	51156 m3s-1
	iv. Mean annual dry season discharge at Pandu	4420 m3s-1
	v. Mean monsoon flow (June to October) Shigatse (Tibet)	507million m3
	vi. Pasighat (India)	3979million m3
	v. Discharge per unit area of Basin	
	T'sela D's Zong (China)	0.01 m3s-1 km-2
	Pasighat (Arunachal)	0.023 m3s-1 km-2
	Pandu (Assam)	0.03 m3s-1 km-2
	Bahadurabad (Bangladesh)	0.032 m3s-1 km-2
5.	Sediment Load	
	i. Average annual suspended load during flood at Pandu 4x108 metric tons	
	ii. Daily mean sediment load during flood at Pandu	2.12 million metric tons
	iii. Sediment yield	
	T'sela D'Zong (China)	100 metric tons km-2
	Pasighat (Arunachal)	340 metric tons km-2
	Pandu (Assam)	804 metric tons km-2
	Bahadurabad (Bangladesh)	1128 metric tons km-2
6.	Mean Basin Rainfall (Excluding Bhutan and Tibet Bangladesh)230 cm	
7.	Basin land use	
	Total forest covers	114992.08 km2
	Total agricultural land	50473.84 km2
8.	Basin population in India and Bangladesh	103 million approx. (more than 50% in Bangladesh).

Source: Data compiled by authors from various sources.

1.12. The "ample water, ample poverty" paradox of the Brahmaputra sub-basin

The Brahmaputra sub-basin is characterised by high levels of poverty. In terms of the new Tendulkar definition of poverty measurement as followed in India, the poverty ratios in Assam and Arunachal Pradesh are 32 percent and 35 percent, respectively. Poverty in Bangladesh is no less, either, and stands at around 26 percent, though the figures may not be comparable with India, due to differences in definitions. Yet, as will be shown in Chapter 2, per capita availability of water is the highest among the Indian rivers in the Brahmaputra sub-basin. Table 1.4 shows that the present and projected water availability in the Brahmaputra sub-basin in the study area is far above the Indian national averages.

Table 1.6

Present and Projected Water Availability and Demand in the Brahmaputra sub-basin including Bangladesh		
Year	**Per Capita Availability (cubic metre/ person)**	**Number of persons per flow unit**
2011	17855.56 (2200)	56 (455)
2031	15001.66 (1768)	67(565)

Note: 1. Figures in parentheses are national averages of India.
2. One flow unit is 1 million cubic metres
Source: Authors' estimates

As shown in Tables 2.1 and 2.2 in Chapter 2 of this report, the Brahmaputra sub-basin falls in the category of "well-watered" basin or region, as per one of the accepted definitions of water availability, i.e., the Falkenmark indicator. In fact, as table 1.4 reveals, the projected situation does not change even in 2031 as per our estimates, since the "well-watered" condition is delineated by the position of "less than 100 persons" per flow unit of water.

This makes it a paradox of development theory, as the high level of precipitation, annual run-off and a large hydro-electric potential of more than 100,000 MW, have often been cited as enabling factors for economic growth and poverty eradication in the Ganges-Brahmaputra-Meghna basin (Bandyopadhyay and Ghosh 2009; Verghese, 1990).

The sub-basin supports the urban centre of Guwahati and feeds the burgeoning population of Bangladesh. Between 1991 and 2001, the urban population in Bangladesh grew by 37 percent, while in Dhaka alone the growth was 55 percent (Bandyopadhyay and Ghosh 2009). The matter is of no less concern at this stage in terms of poverty and food security. Moreover, poverty is substantially higher in rural areas where agriculture is the main livelihood. With GBM basin countries projected to record some of the highest growth of population in South Asia during the first half of the 21st century, it is anticipated that such high growth rates will be a matter of deeper policy concern in terms of water and food security, poverty alleviation, natural resource conservation and, eventually, the ecosystem services flows (Sharma et al 2008).

So far, the "ample water, ample poverty" paradox has not received much attention of professionals in the field of economics. The traditional economic explanation of the causes of the high poverty levels has been sought from the damages from the regular annual floods in the basin. The political explanation has been that in a stratified society such as in the Brahmaputra sub-basin, the politically and economically marginalised are exposed to graver hazards from the vagaries of "ample water". Bandyopadhyay (2009: 49-100) has raised questions against these explanations on the grounds of the complexity and unexplored links between ecology and economy in the context of the GBM basin. This is the beginning of the search for a holistic water governance and engineering that would be informed by the totality of the ecology of river flows in the GBM basin, especially the GBM delta. Hence, a more realistic and holistic understanding of the relationship, if any, between water management and the high level of poverty in the basin needs to be developed. Essentially, this paradox in developmental theory is the central concern of environmental security in the basin.

1.13. About the report

While this chapter intended to set the premise for a more informed discourse on the Brahmaputra, the objective of the report is to present the various critical challenges that must be addressed. These challenges are more than mere water-management challenges: they pose threats to the overall environmental security, as also the hydro-political relations between the various actors in the sub-basin. The ensuing chapters build up on this premise. Chapter 2 relates the reader with various theoretical concepts, including "environmental security" and "environmental flows", on which depend the processes of Integrated River Basin Management (IRBM). It is here that the notion of classification of river basin as naturally "surplus" or "deficit" is questioned and the study's conceptual framework in the form of a modified DPSIR (drivers-pressures-state-impacts-response) is presented. Chapter 3 then gives an overview of the DPSIR (drivers-pressures-state-impacts-response) framework, in the context of the sub-basin. In this context, chapter 4 presents the various water governance challenges. Chapter 5 argues for the setting up of an institutional framework to address these challenges with a river basin organisation that can have its transboundary dominion. The main objective of this report is thus to identify the challenges facing the Brahmaputra, a highly unique river system with its peculiar challenges and opportunities, and address them from a holistic, institutional perspective.

2 Integrated Management of Trans-boundary Water Regimes: A Conceptual Framework in the Context of Brahmaputra Sub-basin

2.1 Introduction

In the previous chapter, the unique features of the Brahmaputra sub-basin have been introduced. These features are related not only to the bio-geo-spherical aspects of the water regime, but also to the social, historical, cultural and economic realities that have defined the use of water in the various parts of the sub-basin. Scientific understanding of the sub-basin as an eco-system and the related evolution of water uses by the resident population, both in-situ and ex-situ, describe a variety of linkages between the riparian ecosystems, terrestrial ecosystems in the sub-basin, and livelihoods of people using their services. The trans-boundary extent of the sub-basin makes the integrated management of it more challenging, especially in the context of Bhutan-India and Bangladesh-India relations. Waters of the Brahmaputra sub-basin not only cross international political boundaries but also has important aspects related to cooperation among the provinces and states within the various co-riparian countries. Recently, the ecosystem services of water have emerged as an important constituent in the approach to integrated river basin management (IRBM).

The diverse stakeholders have interest in several management objectives, which frequently are contradictory, needing external conditioning to arrive at amicable solutions. In light of these diverse factors, the integrated management of trans-boundary Brahmaputra sub-basin would need to be based on a conceptual framework involving these critical issues and based on a more updated interdisciplinary knowledge. Though management of trans-boundary river basins would include water allocation across demanding sectors, in the parlance of the United Nations, a trans-boundary river basin is described by its crossing of international borders. As enlisted by Wolf et al, (1999) there are 263 major trans-boundary river basins in the world, which together cover about half of the land surface of the Earth, not covered by ice. The hydrological changes that could occur due to global warming and climate change add to the diversity of issues. This, indeed, sets the background for the global significance of evolving a futuristic strategy for managing trans-boundary river basins or sub-basins. Till now about 300 negotiated agreements have been forged in various parts of the world for cooperation on shared river basins. However, as the impacts of climate change starts to set in, many of these agreements may have to be re-negotiated to accommodate the new hydrological contexts. All this sets the stage for continued international attention to integrated management of trans-boundary river basins

(Cooley et al, 2009). These experiences will be useful in understanding the challenges in cooperative management of the Brahmaputra sub-basin.

2.2 Integrated Management of Trans-boundary Water Regimes

Trans-boundary water regimes connote not only the flow of water across boundaries of nation states, but also a range of administrative boundaries of other types, between federal States of a nation, and up to smaller administrative units like, districts within a federal state to the boundaries between the ultimate micro-level units of a society, the individual landholdings. The notion "trans-boundary" has also become relevant in cases of allocation among competing sectors. Hence, "trans-boundary water regime" has become a construct not merely limited in a geographical space (Beach et al., 2000), but also to the sectoral spaces. In the process, they refer to water flows shared among multiple stakeholders, with diverse values and different needs. These stakeholder groups may often have conflicting interests over rights and uses of the concerned flows of water, entail sets of individual irrigators and environmental advocates, users in urban and rural areas, to nations that straddle international waterways (Jarvis et al., 2005; Eidem 2012). In addition, trans-boundary water regimes physically include river basins as well as underground aquifers that are spread over and below the land of more than one nation.

Given their multiple characteristics in the political, cultural, and social aspects of access to water over space, time and sectors, the integrated management of trans-boundary water regimes is invariably complicated. This makes holistic management of river basins dependent on awareness of extremely intricate micro-level and macro-level issues and forces. In the present report trans-boundary water regime has been defined in the context of water crossing any form of boundaries, whether it is geographical or sectoral, and at any level of decision making. The present work aims to use emerging interdisciplinary approach to the management of river basins in general, and then super-impose the trans-boundary aspects. It then suggests institutional structures for the Brahmaputra sub-basin for amicable use of its water system in a time-frame extending till the end of this century.

The stress on freshwater systems due to growing demands from irrigation, industries, human settlements, among others, is a global phenomenon (Coates et al. 2012). Environmental factors like land degradation in the catchment and upstream diversions have created many traditional complexities in IRBM. In the past few decades, global warming and climate change would add to that complexity. The growing scarcity of freshwater has frequently encouraged stakeholders at all levels to capture and maintain hegemony over larger share of the available quantities of water flows in streams and rivers, intensifying the existing disputes. While such competitions for access to water have been projected by alarmist writers as the origins of potential conflicts, history indicates that they have acted more frequently as a platform for steps towards cooperation and communication (Zeitoun and Mirumachi 2008; Fischhendler et al., 2013).

Therefore, IRBM mainly includes informed preparations for addressing future water needs and demands, and reconciliation of present and emerging interests (Subramanian et al., 2014). Within a nation state, the conflict of interests might include claims on river flows from irrigation, industry, hydropower plants, human settlements, and others, on one hand, and allocation for maintaining navigation and ecosystem services at a pre-determined level, on the other, would create a situation of competition (Wolf, 2007; Tullos et al., 2013).

The scenario in trans-boundary river basins is not much different. A study of history suggests that while disputes over water in river basins persist, they have hardly been the reason for violent conflicts among co-riparian countries (Wolf, 1998). In reality, situations of potential conflicts have been useful in promoting broader regional cooperation (Delli-Priscoli and Wolf, 2009). There are even cases where countries at war with each other over different political reasons, have continued to honour agreements on trans-boundary waters, as in the cases of the Indus River in South Asia, or the Jordan-Yarmouk basin in the Middle East (Salman and Uprety, 2002; Levitt, 2014).

There are numerous examples of benefits of negotiation and cooperative management of shared river basins being realised at multiple scales, from micro-watersheds to the whole river basin. Such mechanisms of cooperative management and dispute resolution, in recent times, the importance of ecosystem services and the ecosystems-livelihoods linkages are increasingly getting recognised. As a result, reconciliation between the extraction of water from natural sources for allocation for the traditional economic uses in irrigation or industry and allocation of water to keep the natural ecosystems at some agreed sub-pristine state of functioning, have become an important achievement of IRBM. This has opened up a way forward to address the older dichotomy between economic and ecological uses of water in a river basin. With emphasis on the cooperative aspects of transboundary waters, riparian actors in shared river basins will seek to allocate the multiple benefits among multiple parties (Ghosh and Khan 2012). Regional cooperation on trans-boundary waters is the only way to bring amicable benefit to all parties and to open new opportunities for co-riparian stakeholders to develop water regimes with broad agreements (Bandyopadhyay and Ghosh, 2009). In addition, consciousness and understanding of systematic mechanisms for dispute resolution, broadly being named 'Water Diplomacy', has been growing all over the world (Islam and Suskind, 2013). The search for suitable institutions for dispute resolution have now become an important subject of academic research and training. Thus, the traditional mechanism of military interventions as an instrument for dispute resolution is no more taken seriously, while other dispute resolution mechanisms have mainly focussed on diplomatic moves. The Rhine basin in Europe offers a good example of early success in cooperation on a trans-boundary river basin (Ruchey, 1995).

In recent years, perhaps encouraged by the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (1997), several agreements on international river basins have been made or are being initiated. The challenges and solutions practised in each case remain inimitable because of the uniqueness of the associated trans-boundary water regimes, in terms of the ecological specificities as well as the geo-political realities. Given the social, political and economic stresses that temporally and spatially uneven availability of water creates at the various levels and in various contexts, water professionals and researchers have been thinking of new ways of managing the common water regimes of river basins, thereby marking a shift from the existing modes of water development, resulting in a worldwide paradigm change in this subject. Such a paradigm shift has created notable changes in the policymaking process in Europe, Australia, South Africa, some parts of North America, and other regions. However, in many other parts of the world, including South Asia, river basin management is still looked at from the old paradigm which is guided by a reductionist perspective, instead of an integrated one.

2.3 Emerging paradigm for integrated management of river basins

During the past 100 years or so, human perceptions of rivers and river engineering had been dominated by a reductionist paradigm, characterised by structural interventions for storage and diversion. This enhanced human ability to store and transfer water in quantities not known so far. This was made possible by the availability of reinforced cement concrete (RCC) technology. Thus, river engineering became almost synonymous with engineering structures. Europe and the US extensively witnessed such structural interventions between the 1920s and the 1960s. However, over time, it was increasingly being realised that such structural interventions or the 'business as usual' way of managing rivers, had other social, economic, environmental, and hence, political implications. These had not been given the due attention in the traditional paradigm of river engineering. Such concerns have been expressed from the highest international professional platforms (e.g., Anonymous 1992:27, Cosgrove and Rijsberman, 2000: xxi), and in diverse contexts at various points of time by many leading water professionals over the past several years (Falkenmark et al. 2000; Gleick, 1998; Middleton, 2012). The central issue is the new perception of rivers. In the emerging paradigm, a river basin is seen as an ecosystem and the various parts of the basin are linked by various ecosystem processes and services. The livelihoods of people in the various parts of the basin are closely linked with the ecosystem services. Keeping the whole ecosystem in good ecological state has become the main objective for management, followed by the supply of water for diverse uses. The outdated reductionist paradigm considers short-term economic benefits alone, without serious consideration of the economic implications of the impacts of the interventions on the diverse ecosystem services and on the related livelihoods. The dams or barrages constructed during the past decades are examples of the limited considerations that influence decisionmaking in this paradigm. The structures have their economic lives during which they serve the assigned objectives in part, like irrigation, flood moderation, power generation, and others. Further, obstructions and diversion of flows in rivers entail altering the natural hydrological pattern of rivers, and cause changes in the ecosystem processes and services rendered to the stakeholders. It is recognised that longer-term impacts of interventions might lead to irreplaceable and irrevocable losses to the ecosystems that would prove detrimental to the human society in general.

With such concerns, the last few years have witnessed the growing call for a change in the existing paradigm for the management of river basins. The new vision, emerging with the continuous accrual of knowledge with upward shifts of the frontiers of the discipline, involves the replacement of the present reductionist paradigm by a new, more holistic one, backed by an interdisciplinary knowledge base (Bandyopadhyay and Ghosh, 2009). The Water Framework

Directive of the European Union is an example of adopting the paradigm change in policymaking.

There are, however, the proponents of the old paradigm who think that such mindset can address the new challenges with some adjustments and modifications (Prabhu, 2003; Sivanappan, 2012). Nevertheless, traditional water resource management is being replaced rapidly by water systems management which recognises the ecological integrity of a river basin. The following section will discuss the characteristics of the new paradigm.

2.3.1 Internalising ecological integrity in river basin management

Ideas of river basin management in India, even after independence, have remained inherently based on the reductionist paradigm of engineering initiated by the British in the 1860s (D'Souza 2006 and 2010; Gilmartin 2006; Saikia 2014). Consideration of the social, economic and environmental dimensions of engineering interventions has remained largely outside the management approaches. Hence, the engineering interventions often violate the ecological integrity of the basins and generate unwanted social, economic and political impacts. Bandyopadhyay (2012) has described the present state of water engineering in India as 'hydrological obscurantism'. India today has the largest irrigation network in the world with very low water use efficiency. As per the business as usual scenario, it is projected that by 2050 India's annual water demand will surpass water availability. In order to enhance water availability, the River Linking Project (RLP) had been prescribed as the official response to this emerging water scarcity. This is a massive civil engineering project based on the traditional reductionist paradigm. The Brahmaputra sub-basin is taken as the source of additional water for the dry areas of western and southern India. It is probably an imperative that such a large project is assessed through the elements of the emerging new paradigm stressing on the ecological integrity of river basins. In India, the ad-hoc categorisation of river basins as 'surplus' or 'deficit', is taken as a win-win proposition in making official projects on inter-basin water transfers. Such ideas are inconsistent with the integrity of river basins and will be taken up for analysis below.

A. Categorisation of water availability in river basins: the fallacy of 'surplus' and 'deficit'

The most frequently used argument in favour of engineering projects to transfer water from one river basin to another, is a simplistic yet untenable categorisation of river basins/sub-basins as 'surplus' or 'deficit'. It is pre-supposed that such a transfer will be a win-win solution as a 'surplus' basin will be relieved of 'extra' water and a 'deficit' basin will gain much needed water from it. Such an ad hoc classification of river basins has led to major difference in opinion, as can be seen in the case of the RLP of India. The official methodology for this categorisation, as followed by the Ministry of Water Resources (MoWR), Government of India, is based on an unpublished paper by Mohile (1998), which is not available in the public domain. It appears that the method assumes that the overall surface water availability in a basin/sub-basin is assessed both at 75 percent and 50 percent dependabilities. These are compared with the estimated water requirements for irrigable land within the basin/sub-basin. If the irrigation requirements are less, the basin is considered as 'surplus', otherwise 'deficit'. As pointed out by Bandyopadhyay and Perveen (2003,2004), in this methodology there is no recognition of the ecosystem processes and services associated with the basin, for example, how the assessment of the water need for fisheries or salinity control has been made.

This method has not found much support in the global approach to Integrated Water Resource Management (IWRM) and Integrated River Basin Management (IRBM). From the perspective of the emerging interdisciplinary water science that takes into consideration the important ecosystem functions and services, such ad hoc categorisation of river basins/sub-basins as 'surplus' or 'deficit' does not help in any way, evolution of IRBM.

However, an assessment of water availability in a river basin is an important element for IRBM. In international literature, there are other methods for quantification of water availability in river basins/sub-basins to help planning, and even management of river flows (Molle and Mollinga, 2003). The development of such indicators was initiated over the last two decades. The initial indicators mainly followed the Malthusian tradition of defining water scarcity in terms of annual per capita availability of the resource (e.g. Falkenmark et al 1989; Raskin et al. 1997). The indicators are simple and focused on the per capita physical availability of water. According to Falkenmark (1989), a state can be found within five quantifiable conditions, as shown in Table 2.1.

Table 2.1: Falkenmark Water Barrier Scale

Well Watered Conditions	<100 persons/flow unit
Mid-European	100-600 persons/flow unit
Water stressed	600-1000 persons/flow unit
Chronic Scarcity	1000-2000 persons/flow unit
Beyond the Water Barrier	>2000 persons/ flow unit

Note: A flow unit is defined as one million cubic metres of water per year. Source: Jobson (1999)

Subsequently, improved indicators were developed by incorporating future demand scenarios (e.g. Seckler et al. 1998), highlighting sectoral allocations including for the environmental sector (e.g. Salameh 2000; Feitelson and Chenoweth, 2002), putting forth alternative social resources to adapt to water scarcity (e.g. Ohlsson 1998; Turton and Ohlsson, 1999), propounding theoretical models linking economic development and environmental capital (e.g. Allan 1996; Turton 1997), and embodying the society–scarcity nexus (e.g. Molle and Mollinga 2003). Some other interesting approaches involve a grid approach (Meigh et al. 1999), a river basin approach (Alcamo et al. 1997) or a mix of basins and administrative units (Amarasinghe et al. 1999) and composite indicators of scarcity (e.g., Amarasinghe 2003).

The movement from the concept of "water scarcity" to that of "water poverty index" (Lawrence et al. 2002; Sullivan 2002) is an important step forward, in the sense that conditions of access and information have been given recognition. This relates to situations where high physical availability of the resource exists but improper information and lack of accessibility lead to a scarcity situation. With knowledge becoming increasingly important with time, such problems could become even more widespread in the future.

Considering the "supply side" indicators, it can be found, for example, that nations in the Jordan Basin, namely, Israel and Jordan, are water-scarce. According to the Water Barrier Scale (Falkenmark et al. 1989), Israel moved "beyond water barrier" in 1982 (Jobson 1999:11), while Jordan did the same in 1960 (Jobson 1999:14). According to the IWMI indicators, both these nations belong to those with the highest degree of water scarcity, considering present and future conditions. At one time, a situation of conflict over water existed between these two nations. However, effective management of the available water resources, lately, has resulted in the two nations moving towards peaceful hydropolitics, despite the fact that serious problems on other political issues persist in the region. Scarcity indicators have not yet captured the imagination of policymakers. According to Ghosh (2009), the prevailing conflicts in the river basins of India like Cauvery, Krishna, Narmada and Godavari have not reached the level of intensity that existed at one time between Israel and Jordan. Nevertheless, these river basins are facing regular disputes and conflicts between and among the trans-boundary stakeholders (Richards and Singh, 1996; Ghosh 2009). Even the Water Poverty Indicator (WPI) is an incomplete indicator (Ghosh and Bandyopadhyay 2009) for two reasons. First, the WPI does not recognise the role of virtual water imports in mitigating scarcity. Second, the WPI has not been used at the river basin level. In order to implement it at that level, data on a larger number of variables is needed (Ghosh and Bandyopadhyay 2009). However, based on the database of per capita water availability created by Amarasinghe (2003), when one looks at the nature of scarcity, on the basis of Falkenmark Water Barrier Scale on Potentially Utilizable Water Resources, Ganga and Cauvery are both under "chronic scarcity".

Table 2.2: Relative positions of the river basins of India according to the Falkenmark index

River Basin	Number of Persons per flow unit of Renewable Water Resources	Falkenmark Status according to RWR	Number of Persons per flow unit of Potentially Utilisable Water Resources	Falkenmark Status according to PUWR
Narmada	349	Mid-European	362	Mid-European
Mahanadi	429	Mid-European	451	Mid-European
Brahmani & Baitarani	372	Mid-European	489	Mid-European
Godavari	533	Mid-European	536	Mid-European
Brahmaputra	58	Well-Watered Conditions	654	Water Stressed
Meghna	138	Mid-European	657	Water Stressed
Tapi	1074	Chronic Scarcity	755	Water Stressed
Indus	621	Water stressed	755	Water Stressed
Krishna	843	Water stressed	845	Water Stressed
Pennar	1664	Chronic Scarcity	962	Water Stressed
Ganges	739	Water stressed	1004	Chronic Scarcity
Cauvery	1479	Chronic Scarcity	1139	Chronic Scarcity
Subarnarekha	822	Water stressed	1200	Chronic Scarcity
Mahi	1028	Chronic Scarcity	1712	Chronic Scarcity
Sabarmati	4184	Beyond Water Barrier	3311	Beyond Water Barrier

Source: Authors' Estimates from Central Water Commission (1998)

Again, in terms of the UN indicator, both Ganga (The Ganges) and the Cauvery fall in the 'scarce' category, as water extraction is more than 40 percent of the annual renewable water resources (Amarasinghe 2003: 12). This raises further questions on the definitions of "surplus" and "deficit" basins as defined by Mohile (1997). On the other hand, as revealed in Table 2.2, Brahmaputra falls in the "well watered" category, while considering renewable water resources, but falls under "water stressed" category while considering potential utilisable water resources.

The interesting intervention of Amarasinghe (2003) has, however, happened in terms of developing a composite indicator in analysing the severity of water scarcity. This involves four component variables in the form of the degree of development, extent of the depletion of developed water resources, the sustainability of the developed water supply, and surplus or deficit river basin food production. By considering all these, a cluster analysis has led to the classification of river basins into five groups: Water Scarce-Food Deficits; Water Scarce-Food Surplus; Food Deficit; No Water Scarcity; and No Water Scarcity-High Food Surplus. A majority of the basins, including the Ganges and the Cauvery belong to the "Food Deficit" class. According to this indicator, Brahmaputra falls in the category of "Cluster 4: Non-water-scarce, food-sufficient" basins. Along with Meghna, Brahmaputra consists of only five percent of the Indian population and contribute only four and six percent, respectively, of the grain and non-grain crop production. The basins in this category have a low degree of development (only four percent of PUWR), low depletion fractions, low groundwater use, and some crop production surpluses (Amarasinghe et al 2004).

Thus more than one indicator, even when economic concern is considered important, suggests that the Ganges and Cauvery might not belong to different groups in terms of water scarcity.

B. Understanding 'environmental flows' in rivers

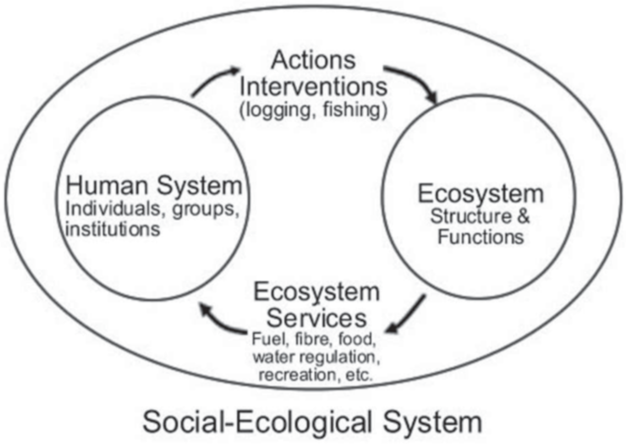
In recent years, especially in connection with the environmental impacts of hundreds of hydro-power plants being constructed in the Himalayan watersheds of the Ganges and Brahmaputra sub-basins in India, the issue of the cumulative impact of such projects on the riverine ecosystem has become highly debated (Bandyopadhyay, 2013). The idea of environmental flows became important in the wake of policy questions on large-scale interventions in the river flows to meet water needs and demands from various social and economic uses. Large diversions from numerous rivers in the world have threatened the ecosystem processes and services in the downstream parts, which raised the consciousness of river engineers about the process for protecting the ecosystems from extinction (Acreman and Dunbar, 2004). In their pathbreaking work, Dyson et al. (2003) observed that "there is no simple figure that can be given for the environmental flows requirements of rivers, wetlands and coastal areas. Much depends on stakeholders' decisions about the future character and health status of these ecosystems." The environmental flows are a hydrograph (not a percentage of the annual run-off of a river) in which amount and periodicity of flows are crucial. Such flows may maintain the aquatic ecosystems in a pre-determined non-pristine state of degradation. The distinction of river systems in their pristine state and a pre-determined non-pristine level of degradation is important to understand. Unfortunately, attempts have continued to 'determine' how much water the river 'needs', under the garb of "environmental flows" without any relation with the pre-determined level of degradation of the ecosystems. Indeed, such an approach makes it possible to generate a utopia that engineering interventions can be made without altering the ecological status of the rivers, as long as some part of the total flow in a river, usually 10 to 15 percent, is left in the riverbed. Criticisms have been made at the international level against such ecologically unaccountable and pure hydrological quantification, irrespective of the water requirements of individual eco-systemic processes and services. (Poff et al. 1997). The Indian scenario is characterised by a confusion and has received criticism from water professionals (Bandyopadhyay 2011, Linnansaari et al.004). Yet, a recent document of the Ministry of Water Resources (MoWR, 2015) continues to ignore the ecologically informed approaches to the idea of environmental flows. There is no doubt that while diversion or extraction of water is needed by the human societies, any form of intervention in the hydrological flow needs an assessment of the social, economic, and ecological downstream impacts. In the emerging paradigm of IRBM, an understanding of and negotiated determination of what amount of flows would be used for environmental purposes, becomes a central element. In the making of an IRBM strategy for the Brahmaputra sub-basin, it is important to get a clear and scientific understanding of the levels of degradation of rivers and their costs, when engineering interventions are made.

C. Ecological Economics in IRBM

In the making of IRBM strategy for any river basin, ecological economics has emerged as an important subject. In the last two decades or so, there has been useful expansion of research and publications on the ecosystem services of water and their economic implications. To a large extent, the recognition by the Millennium Ecosystem Assessment (MA) (2005) was important for this growth. The MA classified ecosystem services into four categories, namely, provisioning services (such as the provisioning of food and water); regulating services (such as the control of climate and disease); cultural services (such as spiritual and recreational benefits); and supporting services for biodiversity. All these services are widely used by humans in the Brahmaputra sub-basin. Monetary values of ecosystem services, though approximate and indicative, are useful for policymaking and advocacy. This is where the criticality of ecological economics of water comes in. Valuation of water from the perspective of its ecosystem services is an emerging field of research that is gaining popularity over time. Ghosh and Bandyopadhyay (2009) have carried out a detailed survey on valuation of ecosystem services of water.

The ecological economics of water is important from the perspective that the very discipline of ecological economics looks at the human society as an integral component of the broader social-ecological system, as shown in Fig. 2.1.

Fig. 2.1: Human Society as a component of the social-ecological system



Source: http://wiki.resalliance.org/index.php/Bounding_the_System_-_Level_2

As shown in Fig. 2.1., the human system is an integral component of the broader social-ecological system. For its own sustenance, the system generates forces in the form of actions which intervene into the ecosystem structure and functions, and in the process, this action impacts the ecosystem services. Generally, ecosystem services are associated with the ecosystem structure and functions. With human actions, which are generally economic in nature (in the form of logging, fishing, agriculture, water diversion, and others), the integrity of the ecosystem structure and functions might be compromised, and this may affect the ecosystem services, thereby creating a dent on human well-being. This scheme of things is ignored by the neoclassical environmental economic thought process, which, in its reductionist mode of thinking, looked at water as a stock of resource to be used for human extraction for meeting short-term economic goals. Further, environmental economics as an offshoot of the neoclassical economic framework viewed human actions as resulting in externalities like pollution or depletion, and talked of internalisation of the externalities through some short-term mode of monetary valuation of the loss. This reductionist thinking hardly takes into consideration the broader social-ecological impacts in the long run that will affect human society. As it is, microeconomic theory bases its the orisation on pre-conceived assumptions about human behaviour.

In the context of water resources, neoclassical economic theory has dealt with the resource in two ways. One is the body of literature put across by natural resource economics that deals with water as a stock of resource that might be depleting (if the rate of extraction is higher than the rate of regeneration) and yields economic value through agricultural production, drinking and sanitation purposes, energy, among others. The approach has primarily been to look at this resource as a stock appearing in the argument of a production function. Environmental economics approaches are no different either, and as stated earlier, is concerned with externalities, and pre-conceived assumptions of optimality. None of these theories really looked at water as an integral component of the broader eco-hydrological cycle.

This is where ecological economics comes into the fore. On the one hand, there is an extensive emerging literature on valuation of ecosystem services, though the concerns are less specific to water bodies. The importance of valuation of ecosystem services has adequately been recognised by MA (2005) and TEEB (2010). When it comes to water resources, water has an extensive contribution to the human society in many ways. First, it provides various provisioning services in the form of agricultural crops, seafood, aquatic species and plants, other food, fisheries, and others. Second, it provides supporting service to terrestrial ecosystem including forests that again play important regulating functions. Third, it plays important roles in cultural services.

While at the interface of the human society and the ecosystem, a few of the services are visible and documented, ecological sciences have merely hit the tip of the iceberg in unearthing the range of services provided by the ecosystems. This is more so because the ecosystem structure and the consequent functions are not well understood till date. However, the significance of valuation of ecosystem services arises on various counts. Firstly, value attached to the ecosystem services is a testimony of the importance of the underlying resource to human society. When expressed in monetary terms, it upholds the significance of the services that ecosystem renders to the human society. Second, valuation of ecosystem services can raise awareness of the market and the policymakers on the importance of the ecosystem services under consideration. Third, valuation can help legal proceedings determine damages where a party is held liable for causing harm to another party, e.g., when pollution from upstream areas affects the downstream ecosystems negatively thereby affecting the downstream ecosystem services. Therefore, to deal with compensation policies properly, the economic value of the harm so caused needs to be assessed to obtain the extent of the negative externalities. Fourth, valuation of ecosystem services can help revise investment decisions. The most probable of these decisions are related to large infrastructure like dam constructions that might otherwise ignore the related harm expected to be caused to the natural environment and consequent loss to the ecosystem services. Fifth, valuation helps designing of efficient management mechanism. Sixth, since livelihoods in poor areas of the developing world are inextricably linked to these ecosystem services, the values generated by the ecosystem services and goods are often referred to as "GDP of the poor" (Martinez-Alier 2012).

On the other hand, there is a large body of literature acknowledged in the domain of ecological economics that deals with institutions (Ostrom 2009). This aspect essentially tries to understand the working of institutions that can help in management of water, keeping in view its integration with the broader socio-eco-hydrological cycle. As it is, the role of institutional rules and structures in framing of action situations within which individuals or groups make choices on the basis of the incentives and disincentives, and jointly affect each other as well asthe outcome of the interactive process, as also the development of a general framework for analysing sustainability of Social-Ecological Systems (SESs), have essentially affected the study of ecological economics, rather than a more reductionist domain of environmental economics. This is where Ostrom (2009) envisaged a different perspective of institutions, which is beyond the self-optimizing behaviours. Ecological Economics further accepts the complementarity of the two approaches (valuation and institutions): this is also because while values affect development of institutions, it is institutions that determine values.

In the context of water management therefore ecological economics is important from both perspectives. Thus while we talk of a complex system like the Brahmaputra, the role of ecological economics emerges from the perspective of thinking of a holistic management regime embedded in frameworks of IRBM. The canonical definition of traditional economics is "canonical of scarce resources among competing ends". Ecological economic theories, however, are not really based on scarcity, as they recognise the eco-hydrological cycle. As such, the Brahmaputra sub-basin cannot really be classified as a water-scarce economy in terms of physical availability of water, and as we have already discussed, the very notion of "surplus" and "deficit" basins are misnomer from the ecological perspective.

Ghosh and Bandyopadhyay (2009) have already discussed how in "water scarce economies", scarcity value of water is an important determinant of water conflicts. Such a hypothesis, however, is not valid for the Brahmaputra, where the situation is too complicated. Thus, to manage the complex Brahmaputra systems with multi-layered complexities arising at social, economic, institutional, and ecological contexts, ecological economics of water is extremely relevant. That is why this paper has taken up a discussion on the DPSIR (drivers, pressures, state, impacts, and response) frameworks. The issues of property rights and governance structures are critical and they deserve to be taken up as important cornerstones of discussions in this context. The role of ecological economics of water becomes even more important in the context of the concern of environmental security, which is discussed in the next section, along with issues related to property rights.

2.4 Emergence of Integrated River Basin Management (IRBM)

The realisation of the need for holistic modes of water management has been reflected in some of the policy actions in countries in the EU, South Africa, Australia and Russia, primarily with the dawning of the social and ecological concerns (Gleick 2000). Continued investments in large engineering supply side interventions are being questioned by those who believe a higher priority should be assigned to projects that meet unmet basic human needs for water (Gleick 1996, Anonymous 1992) and keep the rivers in good ecological state. The US, the country which started the global trend of building large dams, is following "… a new trend to take out or decommission dams that either no longer serve a useful purpose or have caused such egregious ecological impacts so as to warrant removal. Nearly 500 dams in the USA and elsewhere have already been removed and the movement towards river restoration is accelerating" (Gleick 2000).

Following these paradigmatic shifts in notions worldwide, various other means to conserve water in-stream is becoming evident in various parts of the world (Bandyopadhyay 2004, Gazmuri 1992, Mattas et al 2014). Helming and Kuylenstierna (2001), while cautioning against the damages that can be caused by supply augmentation plans, emphasises that "...Demand side management is therefore slowly becoming a new paradigm for water governance". The Murray-Darling Basin Authority in Australia limits water use at environmentally sustainable levels by determining long-term average Sustainable Diversion limits for both surface water and groundwater resources. More importantly, the development of water index trading in an exchange type market infrastructure institution is already in vogue in Australia (Adamson 2013, Ghosh 2011, Ghosh and Goswami 2014, ASE 2006). In another instance, Chile's National Water

Code of 1981 established a system of water rights that are transferable and independent of land use and ownership. The most frequent transaction in Chile's water markets is the 'renting' of water between neighbouring farmers with different water requirements (Gazmuri 1992, Grafton et al 2011). However, such markets are still evolving against the backdrop of weak legal and institutional reforms (Bauer 2008). In that sense, IWRM advocates an integrated approach for managing water regimes in a way that reconciles the critical socio-economic needs with the ecosystem concerns. While potentially useful, such an approach is not beyond disputes.

Advocates of the new paradigm trust that the multi-dimensional nature of water can only be appreciated from a holistic perspective (Grafton et al 2011). Critics, on the other hand, argue that integrated water management lacks sufficiently well-defined rules for its practical implementation (Martinez-Santos et al 2014). IWRM, as such, examines the role of water accounting, food trade, environmental externalities and intangible values as key aspects whose consideration may help the water management community move forward.

While Integrated Water Resources Management (IWRM) became the key mantra, it was further thought that the river basin should be considered as the spatial unit of management of rivers. This further evolved in the notion of Integrated River Basin Management (IRBM), leading to a paradigm shift from the earlier reductionist notion of project-based approach to river basin management. The primary tenet on which IRBM rests is that naturally functioning river basin ecosystems, including accompanying wetlands and groundwater, are integral parts of the water systems. Thus while the entire river basin is treated as an ecosystem, management of the river basin has to include maintenance of ecosystem functions and services so as not to cause destructive impacts on the ecosystem services (Boelee 2011, Mattas et al 2014). This 'ecosystem approach' is the key ideas far as the Convention on Biological Diversity (CBD 1992) is concerned.

Interestingly, over time, many policy documents began acknowledging ecosystem concerns without really understanding how to interpret this. The National Water Policy of India also acknowledges this notion, but shows little application of this approach. For example, in the 2007 Award by the Cauvery Water Tribunal, it apportions certain quantities of water as “unavoidable escapages to the sea”. In many cases, there is a clear misinterpretation of the notion of environmental flows and without much understanding of the eco-hydrological processes associated with it. While environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems, and through its implementation of environmental flows, water managers strive to achieve a flow regime, or pattern, that provides for human uses and maintains the essential processes required to support river ecosystems at an agreed sub-pristine level, most policy documents in South Asia place an ad-hoc quantity or percentage as “flows” that have little eco-systemic and scientific basis. This becomes prominent when the National Water Policy 2012, Govt. of India, states “…A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water use.” (MoWR 2012: 4)

One needs to appreciate here a systems approach to river basin management. River basins are sensitive over space and time, and any single intervention has implications for the system as a whole. Activity taking place in a part of the basin (e.g. disposal of waste water, deforestation) will have impacts downstream. An example of this was the cyanide spill in the River Tisza (a tributary to the Danube) from a mine in Romania in January 2000. The highly toxic chemical swept downstream through Hungary, devastating aquatic life along the course of the river and contaminating the drinking water of hundreds of thousands of people (WWF 2002). The other example is the construction of the Farakka barrage in 1975 on the lower Ganges in India. The idea of constructing this barrage was to divert water to resuscitate the Kolkata port. However, over time excessive sedimentation in the barrage led to stream-flow depletion further downstream along the natural course of the Ganges, especially in the estuarine zones (Rudra 2004, Bandyopadhyay 2012, Danda et al 2011). There have been ecosystem losses in the form of mangrove depletion and other species loss, as well as damage to livelihoods (Bandyopadhyay and Ghosh 2009, Bandyopadhyay 2012).

While today's best practices in water resources planning entail integration of water quantity and quality management for both groundwater and surface water, there remains a need for a comprehensive understanding of how the natural environment and the resident population of a basin are impacted by various levels of interventions in the rivers or by adoption of new policies, land use as well as land and vegetation management that need to be considered. This is best done in a participative manner, involving all the major stakeholder groups, and in a way that achieves a balance between the level of economic development and the consequent impact on the natural resource base of a river basin as agreed by the stakeholders. This participatory and comprehensive approach is what is generally referred to as good integrated river basin management (IRBM).

Generally, the national or sub-national governments set the policies for the use and protection of water resources in a country. Differential policies can create problems when a river basin encompasses various nations or counties or states in a federal structure, implying a transboundary dimension of the river water. Implementation of the national policies may not be effective at a basin scale in the context of transboundary waters. This brings the discussion to the management regime at a basin scale.

In many cases, the spatial problems take the upstream-downstream dimension (for a river) and/or a region-to-region dimension. The basin approach is nothing but an entailment of a system approach, and can help in assessment of basin-level impacts of any kind of intervention on the stream-flow. In other words, national policies, as well as international agreements and regional conventions for transboundary waters, are applied to natural basins. The relationship between administering water resources within country and managing water in basins thus becomes dynamic and more responsive to changing circumstances, whether environmental, social or economic. The concern is how to conceptualise and implement IRBM in terms of the existing practices and literature.

The tenets of IRBM can be summarised as follows:

I. *Incorporation of community and stakeholder participation into the planning and management processes:* The views of the basin community must be systematically incorporated. Active participation by all relevant stakeholders in well-informed and transparent planning and decision-making is highly important.

II. *Drafting a long-term river basin vision, through the process of a consensual agreement among all stakeholders:* There should also be an integrated natural resource policy agenda and clear financing and budgeting systems for the range of basin-wide activities.

III. *An integrated approach toward policy making, decision-making, and cost-sharing across various sectors including industry, agriculture, urban development, navigation, ecosystems, taking into consideration the poverty reduction strategies:* The development of all policies, strategies, decisions, and projects in an integrated manner in recognition of the holistic and interactive way that natural resources behave. This integration needs to be built into how institutions interact, and how policy is developed and resource management undertaken.

IV. *Decision-making at a macro river-basin-scale should also take into consideration concerns at the sub-basin or local levels:* Sub-basin level actions should be guided by the macro-policy accordingly.

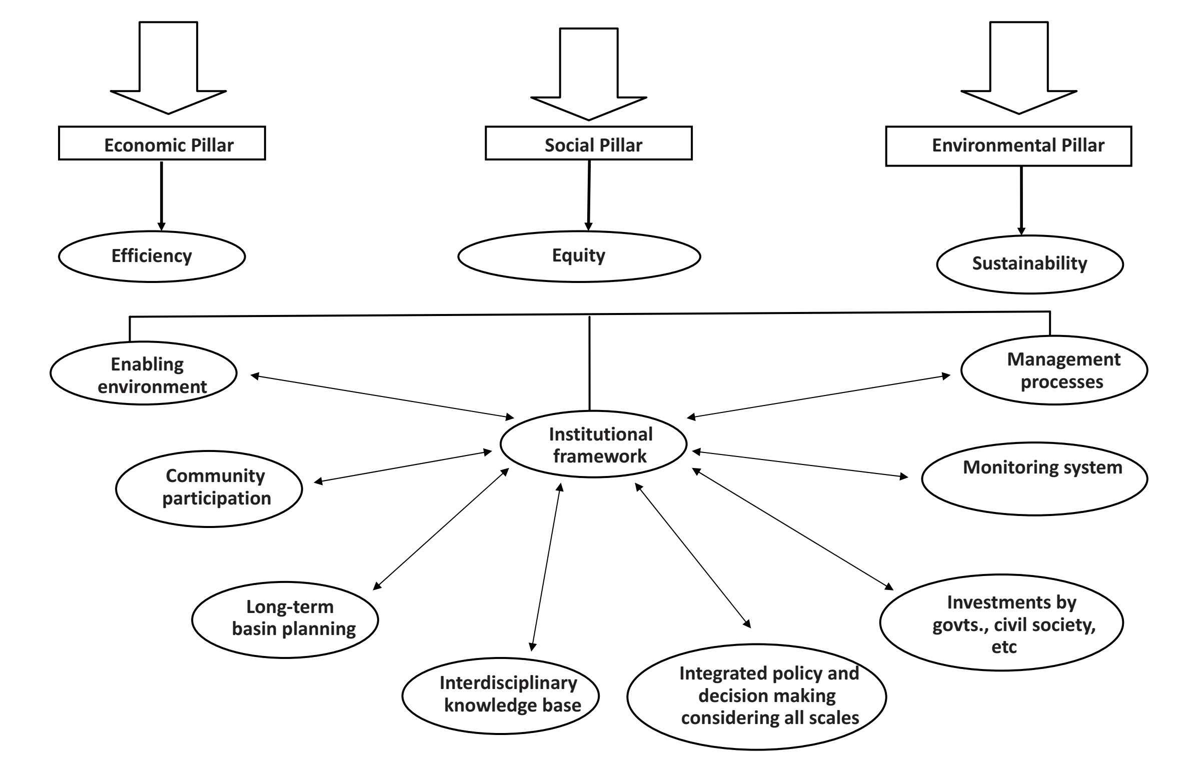
V. *Adequate investment by governments, the private sector, and civil society organisations in capacity for river basin planning and participation processes:* There needs to be adequate investment and cost-sharing by all relevant stakeholders in the system, thereby making them more responsible for the success of such a system.

VI. *A comprehensive foundation of knowledge of the river basin and the natural and socio-economic forces that influence it:* One needs to note here that one pre-requisite is good knowledge of the condition and behaviour of the social-ecological system of the basin. This refers to the strategic assessment of water and related resources to include all aspects of catchment data, not just water quantity.

VII. *Establishment of a monitoring system:* There needs to be a detailed, ongoing monitoring and auditing process to openly assess if the basin-wide institutional arrangements are achieving the goals and objectives set by governments.

Fig. 2.2 shows the Integrated River Basin Management framework with its economic, social, and environmental pillars. This depends on promoting economic efficiency, distributional equity, and environmental sustainability. Fig 2.2 further suggests that at the centre of promoting IRBM is creation of the right institutional framework, which in later parts of the volume will emerge as the River Basin Organisation (RBO) for the Brahmaputra sub-basin. It is the institution that will essentially bring about the enabling environment and the management processes for promotion of IRBM.

Fig. 2.2.: Integrated River Basin Management



Interestingly, despite acknowledgements of the ideas of IRBM, experiences in the US, the UK and Canada suggest that by the late 1970s, governments continued to subscribe to the idea that IRBM could be achieved through a bureaucratic and largely government-led institutional approach (Mitchell 1990). Watson (2004) documents the case of IRBM with reference to the Fraser Basin Council in British Columbia, Canada. This case provides valuable insights regarding the key institutional conditions and arrangements required for a collaborative approach to IRBM to succeed. It highlights the importance of a common vision for effective collaboration because of heterogeneity in cultures, values and objectives among government and non-government organisations with interests inland and water management. In the case of the Fraser Basin, a common vision is presented in the Charter for Sustainability, which articulates the agreed long-term management goals, the major sustainability challenges to be addressed and managerial principles to guide action. The Charter provides strategic direction and is also used at the operational level to ensure that initiatives are consistent with the agreed vision and principles. Two more important issues that it highlights are: adaptive capacities, and resources.

In France, water resources management and planning is institutionalised at three levels: national, basin, and sub-basin. At national level, a Member of Parliament nominated by the Prime Minister chairs a National Water Committee (NWC). In each of the six large river basins, a River Basin Committee (RBC), chaired by a local elected official, consists of representatives from local authorities (40%), water users and associations (40%) and the State (20%). The RBC prepares a Water Development and Management Master Plan for approval by the State. Each has now been revised as a River Basin Management Plan that complies with the European Water Framework Directive. At the local level – tributary, sub-basin or aquifer – Local Water Commissions (LWCs) prepare a Water Development and Management Plan. LWCs consist of representatives of local authorities (50%), water users and associations (25%) and the State (25%). A Local Water Commission can implement plans through a Local Public Basin Establishment or other local group. Inter-municipal bodies may also undertake studies or work at the sub-basin scale.

2.5 The importance of Environmental Security in the context of trans-boundary water management

The notion of environmental security came under policy and strategic considerations in the 1980s mainly for two groups: (1) the environmental policy community, addressing the security implications of environmental change, and (2) the security community, looking at new definitions of national security, particularly in the post-Cold War era. From these perspectives, the Environmental Change and Security Programme of the Woodrow Wilson School of Public and International Affairs appeals, "... Environmental challenges—such as land degradation, deforestation, climate change, and water scarcity and pollution—can threaten our security. But managing these environmental challenges can also build confidence and contribute to peace".[1] Despite such concerns, there hardly exists a proper delineation of "environmental security", though such a notion can be amply found in the academic literature. Most of the few existing definitions are context-specific, with a generic one being conspicuous by its absence.

The initiation to the problems of environmental security is offered by the spatial inequity in distribution of environmental resources across the globe. In fact, the initial endowment and distribution of environmental resources as a potential contributor to conflict has been the subject of considerable research. The literature amply shows evidence of the Malthusian creed of hypothesising "scarcity induces disputes" as an explanation of environmental conflicts in general (Westing 1986; Homer-Dixon 1991 and 1994; Gleick, 1993; Richards and Singh, 1997; Hall and Hall 1998; Rowley 1998). Chalecki (2002) attempted to offer a definition of "environmental security" in a broader context by defining the notion in terms of the ability of a nation or a society to withstand environmental asset scarcity, environmental risks or adverse changes, or environment-related tensions or conflicts. The idea comes close to Homer-Dixon's Ingenuity thesis, where Homer-Dixon stated that the ability of a nation to combat resource scarcity is through generation of new ideas, which he called "ingenuity" (Homer-Dixon 2000). Steiner (2006) expresses that environmental security is an overarching term that entails energy security, climate security, water security, food security, and health security. Myers (1989, 2004 and 2008), one of the long-standing scholars working in the arena of environmental security, feels that the nature of the concerns of environmental security have been changing because of the changing nature of the relation between human society and its ambient environment. Environmental security, therefore, needs to be construed in terms of humankind and its institutions and organisations anywhere and at anytime (Myers 2004).

This interpretation of Myers (2004) is an important entry point to the entire discourse on environmental security as, essentially, the interaction of human society with nature and their

1. "https://www.wilsoncenter.org/program/environmental-change-and-security-program?topic_id=1413&fuseaction=topics.categoryview&categoryid=A82CCAEE-5BF-E7DC-46B3B37D0A3A575F" (accessed on January 23, 2015)

resulting dynamic relationship have been at the core of post-Cold War interest (Stucker 2006, UNEP 2011). Human activities have transformed the natural environment to such an extent that in many instances the security of humans themselves has often been threatened as a result. This state of symbiotic relation between the changing natural environment and security of human societies is one of the ways of looking at Environmental Security (Myers 2008, Homer-Dixon 1999).

One important concern is the state of the social stress created by resource scarcity or extreme natural events thereby often leading to conflicts. The other important concern is environmental change that often acts as a stressor at the socio-ecological stratum of human existence (Homer-Dixon 1990 and 1994). Therefore, a conflictual state may exist within the human societies with nature acting as the stressor, while there might also be a state of conflict between the human society and nature that poses a threat on environmental security. The context of conflict within human societies for natural resources is well-evidenced and well-understood. They can be evidenced from the various cases of water conflicts, conflicts over agricultural land-use, forest rights, and conflicts over oil resources. The less understood part is related to human interventions in the natural resource flows, and eventually disrupting ecosystem service flows for short-term economic gains in the name of "development". As an example, anthropogenic interventions in the natural hydrological flows have often proved counter-productive in the long-run, despite yielding short-run economic benefits, as has already been stated earlier. Such interventions have negatively affected human livelihoods further downstream by affecting ecosystem services (Bandyopadhyay and Ghosh 2009). These are all concerns for environmental security. Dalby (2013 and 2016), however, has expressed that there remains lack of social-scientific evidence on the Malthusian creed advocating environmental scarcity as a cause of conflict. The neo-Malthusian creed has also been challenged by the extensive body of work on "securitization" by the Copenhagen School, mainly associated with the work of Barry Buzan and Ole Waever (see for example, Buzan and Waever 2003, Booth 2007).

With this background, departure is taken from the neo-Malthusian creed of environmental security. As has been stated earlier, the neo-Malthusian creed of scarcity does not apply to the Brahmaputra basin, which is endowed with "ample water". Therefore, this work's definition of 'environmental security' is devoid of the "scarcity" dimension, but takes into account the dimension of "conflicts". Environmental Security is thus defined as a state of absence of conflicts in the complex and interconnected relations in and between the biological, social, economic and cultural processes of human societies and the natural environment. In the process, one may state that environmental security depends on the dynamics in the natural environment, population change, degree of access to the environmental resources, among others. Interaction between and among the determinants of environmental security sets the stage for addressing the environmental security challenges.

2.5.1. Environmental Security in the river basin context

It has been claimed that freshwater is likely to trigger future inter-state wars, being the most famous renewable resource cited as a possible source of acute conflict. More specifically, these potential conflicts can emerge in those particular cases where there are transboundary water

management issues and, particularly, international rivers. However, cases of interstate disputes over water are also ubiquitous in federal nations like India, where water is a state subject.
The literature supports the validity of such a notion in the case of disputes over various other competing uses of water, namely, inter-sectoral allocations and interstate or international allocations (e.g. Bandyopadhyay 1995, Bandyopadhyay and Perveen 2004, Flessa 2004). In fact, in the international context, Homer-Dixon argues, wars over river water between upstream and downstream countries can emerge under four circumstances:

- The downstream country must be highly dependent on the water for its national well being.
- The upstream country must be threatening to restrict substantially river's flow.
- There must be a history of antagonism between the two countries.
- The downstream countries must believe that they are militarily stronger than the upstream countries (Homer-Dixon, 1999: 139).

There is no doubt that, over time, the resource is being put to diverse use, and the conflict arises at the river basin level over user rights, as well as property rights. Environmental Security in the context of transboundary waters has to take into consideration multiple uses and users' perspectives, and need to reconcile between them. The environmental security concern becomes prominent in the present era in the context of the fact that the rise in human pressures on global freshwater resources is in par with other anthropogenic changes in the Earth system (from climate to ecosystem change), which has prompted science to suggest that humanity has entered a new geological epoch, the Anthropocene (Rockström et al 2014). Of course, the critical role of integrated water resource management (IWRM) for the resilience of social-ecological systems at the scale of a basin, by avoiding major regime shifts away from stable environmental conditions, and in safeguarding life-support systems for human wellbeing, is being recognised in the Anthropocene. Environmental security concerns in this new geological era, as documented by Rockström et al (2014), entail the dramatic increase of water crowding: near-future challenges for global water security and expansion of food production in competition with carbon sequestration and bio-fuel production. The broader concerns entail human alterations of rainfall stability, due to both: land-use changes and climate change, the ongoing overuse of blue water, reflected in river depletion, expanding river basin closure, groundwater overexploitation and water pollution risks. The rising water turbulence in the Anthropocene changes the water research and policy agenda, from water resource efficiency to water resilience.

From the broader global environmental security goal, there are changing visions that there needs to be a global response to global challenges in the water sector. A global response may embody elements ranging from UN conventions to international economic trade, but requires critical assessment and the design of creative solutions (Vorosmarty et al 2013).

In any case, there is no doubt that in the Anthropocene, the concerns of environmental security need to be addressed by taking into account the ecosystem services and the livelihoods, through an Integrated River Basin Management approach. Here comes the role of cooperation. Though historically large-scale water conflicts have not yet occurred, there is a generic perception that the prevalence of new stressors like climate change placing more pressure on already limited water resources, may intensify conflicts (Ghosh 2015).

Historically, conflicts have occurred less often when institutional mechanisms facilitating dialogues were present (Wolf et al., 2003). On a similar note, the potential for the increasing intensity for future conflicts may be ameliorated by enhancement of institutional capacity, such as river basin organisations or treaties (De Stefano et al., 2012). Cooperation over international waters is, therefore, seen as an important step in building and securing regional peace. It needs to be remembered here that as in many cases in federal structures, when water turns out to be the sub-national federal state subject, cooperation has often helped in reaching a peaceful equilibrium. Cooperation promises substantial economic benefits, as well, including access to external markets, improved management and coordinated operation of water infrastructure, and optimal location of infrastructure, to name a few (Subramanian et al 2014: 825). Even further, cooperative development of shared waters can enhance the sustainability concerns of the resource, thereby helping the concerns of various stakeholders. There is a more interesting aspect to cooperation that extends beyond the river benefits. These entail opportunities for regional cooperation over labour, markets, and infrastructure not directly related to the river (Sadoff and Grey 2002). A growing literature documents the many benefits of cooperative action (e.g. Yu 2008; Alam et al. 2009).

It needs to be acknowledged that cooperation is not a simple issue. Subramanian et al (2014) review the experience of cooperation in five international river basins, namely, Eastern Nile, Ganges, Niger, Syr Darya, and Zambezi. They focused on the perceptions of risks and opportunities by country decisionmakers responding to a specific prospect of cooperation, and the effects of risk reduction and opportunity enhancement on the cooperation process. They explore the five categories of risk in the process: Capacity and Knowledge; Accountability and Voice; Sovereignty and Autonomy; Equity and Access; and Stability and Support. The paper, which is an outcome of a comprehensive World Bank report consisting of five case studies, infers that risk perception plays a key yet less understood role in decision-making processes over shared rivers cooperation. Further, countries and third parties can best achieve sustainable cooperation when long-term investments are made in risk reduction.

In fact, while most of these studies are conducted at an international level, one needs to appreciate the two-level game that river basins are exposed to. In that sense, for the Brahmaputra sub-basin, cooperation has to evolve from the state and the international levels, taking into consideration the needs of the various stakeholders at various levels. Environmental security concerns can thus be addressed in the basin considering issues of food security, energy security, drinking water needs, and various other sectoral demands at the basin scale.

Ghosh (2015) poses the concerns of environmental security in the Ganges-Brahmaputra-Meghna basin, and places this in the context of three perspectives, namely, the ecological perspective acknowledging the ecosystems-livelihoods linkages, the perspective of economic valuation of the in-situ services of water, and the development of institutions. Mirumachi (2015) presents an analytical framework in order to advance the conceptual thinking beyond simplistic analyses of conflicts and cooperation of transboundary waters. The Transboundary Waters

Interaction NexuS (TWINS), which she developed, examines the co-existence of conflict and cooperation by highlighting the power relations between basin states that determine negotiation processes and institutions of water resources management. Valvis (2011) infers that lack of a strong international institution should be viewed along with the states' interest for security via the pledge of sovereignty rights. In the case of a transboundary river Evros-Meric-Maritza river in EU which is concerned with three nations—Greece, Turkey, and Bulgaria—there is a lot of concern, however not followed with sufficient enough initiatives concerning its triangular management. Moreover, it is common every year to observe extended flood incidents in the river's delta both in the Greek and Turkish side with local farmers being frustrated from the lack of cooperation.

2.6 The Drivers-Pressures-State-Impacts-Response (DPSIR) framework

In order to understand the nature of the ongoing transformations in the society, economy and the natural environment in the Brahmaputra sub-basin, the Driver Pressure State Impacts Response (DPSIR) framework is being introduced in this section. The DPSIR is a causal framework describing the interactions between the society and the environment. It is a flexible framework developed to assist decision-making in the entire scheme of strategic decision process. The framework was initially developed by OECD (1994). Later on, the United Nations (UNEP, 1994 and 2007) and European Environmental Agency (EEA 1999) further modified this framework to relate human activities to the state of the environment.

Drivers: Drivers are the social, demographic and economic transitions in societies and the corresponding changes in production patterns, lifestyles, overall levels of consumption, among others. (EEA, 2007). The drivers are exogenous to the environmental system and entail forces or shocks emerging from the social, economic and institutional system that trigger pressures on the environmental state, directly or indirectly. Such driving forces are often interactive, and non-hierarchical in nature and affect the structure and relation between the social, economic, political and environmental systems (Rodríguez-Labajos et al., 2009). These drivers are categorised as: primary, secondary, tertiary, and base drivers. The 'primary driving forces' emerge from the human economic activities like industry, agriculture, tourism, and others. Policies (e.g. water policy, statutes, others.) or policy changes emerge as the 'secondary driving forces'. The longer term emerges with a broader spatial sphere of influence, creating 'tertiary driving forces', through changes in perceptions and lifestyle (e.g. impacts of the media, changing consumption patterns, and others). Finally, the 'base driving forces' include fundamental trends (demographic or cultural), which are only influenced by social decisions in the long term.

Pressures: The EEA defines pressures as 'developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities'. Pressures are the direct effects of the drivers. In that sense, pressures are the anthropogenic factors inducing environmental impacts.

State: State refers to the existing state of a natural or social-ecological system. A state can vary from the qualitative and the quantitative characteristics of ecosystems, natural resources, human society, quality of life indicators to even larger socio-economic issues. In the context of a water body, the state reveals the condition of the water body resulting from both natural and anthropogenic factors (e.g. ecological characteristics, water quantity, and others) (Mattas et al 2014).

Impacts: Operation of Pressures on the existing state creates Impacts. Impacts involve changes in the ecosystem functions and services affecting environmental, social and economic dimensions. These might be in the form of water and air quality, soil fertility, health or social cohesion, among others. (Maxim et al., 2009). Essentially, Impacts entail the resulting influences on human well-being. Through a feedback loop, Impacts trigger Responses.

Response: Responses are the actions, which might evolve in the form of mitigation or adaptation processes, either in the form of a policy or a strategy, to combat the Impacts either through elimination or reduction of their negative consequences or promotion of positive consequences. Social groups, individuals, governments, civil society groups can come up with the Responses. It is a feedback loop of impacts that help initiate Responses. In turn, Responses can influence trends in the drivers, which in turn, can alter or modify the entire loop. These are responses to improve the state of the water body.

2.6.1 DPSIR in a river basin context

A generic identification of forces in the DPSIR framework in the river basin context is given in Table 2.3 below, as has been identified by Kagalou et al. (2012).

Table 2.3: Identifying DPSIR in a river basin context

<table>
<tr><th>Drivers</th><th>Pressures</th><th>State</th><th>Impacts</th><th colspan="2">Response</th></tr>
<tr><td>Agriculture</td><td>Fertilizer use, pesticide use, land use change, irrigation, livestock</td><td>Water quality concentration of chlorophyll-a, habitat destruction</td><td>Deterioration of water quality, eutrophication, conservation status</td><td>Agricultural policies, management plans for diffuse pollution loads</td><td rowspan="5">Integrated River basin Management through demand management, cooperative management systems, treaties and agreements among stakeholders, stakeholder education, water pricing, and development of institutional frameworks to facilitate the process.</td></tr>
<tr><td>Urbanization</td><td>Growth of urban and semi urban areas, demand for sewage treatment</td><td>Dissolved oxygen, nutrients concentration</td><td>Eutrophication, increase of oxygen demand, habitat loss</td><td>Agricultural policies, management plans for diffuse pollution loads</td></tr>
<tr><td>Industrial development</td><td>Industrial effluents</td><td>Flow variability, conservation status</td><td>Water quality, habitat loss, species extinction</td><td>Implementation of pollution level and quality standards</td></tr>
<tr><td>Recreation demands</td><td>Urbanization, waste generation, soil sealing</td><td>Waste disposal, touristic infrastructure/ facilities</td><td>River basin degradation, habitat alterations</td><td>Holistic management approach</td></tr>
<tr><td>Need for nature protection, climate change</td><td>Demands for conservation, species conservation, floods/droughts</td><td>Area demand for nature, populations decline</td><td>Conservation status, effects on biodiversity</td><td>Measures for species and habitats conservation, evaluation of goods and services, community participation.</td></tr>
</table>

Source: Kagalou et al (2012)

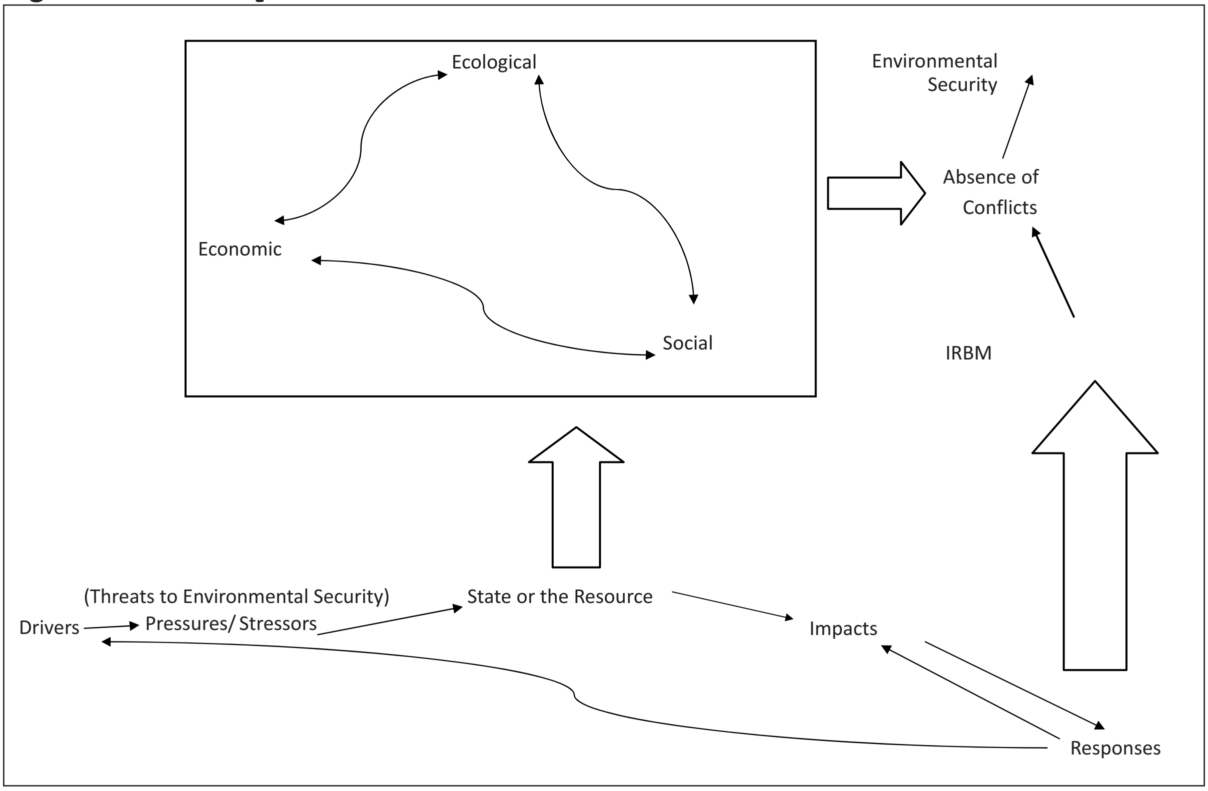
While identifying the DPSIR framework in the context of a river basin, as stated in Table 4.1, the driving forces in a river basin are generally anthropogenic in nature. These take the form of urbanisation, thereby increasing the demand for domestic water supply, sanitation, energy, among others; industrialisation, thereby increasing the demand for industrial water use; and of course, rising agricultural water use to meet the water demand for irrigation; and recreation demands – these driving forces create the pressures on the state of the resource through pollution and overexploitation. Further, there are ecological drivers as well, where civil society groups raise voices for environmental sustainability. This affects the state of the resource by drawing down the water levels or polluting it further. The impacts are evident: water becoming non-potable, non-usable for agriculture, and scarce for use. To combat these forces, there might be host of responses, as stated in the circle, and they might entail a host of issues like stakeholder education, water pricing policies, artificial recharge of groundwater, waste water treatment, water use restrictions, upstream-downstream treaties, and others.

Mattas et al. (2014) used the DPSIR framework to investigate the main causes and origins of pressures and to optimise the measures for sustainable management of water resources in the Gallikos River basin located in the northern part of Greece, and the coastal section is part of a deltaic system. In a similar note like Kagalou et al. (2012), who employed similar methodology for a site in Mediterranean, they come up with the major driving forces affecting the Gallikos River basin as urbanisation, intensive agriculture, industry and the regional process of economic growth. The pressure points emerge from overexploitation of aquifers, water quality degradation, and decrease of river discharge. Recommended responses were based on the EU Water Framework Directive (WFD) 2000/60/EC, and sum up to rationalisation of water resources, land use management and appropriate utilisation of waste, especially so, effluents. There needs to be an integrated approach as a response to the management of the river basin, and DPSIR seems to be an appropriate methodology for analysis. More importantly, while upstream-downstream concerns need to be taken into account, so are the sectoral needs also need to be taken into consideration, keeping in mind the sustainability concerns. This is the reason behind the application of DPSIR framework in the context of this study.

2.7 Conceptual Framework

From the above discussions, this study proposes the following conceptual framework, as given in Fig. 2.2. The framework presents itself in the form of modifying the DPSIR to fit this study's needs. As such, the state of the resource, which is the river basin in this case, presents the interactivity of the social, economic, and ecological forces. The anthropogenic drivers create the pressures or the threat points for environmental security, defined as absence of conflicts in this interactive dynamics of the three forces, as per the definition given in section 2.5. The possible impacts of such threats will be conflicts. So far, there have been existing institutional responses. Their impacts on the drivers need to be examined. In this report, a proposal is made for the response to take the form of Integrated River Basin Management (IRBM), which the authors envision as an important intervention to create a possible condition of absence of conflicts, thereby helping the cause of environmental security. This is represented in Fig. 2.3.

Fig. 2.3: The Conceptual Framework



2.8 Summary

This chapter intended to lay the foundations for the ensuing exercise to devise an optimal management framework for the transboundary waters of the Brahmaputra sub-basin. While management regimes for "water-scarce economies" have been defined theoretically in the literature (Ghosh and Bandyopadhyay 2009), there is a gap in the literature on identifying management regimes of a basin like that of the Brahmaputra sub-basin which does not qualify with the Malthusian creed of "scarcity induces conflicts". Yet, the concern of an impending conflict remains because of non-acknowledgement of the ecosystems-livelihoods linkages, a lack of understanding of the concern that floods and droughts are integral components of the eco-hydrological cycles, a similar lack of a river basin approach of management, and an ignorance of ecological economics from the valuation as also the institutional perspectives of governance and property rights. Ecological Economics, from the perspective of the social-economic-ecological interactivity and from the perspective of promoting IRBM is, therefore, an important cornerstone of this framework. The next chapters will relate the ecosystems-livelihoods linkages with the theoretical foundations of DPSIR (drivers-pressures- state-impact-response), and propose how IRBM can be the possible response through an institutional mechanism of River Basin Organisation for a better management regime for the Brahmaputra.

3 The Brahmaputra Sub-basin in the DPSIR Framework

3.1 About this Chapter

In this chapter, an attempt is made to identify the various drivers and pressures on the existing state of the Brahmaputra sub-basin. The drivers that lead to pressure points on a resource can generally create impacts on the state of that resource. In those cases where the impacts are destructive, change is needed, which in turn requires institutional responses. In the context of the Brahmaputra sub-basin, there is a need to identify these drivers and the pressure points emerging from the drivers and to document the impacts and the institutional responses. Through the feedback loop, the DPSIR framework provides the opportunity to look at how the responses have worked on the state of the resource. This chapter presents an analysis of the Brahmaputra Socio-Ecological-System (SES) using the DPSIR, which was earlier described in Chapter 2.

3.2 Identifying the Drivers, Pressures, Impacts and Responses in the Brahmaputra Sub-basin

The uniqueness of the Brahmaputra sub-basin lies in the fact that the conventional driving forces, as thought to exist in the context of a river basin,are not strictly valid in the case of the Brahmaputra. As stated in Chapter 2, though the forces of urbanisation act as drivers in parts of the sub-basin, the situation in the context of per-capita water withdrawal or availability in the Brahmaputra sub-basin as a whole cannot be described as acute as compared to the situation pertaining to other river systems like Cauvery, Krishna, Godavari, Sabarmati, or for that matter, even the Ganges.

While urbanisation and agriculture are drivers of water use in the Brahmaputra sub-basin, they have created certain pressure points that do not really conform with the Malthusian creed of relative scarcity. The pressure points emerging from the drivers essentially affect water quality, rather than leading to problems of per capita availability. As far as agriculture is concerned, the region has primarily been subjected to high growth, with acreage under paddy registering one of the highest growths. As such, with agricultural water being recycled back to surface and groundwater, it has often been stated that the origin of water quality problems can be traced back to the indiscriminate use of fertilisers and pesticides. This has jeopardised human health through eutrophication of surface water and nitrate pollution of groundwater in the downstream areas of Assam and in Bangladesh. In addition to this, overgrazing and poorly managed animal feeding operations are also responsible for pollution. At the same time, increasing siltation, eutrophication of lakes and shrinkage of wetlands through weed infestation have been adversely affecting the fishery economy.

The other potential driver of the economy is the extensive hydropower potential of the upper reaches of the Brahmaputra sub-basin. A detailed discussion of this driver is discussed in the latter part of this chapter. China's plans of constructing hydropower projects in the upstream of the Great Bend of the Yarlung Tsangpo River are well documented. The hydropower projects in China have been projected in the media as a major stressor but probably without much validity. The Brahmaputra is fed by snowmelt, glacial melts and monsoon rains. A large part of the flow in the Brahmaputra is generated within the Indian boundary and is fed by the Indian tributaries. A conservative estimate will suggest that around 85 percent of the total stream-flow emerges within the Indian boundary (Ghosh, 2015). There is a huge difference in stream-flow between the Bahadurabad measuring station in Bangladesh and the hydropower project at Zangmu in Tibet. The respective annual flows suggest that the flow at Bahadurabad is more than five times the flow at Zangmu. In fact, as suggested in one of the most comprehensive assessments of the Brahmaputra River, the peak flow in Guwahati, Assam is to the tune of 60 cumec, almost nine to 10 times that at the Tsela Dzong measuring station located close to Zangmu, where it is barely six to seven cumec (Singh et al., 2004).

3.2.1 Stress as a Two-Level Game

Nevertheless, the Brahmaputra's pressure points emerge from the fact that it presents itself as a two-level game. The first level is the dispute between the Northeastern states of India, especially Arunachal Pradesh and Assam. There is a widely held view in the Northeast that hydropower can be extracted in the Brahmaputra sub-basin, irrespective of the protests against the projects at the local level. On the other hand, Arunachal Pradesh's rejection of the proposal of North East Water Resource Authority (NEWRA) and creation of its own Arunachal Pradesh Water Resource Authority (APWRA) has not been received too kindly by downstream Assam.

At the same time,a stress point is created by India's plans of interlinking of rivers. The opinion that the lack of flow in the summer months in Jamuna (Brahmaputra) causes sedimentation and water scarcity in agriculture in the sub-basin areas in that country has frequently been expressed in Bangladesh. The proposed linking of the Brahmaputra to the Ganges to improve the water flow in the Ganges is part of the larger River Link Project (RLP). The proposed RLP is a project for storage and long-distance transfer of water promoted by the traditional engineering perspective (Figure 3). However, this project has drawn serious criticism from the perspective of sustainability and equity (Bandyopadhyay, 2009:147-83) and from that of economics (Alagh et al., 2006). Bandyopadhyay and Perveen (2008) have expressed their apprehensions about the project to interlink rivers and feel that it may further worsen inter state water disputes, in addition to aggravating the hydro-political situation in South Asia. They identify avenues through which new inter-state conflicts may emerge with the project. It is a fact that the federal states in India have always enjoyed apportionment and allocation rights over water. However, within the centralised scheme of allocation under ILR, the existing modes of riparian rights of the states would have to be compromised. This would fundamentally lead to disputes and conflicts. Already, a few states have expressed dissent against the project. Unfortunately, these views, critical to the scientific credibility of such a large project, have not had any impact on official policy. Therefore, the question remains whether the official approach will continue to take investment decisions following a traditional engineering perspective or be willing to accept the emerging holistic perspective of ecological engineering.

Several talks have taken place between India and Bangladesh on Brahmaputra basin water management. The official discussion was initiated by section B (Articles VIII-XI) of the 1977 Ganges agreement that deals with the long-term arrangement for augmenting Ganges water at Farakka. Article IX instructed the Indo-Bangladesh Joint River Commission (JRC) to carry out investigation and study of schemes for augmenting the dry season flow of the Ganges, with a view to finding a solution that is economical and feasible. According to the instruction, in 1978, Bangladesh and India exchanged their official proposals for augmenting the dry season flow of the Ganges. These were subsequently updated in 1983. However, the principles of the 1983 proposals were identical to the 1978 proposals (Crow et al., 1995:262). India's response to flow augmentation of Ganges has been the thinking of creation of link canals for transfer of flow from the Brahmaputra to the Ganges, though the idea is yet to be operationalised.

On the other hand, there has also been a proposal of the construction of three storage reservoirs—Tipaimukh, Subansiri and Dihang—in the eastern foothills of the Himalaya for flood management and supplementing the dry season flow of the Brahmaputra. The dams at Dihang and Subansiri were estimated to lower the peak flood of Bangladesh by 1.3 m, while the proposed Tipaimukh, Suban is expected to reduce the flood in the Meghna basin of Bangladesh especially in Dhaka (Crow et al., 1995:164-168; Verghese, 1999: 363). The proposal mentioned four potential reservoir sites but estimated that the water from these reservoirs would not be enough to meet the demand of the three countries, namely, India, Bangladesh and Bhutan. Bangladesh rejected India's plan, claiming that it would not be technically feasible (Crow et al., 1995:170-174; Rahaman, 2008). In addition, Bangladesh claims that dry season flow of Brahmaputra is not abundant. Therefore, the country has objected to India's plan on the grounds that Bangladesh needs 5,100 cumec of water from the Brahmaputra for irrigation alone during February to April (Rahaman, 2008).

3.2.2 Lack of Ecosystems Perspective as a Pressure Point

It is essentially the unexplored nature of the Brahmaputra that creates immense potential for diverse uses of the river. Therefore, while the existing drivers like irrigation and urbanisation have created pressures on the state of the resource, especially from quality perspectives, the impending pressure will emerge from sources like hydropower plants that are coming up in hundreds in the upper reaches of the sub-basin, especially in Tibet, China and Arunachal Pradesh, India. The relative lack of human interventions in the sub-basin creates responses such as hydropower development. In the Environmental Impact Assessment (EIA) of these projects, considerations of many important downstream issues are limited, if not absent. In India, interlinking of rivers is the other institutional response to the natural variations in water availability at a national scale. This is prone to create further pressure due to the lack of ecosystems perspective in project assessment. The impact of this response mechanism is a potential future conflict. The "state of conflict" over water use can be detrimental to the hydro-political situation in the South Asian region as a whole, creating stress on the environmental security in the context of India–Bangladesh transboundary water relations at the international level and problems at the state-level. Therefore, four major issues are identified here, in the context of the drivers that may create problems for the environmental security in the region. Of course, there are many more issues, but these four, more or less, encompass the entire domain of the critical concerns.

Table 4.2. Drivers, Pressures and Impacts on the Brahmaputra Sub-Basin

Drivers	Pressure	State	Impact
Agriculture	Increased fertilizer and pesticide use	Arsenic pollution, eutrophication of surface water, nitrate pollution	Drinking water getting non-potable, health costs increasing
Urbanisation	Construction over floodplains	Increased intensity of floods affecting property	Increasing losses due to floods
Hydropower	Large-scale constructions of dams	Ecosystem service losses, changes in sediment dynamics.	Downstream impacts, conflicts among riparians
Climate Change	Changes in precipitation cycle	Impacts on agriculture, and productivity losses.	Threat to environmental security

The overall impact is on the environmental security of the region. The problem is rooted in the lack of an ecological perspective in water management projects. This is more so as the various stakeholders at the sub-national and international transboundary levels have taken a reductionist approach towards the pursuit of short-term economic gains.

This is clearly in contravention with the growing consciousness that a riverbasin needs to be looked at as a collection of productive ecosystems that greatly affects livelihoods further downstream. The growing recognition of the importance of the ecosystem services has been highlighted in the report of the Millennium Ecosystem Assessment (2005). Based on recent research on the economic role of ecosystem services, in several countries, the sustaining of healthy and functioning natural ecosystems has become a genuine contender in the allocative mechanisms for water (Aylward et al., 2005; Dyson et al., 2003).

To complement the ecological perspective, a fundamental re-examination has been going on with the internalisation of important perspectives of ecological economics, which, most importantly, entails identification of economic values with ecosystem processes (Ghosh and Bandyopadhyay, 2009b). Such valuation exercises are often conducted by offering a range of values, which, by themselves, are approximations. The importance of such valuation exercises is their usefulness in providing the means to internalise factors that are not considered in the traditional assessment of river projects. Even theoretical papers, at times, become useful in providing a baseline for broader assessment at the local level (e.g., Ghosh and Shylajan, 2005). Bouhia (2001) and Hitzhusen (2007) have created some interesting applications using extensions of the valuation frameworks for understanding the impacts and assessment of water projects and river systems. However, a comprehensive process of valuation has evolved from the Water Allocation Systems (WAS), developed by a project at Massachusetts Institute of Technology (MIT) on water management and conflict resolution in West Asia. One of the outcomes of this project is a volume by Fisher et al. (2005). The volume incorporates not only social and private economic issues but also environmental concerns. Models such as this need to be developed for comprehensive evaluation at the river basin scale, in the context of GBM. For India, Desai (undated), Bandyopadhyay and Ghosh (2009b) and Ghosh (2008) have suggested expansions of the valuation framework in the assessment of projects, though, in reality, little has been done to expand the framework.

Moreover, there has been little work on the institutional aspects of water management at the basin scale over the Ganges–Brahmaputra–Meghna basin. Crow and Singh (2000) have highlighted the need for extending bilateral exchange to multilateral exchange and for expanding negotiations from conventional diplomacy to incorporate private economic actors. This entails considering intersectoral modes of water distribution and considers the ecosystem as a sector that plays an important role in human civilisation. Simultaneously, there needs to be a redefinition in the ways the property rights over water are being looked at.

3.3 The Escape Route from the Impasse

In this chapter, the broad contours of the drivers that create pressure points on the state of the resource are discussed. At a broader level, it is lack of the ecosystems perspective in management that creates pressure points in Brahmaputra sub-basin management. The escape route from this impasse lies in an integrated approach to river basin management over the Brahmaputra sub-basin. However, there are contending actors and contesting interests. The trade-offs need to be understood at a broader level. This is only possible through a transnational river basin organisation. Designing a river basin authority is as difficult as the job of the RBO. However, the only way that an ecosystems perspective or an integrated river basin perspective can be made possible is through an authority that looks beyond parochial and short-term economic gains and instead focuses on broader concerns of sustainability. In the next chapter, the various management challenges that emerge from the pressure points due to this ecosystems perspective are discussed in detail. This is important from the perspective of the institutional mechanism that this report will propose in the ensuing chapters.

4 Management Challenges Facing Human Well-being and Environmental Security in the Brahmaputra Sub-basin

4.1. Introduction

Based on the analysis presented earlier, the main threats to the broader concerns of human well-being and environmental security in the Brahmaputra sub-basin emerge essentially from three pressure points: floods with erosion of land and embankments; water transfer projects (the perceived impacts of the proposed river-linking project) i.e., with the transfer of water from the Brahmaputra sib-basin; and generation of hydropower. There is, of course, a fourth challenge which is more global in nature: the effects of climate change. Climate change essentially emerges as a cross-cutting stressor across all other management challenges, too.

All these pressure points are equally critical and can lead to various forms of "conflict" at different levels of human survival and economic activities in the sub-basin. The DPSIR analysis discussed earlier makes it easy to identify the important management challenges in the Brahmaputra sub-basin. When viewed from the DPSIR perspective, it should be noted that the drivers are essentially "economic" forces, while the pressure points on the state are mostly "ecological" that lead to damages to environmental security of human societies. The approach to the solutions of the management challenges will be based on the concept of IRBM as outlined in Chapter 2. Each of these forces will be discussed in turn.

4.2. Floods

In the meteorological and physiographic situation in the Brahmaputra sub-basin, floods are generally witnessed four to five times during the monsoon high-flows period. The flood waves occur mostly during July and August, the two months with highest rainfall, though there have also been instances of major flooding in May under typical meteorological situations (Datta and Singh 2004). Floods carry high sediment loads, cause land erosion and the shifting of river channels. All these result in extensive losses to life and property as well as rapid changes in ecological situations in areas around the mainstreams. Floods are regular events in the Brahmaputra; they are not an aberration. It is thus surprising that till now, a holistic approach to flood management has not yet emerged.

The part of the Brahmaputra sub-basin falling within India, particularly the valley in Assam, represents an acutely flood-prone region characterised by serious hazards of flood and erosion that, year after year, create massive devastation and bring untold miseries to the people, causing colossal damage to public property and infrastructure. The Brahmaputra river is characterised by high-intensity flood flows during the monsoon season of June to September, with an average annual flood discharge of 48,160 cumec (Goswami and Das 2003).

These floods also disrupt the fragile agro-economic base of the region. With 40 percent of its land surface susceptible to flood damage, Assam's Brahmaputra valley represents one of the most acutely hazard-prone regions in the country, having a total flood-prone area of 3.2 million ha. While these floods are largely a natural phenomena, they have also been aggravated by anthropogenic interventions. Some of the dominant factors that cause and intensify floods in Assam include: the unique geo-environmental setting of the sub-basin vis-à-vis the eastern Himalaya, the highly potent monsoon regime, seismically active landscape, weak geological formation, accelerated erosion, rapid channel aggradations, massive deforestation, intense land-use pressure and high population growth, especially in the floodplain belt, and the dependence on ad hoc temporary flood-control measures. The scenario is exacerbated by a myriad of social, environmental and economic factors that make the resident populations increasingly vulnerable.

Studies have shown that deforestation in the Brahmaputra watershed has resulted in increased soil erosion, higher sediment loads, flash floods in critical downstream areas, in particular the wetlands, such as the Kaziranga National Park in middle Assam (Das 2000; Mipun 1989; Shrivastava and Heinen 2005). The breaching of embankments has been a major cause of intensification of the flood hazards in recent years. The undesirable consequence of embankments—especially in aiding channel aggradation and overbank flooding—is clearly visible. Structural measures, mainly embankments, have been used so far as the sole answer to mitigating the impact of floodings. Out of a total of 15,675 km of embankments built in the entire country, Assam alone has as much as 5,027 km, or about 32 percent of the total (Goswami 2005; Hazarika, 2005).

The state of Assam has experienced major floods in the years 1954, 1962, 1966, 1972, 1977, 1984, 1986, 1988, 1998 and 2002. Floods became increasingly destructive following the great earthquake in Assam in 1950, with those in 1988 and 1998 being the worst recorded in contemporary history. The 1988 flood broke all previous records of flood damage, affecting 1.12 million ha of cropland and claiming 226 human lives and innumerable cattle and wildlife. The total damage was estimated at INR 1,512 crores.Similarly, the 1998 floods were unprecedented in terms of inundation and persistence. New records for high flood levels were created at many gauge stations. In the second wave, the river flowed above danger level in the upstream reach between Dibrugarh and Neamati for a record 100 days and in the downstream reach at Dhubri for 83 days. All the 21 districts in the valley with 4.7 million people in 5,300 villages were affected, damaging 0.97 million ha of cropland. Some 30,400 houses were washed away or damaged and 156 lives were lost. Damages to property were estimated at INR 1,000 crores. In 2002, almost the entire Brahmaputra valley of Assam was submerged; the losses were estimated at INR 2,000 crores.

The most recent destructive floods occurred in 2012, following an episode of heavy monsoon.The floods killed 124 persons and displaced around six million people. It also severely affected the Kaziranga National Park, where 540 animals died, including 13 rhinos. The river swelled to the extent that the braided channels through which the river used to flow were no longer detectable.

Assam would suffer more flooding incidents in the subsequent years. In 2013, the state witnessed floods triggered by heavy rainfall at the end of June in the neighboring state of Arunachal Pradesh through Brahmaputra and its tributaries (Bhaumik 2013). The flood submerged 12 of the state's 27 districts and affected more than 100,000 people. (The districts were Bongaigaon, Chirang, Dhemaji, Golaghat, Jorhat, Kamrup, Karimganj, Lakhimpur, Morigaon, Nagaon, Sivasagar and Tinsukia.)A total of 396 villages were affected and around 7,000 ha of agricultural land were destroyed. The flood also affected the Kaziranga National Park and Pobitora Wildlife Sanctuary, where resident animals were later found to have saved themselves by moving to higher ground(ASDMA 2013). The floods also affected some of the northern districts of Bangladesh, where an estimated 100,000 suffered from lack of food and safe drinking water (*Dhaka Tribune* 2013).

Again in 2015 there was a major flood, triggered by heavy rainfall at the end of August in Arunachal Pradesh through Brahmaputra river and its tributaries. The floods are said to have caused the deaths of 42 people and triggered numerous landslides and road blockages, affecting some 1.65 million people across 21 districts.[1] Flooding affected 2,100 villages and destroyed standing crops across an area of 180,000 ha.

Table 4.1: Damages in major flood years

Year of Major Floods	Area affected (mha)	Cropped Area (mha)	Population Affected (million)
1954	2.9	0.3	1.3
1955	1.35	0.07	0.18
1958	1.23	0.06	0.4
1962	1.59	0.36	3.91
1966	1.51	0.06	3.62
1969	1.06	0.07	0.89
1972	1.01	0.36	2.95
1973	2.31	0.17	1.84
1977	1.02	NA	4.54
1980	1.14	0.26	3.35
1984	1.49	0.14	5.61
1987	1.62	0.43	10.49
1988	3.82	1.12	8.41
1993	1.25	0.22	5.26
1996	1.33	0.28	5.12
1998	0.97	0.29	4.7
2002	0.80	NA	5.36
2012	1.45	NA	1.5
2013	NA	0.07	NA
2015	0.65	0.18	1.65

Source: Compiled by the Authors

As identified by scholars like Goswami (2014), while there has been a long history of floods in the Brahmaputra valley, the great earthquake of 1897 (measuring 8.7 on the Richter scale) caused tremendous changes in the fluvial regime by suddenly raising the channel beds. Devastating floods, in absence of appropriate flood management systems, occurred in succession thereafter—in 1898, 1905, 1907, 1916, 1921, and 1931. In 1950, another major earthquake (magnitude 8.6) led to excessive siltation of the bed, thereby raising it even further. This led to increased frequency of floods. This fluvial geomorphology must be understood to appreciate the massive challenge posed by floods (Bhattacharya and Bora, 1997). While the 1897 earthquake disrupted the topography of the lower Brahmaputra, the earthquake of 1950 created a huge impact on the upper part of the sub-basin (Bora 2004). As would be eventually reported by Assam's Flood Control Department in 1989, the bed near Dibrugarh and further downstream rose by some 2.5 to three meters in the aftermath of these earthquakes.

As such, the Brahmaputra is vast, and flows through a narrow valley that is laden with easily erodible rocks in its steep slopes. The width between outer banks has a range of 1.2 km at one nodal point to 18 km or more at one or two sections. Individual low-water channels can have widths of up to 1 km or so. Some sources indicate that the average width in Assam increased from about 5.8 km in the 1920s to about 7.3 km in the 1990s, and that the 1950 earthquake led to short-term increases of about 200 meters per year during the 1970s. The average rate over 70 years would be about 20 meters per year (Wiebe, 2006: 5).

Such large overall widths, considered together with the magnitude of its water flows and the multichannel nature of its platform, suggest that, compared to other major rivers of the world, the Brahmaputra is supplied with and transports high concentrations of bed sediment. The reported increases in width in the second half of the 20th century presumably reflect increases in bed sediment inputs resulting from the 1950 earthquake. Experts say that if no other major earthquake happens in the future, the average width might go down (NHC 2006). Therefore, heavy monsoon rains coupled with devastating landslides are highly prone to raise the bed levels. The riverine valley, with a width of 80 km, is bordered on both sides by hills and highlands and stretches for around 720 km. Of the 80-km width, the river itself covers a width of six to 10 km in most of the stretch. Heavy monsoon rains—ranging from 2,500mm to 6,500 mm over June to September—frequently cause the floods. The peaking of the tributaries at the confluences within a short period of time raises the water to above-dangerous levels. With flood waves remaining above the danger levels for prolonged periods in the absence of adequate sinks, what follows is acute congestion. The tributaries are unable to discharge their own flows.
While natural and hydro-meteorological phenomena contribute to the occurrence of floods, their frequency and severity have been aggravated by anthropogenic factors. For one, there has been large-scale deforestation in the sub-basin, leading to heavy soil erosion and the generation of enormous quantities of sediments.The practice of shifting cultivation on the hill slopes of the basin worsen the soil erosion. Man-made embankments, human settlements in the floodplains, and steady disappearance of wetlands—which offer the natural, ecosystem service of flood mitigation sink—have been aggravating the situation. The issue of disappearance of wetlands has also been worsening due to the increasing urbanisation in the Brahmaputra valley in the state of Assam.

Similar is the case with the Jamuna (the name of Brahmaputra in Bangladesh) floodplains in Bangladesh. Various studies show that the area of flooding across different episodes has varied from 31 percent to 85 percent of the country's total area (Choudhury and Hossain 1981, Pramanik, 1988 and Rashid and Pramanik, 1990). As such, the main source of floodings is the Jamuna. In most cases, embankments have been built as a flood-control measure. But like in Assam, the embankments have only served to aggravate the floods.

As reported by Rahman (2010), there is no systemic pattern of the erosion hazards because of the involvement of a large number of variables in the process. The intensity of bank erosion varies widely from river to river, depending on such characteristics as bank material, water level variations, near bank flow velocities, plan form of the river and the supply of water and sediment into the river. Rapid recession of floods accelerates the rates of bank erosion in such materials.

The Jamuna is a braided river with bank materials that are highly susceptible to erosion. Since the Brahmaputra switched to the course of the Jamuna at the western side of the Madhupur tract, the average width of the river has fluctuated substantially. The recorded minimum average width of the Jamuna was 5.6 km in 1914. Locally, the maximum width has often exceeded 15 km, while the recorded local minimum width was about 1.1km. The rate of widening of the river within the period 1973 to 2000 is 128m/year (68m for the left bank and 60m for the right bank). The annual rate of widening has been as high as 184m during 1984-92, of which 100m occurred along the left bank and 84m along the right. In this period, the average width of the river increased from 9.7 to 11.2 km. The maximum bank erosion during 1984-92 occurred at the left bank, just upstream of Aricha. Both rotation and extension bank erosion mechanisms do occur. The Jamuna has widened in increments from 1973 to the early '90s, but the yearly rate seems to have gone down significantly in the latter part of that decade. The widening of the river over a 28-year period resulted in a loss of floodplain of 70,000 ha over the total 220-km length of the river in Bangladesh (or an average of 2,600 ha/year). Within the 1984-92 period, the river has eroded 40,150 ha of floodplain and accreted 7,140 ha, corresponding to an erosion rate of about 5,000 ha/year, and an accretion rate of about 900 ha/year.

In recent years, human interventions in the Jamuna are growing construction of the Jamuna Bridge, and bank protection structures at Sirajganj, Sariakandi and Bahadurabad will doubtless have some influence on the changes of the width of the river. These structures are impeding the freedom of the river to widen through bank erosion.[2]

4.3. Water transfer out of the Brahmaputra sub-basin

An unsubstantiated categorisation is frequently used in India that classifies river basins as either 'surplus' or 'deficit'. Such a classification is based on the exclusive and incomplete use of water based on potential limit of irrigation, and has no consideration for other diverse uses. The Brahmaputra has been identified on this incomplete and unrealistic categorisation as a 'surplus' sub-basin, from which, it is assumed, water can be transferred as a win-win solution to floods and droughts, without paying any compensation to other users of water, whose livelihoods and

2. http://en.banglapedia.org/index.php?title=Riverbank_Erosion

economic activities like fisheries, navigation, and cultural uses, or the ecosystem processes as a whole. Thus, water may be transferred from a 'surplus' basin to a 'deficit' one without consideration of any compensation to other stakeholders whose access to the water is simply denied, jeopardising livelihoods, ecosystems and economies. On the basis of such a categorisation, transfer of water from the Brahmaputra sub-basin to the Ganges sub-basin has been accepted as part of the River Link Project of India. One way of realising such a transfer is the construction of a barrage at Jogighopa located in India upstream of the entry of the river into Bangladesh. A canal within India will take the water westwards, into the Ganges sub-basin. An alternate route for such a transfer has been also planned in the form of the Manas-Sankosh-Teesta-Ganges (MSTG) link canal.

In the case of a transfer being realised within this conceptual framework, there is a need for a negotiated trade-off, between those interested in the transfer and downstream stakeholders who were so far using the flow of water that is to be diverted. In the absence of such a negotiated trade-off, issues of environmental security and human well-being will remain unsolved, potentially leading to upstream-downstream conflicts. A detailed examination of the social impacts, economic justifiability and contribution or otherwise to environmental security of the River Link project of India has earlier been made by Bandyopadhyay and Perveen (2008).

In the absence of details on the volumes and timing of the transfer, only the general impacts on environmental security and human well-being in the downstream areas can be described. The impact of water transfer from the Brahmaputra before it enters Bangladesh can vary from moderation of monsoon floods to increased scarcity of irrigation water in the pre-monsoon months. It will depend on the period when the transfer will be effected.

4.4. Hydropower projects in the Brahmaputra sub-basin

In recent years, hydropower projects have become the most important focus of human interventions in the Brahmaputra sub-basin. By current norms in India, 12 percent of the annual power generated from the existing hydropower projects is earmarked for the states as royalty paid to them for the use of their natural resources. Two potential benefits are reduced flooding in the valley by flood cushioning, storage facilities in the hydropower reservoirs upstream, and substantial employment generated from the significant investment of more than INR 1,000 billion. There are anticipated influences and implication on other sectors as well, such as service, transport, and tourism. The proposed Brahmaputra Valley Authority is expected to be the institution to drive ahead most of the future water resource development mandates. The Authority will obviously have lessons to learn from the experiences of River Basin Organizations (RBOs) established for other large river basins, especially those on Himalayan rivers in China, such as the Yellow River Conservancy Commission (YRCC). A major learning aspect will be the 'basin scale' approach to human well-being and environmental security, including accommodation of the downstream social and environmental implications of the projects.

The hydropower initiative in NE India indeed requires useful analysis for net benefits that will consider both long-term tangible and intangible gains and losses. Embarking on any large hydropower project in the region is currently fraught with a range of technical and non-technical challenges, mainly due to the threat to socio-economic resources, biodiversity and potential downstream threats and impacts, including of seismic activities. The protest against hydro-power projects in the northeast has been primarily related to the downstream impacts, with no sincere efforts visible to address the issues adequately. The Environmental Impact Assessment (EIA) reports accepted by the Ministry of Environment and Forest for the projects in Arunachal Pradesh, (like the Lower Subansiri, Kameng, Siang hydropower projects) are inadequate (Menon et al., 2003).

Full and free participation of all stakeholders in decisionmaking, focus on environmental security, safety of locations, availability of power grid system, international transmission routes are some of the major issues pertaining to hydropower generation in the sub-basin. Clearly, any project in this region before being implemented should ensure that elaborate technical investigations covering all pertaining aspects are carried out to allay apprehensions and putting in place fool-proof mitigation measures of unavoidable yet reconcilable impacts—including ensuring security of socio-economic activities, livelihoods, environment including water, and food is not jeopardised. A well-enforced licensing system for hydropower projects, as practiced in countries like Switzerland and the US, can be a good mechanism to ensure implementation of all essential mitigation measures to safeguard environment and people from possible harm. The development of small hydroelectric projects, wherever feasible, should be a priority. They benefit villages by job creation, monetary compensation including other priority activities like safety and livelihood security. In many instances, at local levels, these are being argued as better options and thus deserve careful examination, although from the monetary viewpoint, it may appear less profitable. Structural modification, change in location and combination of both (scaling down and change in location) are effective options to minimise the negative impacts of large hydropower projects as well as to safeguard the environment and society.

4.5. Hydropower projects of China on the Yarlung Tsangpo

Quite a few articles have been published in the recent past on the perceived impacts on India of the hydro-power projects China is building in Tibet on the Yarlung-Tsangpo. The estimated hydro-power potential of river Yarlung is around 114,000 MW. In the background of the growing pressure on China for reducing greenhouse gas emissions, this hydro-power potential is very important. The diverse opinions expressed both in the national and international media on the perceived impacts of such interventions by China, are inaccurate and based on scanty data.

There is a widespread public perception in India (especially in the State of Assam), that these structural interventions by China will reduce the flow of the Yarlung river, and of downstream Brahmaputra. A senior strategic thinker in India has expressed that the Chinese interventions on the Yarlung is "most dangerous" for India (Brahma Chellaney in *The Asian Century*, 2009 and more recently in *Hindustan Times*, New Delhi, 28 Nov 2015). Such statements have the potential to generate new points of contention in China-India hydro-political relations. The contentions have been further intensified by the recent operationalisation of the Zangmu hydro-power project on the Yarlung. This project, believed to be the hydro-power plant positioned with the highest altitude, is expected to produce 2.5 billion KWH of electricity per year. In 2016, five more hydro-projects are proposed to be completed on the Yarlung.

Despite a lot of clamour about such projects among strategic experts and the media, hardly has there been ascientific, data-based analysis of the issues placed in the public domain. This has led to unsubstantiated myths and claims. There is no doubt that these contentions deserve to be examined in terms of the structural interventions and their downstream hydrological implications.

To start with, the downstream impacts of hydro-power and water transfer projects are quite different and should be distinguished. The concern of many in India has often been based on the unrealistic perception that all structural interventions always reduce downstream flows. As a result, the fear of the drying up of the Brahmaputra has become widespread in the public mind, especially in Assam. The growing water demand in Tibet and the option available in principle to China of building water storage and transfer projects on the Yarlung has given birth to such fears. The Brahmaputra is identified as the flow downstream of the meeting of three tributaries, namely Luhit, Dibang and Dihang, near Sadiya. The link of Brahmaputra with Yarlung river, which originates from the Angsi glacier near Mt. Kailash, was discovered rather recently. Out of the total length of the Brahmaputra of 2,880 km, 1,625 km is in Tibet flowing as Yarlung Tsangpo, 918 km is in India known as Siang, Dihang and Brahmaputra and the rest 337 km is in Bangladesh has the name Jamuna till it merges into Padma near Goalando.

It needs to be understood that the series of projects undertaken by China on Yarlung and tributaries is reportedly for hydro-power generation, which does not reduce the total flow but changes its daily hydrograph (flow pattern). As such, the impacts on the hydrographs of Brahmaputra will be generated not only from the hydro-projects on Yarlung, but also from the projects on Siang/ Dihang, Dibang, and Luhit. In order to make the discourse more pragmatic, a better understanding of the flows in the Yarlung and the Brahmaputra at various locations will be useful.

As a trans-Himalayan tributary, Yarlung is substantially fed by snow and glacial melts, in addition to rainfall. The annual precipitation in the trans-Himalaya averages about 300 mm per year. As the tributaries cross the Himalayan crest line, the annual average precipitation (mainly rainfall) reaches about 2,000 mm. Thus, a large component of the total annual flow of Brahmaputra is generated in the southern aspect of the Himalaya in India by tributaries from Buri Dihing in the East to Teesta in the west. As per data published by Jiang et al.,the total annual outflow of the Yarlung River from China is estimated to be about 31 BCM while the annual flow of Brahmaputra at Bahadurabad, the gauging station near the end of the sub-basin in Bangladesh, is about 606 BCM. These figures do not support the linear algebraic thinking that the flow in a river is proportional to its length inside a country. Further, while the peak flows at Nuxia and Tsela Dzong, a measuring station at the great bend in the Tibetan plateau, are about 5,000 and 10,000 cumecs, as presented by Vijay Singh and colleagues in The Brahmaputra Basin Water Resources, the peak flow at Bahadurabad is approximately 50,000 cumecs.

In the peak flow periods, the Brahmaputra is fed by the summer monsoon but during the lean season, the share of its flow from the Yarlung river would be larger, the extent of which needs to be based on flow data. The lean season flow in Nuxia, as identified from a hydrograph given in Rivers and Lakes of Xizang (Tibet) (in Chinese), is to the tune of 500 cumecs, while the lean flow at Bahadurabad is about 5000-odd cumecs, all these being peer-reviewed and published data.

Another point of concern relates to the impact of the projects on the sediment flow. The sediments offer immense ecosystem services for the downstream economies of Indian north-eastern states, and Bangladesh. Of course the sediment flow in downstream Brahmaputra will mainly be impacted by all the hundreds of hydro-power projects functioning or being built on the tributaries to that river. Most of these are in India. The series of projects around Zangmu will also affect the flow of sediments, though sediment-exclusion technology has improved manifold lately. Further, the actual sediment flow into Brahmaputra will be more directly linked with hydro-power in India on Dihang, Dibang and Luhit, upstream of Sadiya. This is particularly due to the intense monsoon precipitation on the southern aspect of the Himalaya. While Nuxia (Tibet) receives around 350 mm of rainfall during monsoon, as one crosses the Himalayan crestline and reaches the southern aspect, the annual rainfall in Pasighat touches about 4500 mm. The flow volume and discharge in the Yarlung river is not sufficient to generate and transport carry a large sediment load. Further, the annual suspended sediment load near Nuxia has been measured to be around 30 million metric tonnes, (as suggested in a 2016 volume titled River Morphodynamics and Stream Ecology of the Qinghai-Tibet Plateau by Wang and colleagues), which is minuscule as compared to the same load measured as 735 million metric tonnes at Bahadurabad. However, in the case of hydro-power projects in the southern aspect, the sediment trapping role will be significant.

It thus can be said that 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 aspects of the Himalaya. With negligible 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 can have negligible impact on the downstream southern aspect. The widely held views being propagated in the media will not pass scientific scrutiny. This is unfortunate, because both policymaking and public opinion must be informed by science—and not sensationalism that is based on jingoistic emotions and simplistic logic.

4.6. Climate Change: Projected Impacts

The potential impacts of climate change on the world's river systems have become a growing concern. This is true for India's water resources, too, including the Brahmaputra. The sub-basin is vulnerable to climate change impacts due, first of all, to its location in the Eastern Himalayan periphery. Its geo-environmental setting is fragile and it is experiencing economic under-development. A comprehensive assessment across five major river basins (with Brahmaputra sub-basin being a component) in the Hindu Kush Himalayan region, conducted by the ICIMOD

(2015) reveals, among others, the following: (1) Temperatures across the mountainous Hindu Kush Himalayan region will increase by about1 to 2°C (in places by up to 4 or 5°C) by 2050; (2) The monsoon season is expected to become longer and more erratic; (3) Precipitation across the Hindu Kush Himalayan region will change by 5 percent on average and up to 25 percent by 2050; (4) Extreme rainfall events are becoming less frequent, but more intense and are likely to keep increasing in intensity; (5) Glaciers will continue to suffer substantial mass loss.

The eastern Himalayas are experiencing warming of 0.1 to 0.4°C/decade (ICIMOD 2015) and a simulation model indicates widespread warming of NE India by 1.8 to 2.1°C in the 2030s, with rainfall of higher intensity during monsoon (INCCA 2010). Since 80 percent of the flow in the Brahmaputra takes place during the monsoon period (Dutta and Singh 2004), erratic monsoons or any seasonal changes in rainfall intensity becomes of great significance. Again, more than 12 percent river flow of the Brahmaputra is due to glacial melt, and increased temperature resulting from glacial melt would lead to increased summer flows for a few decades, followed by a reduction in flow as the glaciers disappear (IPCC 1998). Despite the growing attention to quantify freshwater resources and to assess the vulnerability of freshwater to global change (Srinivasan et al., 1998a), basin-wide assessments of the impacts of climate change and land-use change on freshwater availability in the Brahmaputra basin remains quite limited.

The primary source of precipitation in the Brahmaputra sub-basin is the Indian summer monsoon, which is projected to be affected by global warming (Kripalani et al. 2007). Average monsoon precipitation is projected to increase with a possible extension of the monsoon period (Kripalani et al., 2007). Numerous studies have assessed climate change impacts on a particular component of the climatic and hydrological processes in the Brahmaputra basin, e.g. temperature (Immerzeel, 2008 and Shi et al., 2011), precipitation (Kripalani et al., 2007), snow (Shi et al. 2011), streamflow (Gain et al., 2011 and Jian et al., 2009), groundwater (Tiwari et al. 2009), runoff (Ghosh and Dutta 2012), extreme events (Webster and Jian 2011), and even water quality (Huang et al. 2011). However, few studies have assessed how projected changes in climate and land use and land cover could impact long-term patterns in the basin's hydrological components. Using results from multiple global climate model experiments, Mirza (2002) predicted an increase in the average peak discharge in the Brahmaputra basin. Immerzeel (2008) found that the temperature gradient in the Himalayas (from floodplain to Tibetan Plateau) will likely decrease, resulting in a rise in average precipitation and average seasonal downstream streamflow in the Brahmaputra basin. However, the seasonal streamflow in late spring and summer was eventually predicted to be reduced considerably after a period of increased flows from accelerated glacial melt (Immerzeel et al., 2010).

4.7. Summing up

The above analysis identifies three major management challenges in the Brahmaputra sub-basin. The first is that of monsoon high flows, or floods. Damage due to these floods will increase if human settlements expand into the floodplains in a big way and try to establish permanent location for habitat and economic activities. Sharing of space between the humans and the river during the course of the year is a necessity. The engineering of embankments need to be revised with inputs from ecological knowledge. The main objective will be to recognise the monsoon high flows as a natural event, and not a natural disaster.

The topic of transfer of water out of the sub-basin should not be justified on the unsubstantiated basis of 'surplus' to 'deficit' basins but on a comprehensive social and economic parameters and broad stakeholder agreement. In doing so, ecological economic assessment of all the gains and losses related to the transfer needs to be undertaken.

The Brahmaputra sub-basin is rich in hydro-power potential. All three countries in the sub-basin having Himalayan areas—Bhutan, China and India—have made ambitious plans for harnessing that potential. Bangladesh has also shown interest in investing in hydropower projects in countries like Bhutan, and transmits the power to that country. Hydro-power projects are going to be constructed in large numbers; the question is at what scale and on what basis of social and environmental impact analysis. The present process for EIA has become highly incomplete and should no longer be used (Menon et al. 2009). Hardly have processes of Comprehensive Impact Assessments (CIA) or Strategic Environmental Assessments (SEA) have appeared in the government framework for prior assessments before projects are taken up.

Finally, it cannot be overemphasised that climate change is a critical stressor in the sub-basin; it is a cross-cutting stressor. The changes in the precipitation cycle may cause further flooding problems, and structural interventions like the interlinking of rivers and the construction of dams, can prove disastrous if the potential impacts of climate change are not considered. Climate change can make its impacts felt on agriculture and other ecosystem services, and so far there is hardly any literature in this domain as far as the Brahmaputra sub-basin is concerned. This is a research gap which must be filled, with the aim of assisting policymaking.

5 Institutional Response: A Regional Organisation for the Lower Brahmaputra

5.1. About this Chapter

The previous chapter discussed the various management challenges in the Brahmaputra sub-basin in the context of promoting human well-being and environmental security. In terms of the DPSIR framework, the challenges emerge from various drivers that serve as pressure points impeding the objectives of environmental security and human well-being in the sub-basin. It is in light of these issues that institutional responses have been thought of. The Brahmaputra Board has been institutionalised to manage the area of the Brahmaputra sub-basin in India. This chapter discusses the mandate and dominion of the Brahmaputra Board, and the proposed Brahmaputra River Valley Authority. It examines the existing gaps in this institutional set-up, and in the process, expands the spatial requirements for an institution beyond India and talks of a broader trans-boundary institution for the governance of the lower Brahmaputra sub-basin.

The chapter presents a global review of experiences of governance of trans-boundary river basins. The lower Brahmaputra sub-basin, in this context, has been delineated by the area within the Brahmaputra sub-basin that falls within the political boundaries of Bhutan, Bangladesh and India. For now, when institutional development is in its initial stages, the inclusion of Yarlung-Tsangpo upto the point where it enters India, draining the dry region in the Tibetan Plateau, is considered of little significance, as has already been argued in earlier chapters (Bandyopadhyay and Ghosh, 2016). An expansion of the functional area of the new trans-boundary institution to the whole of the sub-basin needs to be considered in the future.

The objective of setting up an RBO is to address the critical management challenges that have been discussed in the previous chapter. Even a cursory view of the four-fold management challenges presented in Chapter 4 shows that these challenges have arisen primarily from lack of both an ecosystems perspective and a systems approach to basin management. Such fragmented approach to river management has led to the aggravation of damages caused by floods. There is hardly any knowledge creation on the eco-hydrology of the floods, nor is there serious attempt to understand—at a broader basin scale—the hydro-geo-morphological foundations of the floods. Every nation in the sub-basin has attempted to address floods in their own ways and that too through local-level structures like embankments. Further, the lack of data and information dissemination has fractured research on creating better models for prediction of flood intensity, and the setting up of early warning systems. As such, the fundamental relation between flood and sediment load is not properly established—floods have thus been viewed as "unmixed" damage, and their role in provisioning services of the ecosystem by enhancing soil fertility and supporting ecosystem services through soil formation is often not understood (MA 2005). It has often been stated that further downstream in the Brahmaputra, the main course is carrying more of sand than nutrient-rich sediment. One of the reasons for this might be the extensive boulder mining in the upper reaches of the sub-basin.

At the same time, there is hardly any systematic approach to arrive at a comprehensive understanding of the impacts of hydropower projects and the interlinking of rivers at the scale of the sub-basin. This is another example of a missing ecosystems approach in river management, threatening the environmental security of the region. What is needed is a "bird's eye" approach by looking at the holistic development at the sub-basin scale so that environmental security is not hampered.

Giving more nuance to the entire discourse is global warming and climate change. Though there might be national-level climate adaptation plans in place, the impacts across the sub-basin as has been documented by ICIMOD (2015) need special attention. As such, understanding the impacts of global warming and climate change at the scale of the sub-basin is important for creating a sustainable management regime. Without a broader systematic approach, this will not be possible.

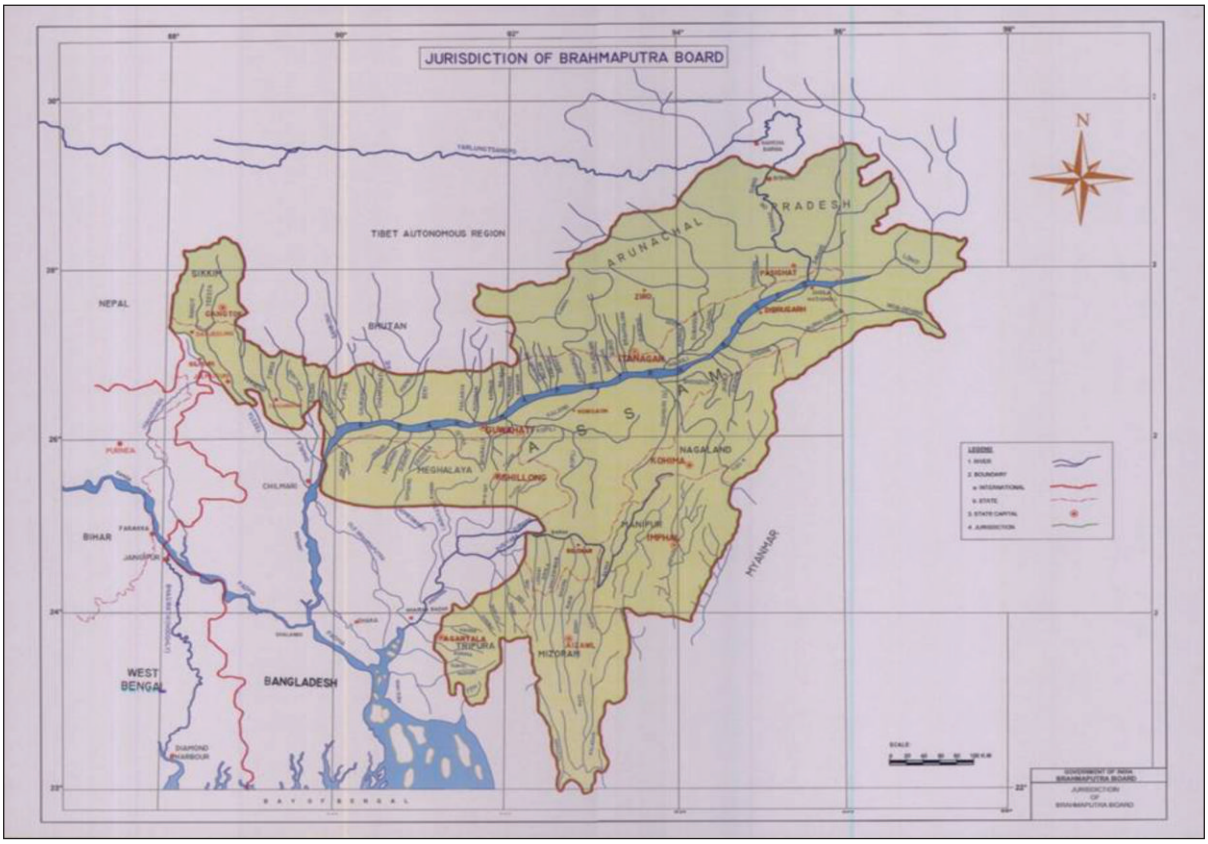
Therefore, the existing institutional mechanisms at the national levels might not be adequate to address regional-level challenges. This makes it an imperative to set up a transboundary organisation that will be mandated to take on a bird's eye view of the challenges, to understand and intra-correlate the micro-level nuances in the cross-section of the sub-basin, and thereby take a systems approach to combat the issues.

5.2. The Brahmaputra Board and the Brahmaputra River Valley Authority

The institutional response in India emerged with the setting up of the Brahmaputra Board, an autonomous statutory body, under an Act of Parliament called the Brahmaputra Board Act (Act 46 of 1980) under the Ministry of Irrigation (later renamed Ministry of Water Resources; and recently changed to Ministry of Water Resources, River Development, and Ganga Rejuvenation). The jurisdiction of the Board is not confined to the Brahmaputra sub-basin, but extends to all the states of the North East India, and part of West Bengal falling under Brahmaputra sub-basin. Therefore, even the Barak sub-basin (which enters Bangladesh as Meghna) falls under the domain of the Board.

The Board consists of 21 Members (four full-time Members and 17 part-time Members), representing states of the North Eastern Region, North Eastern Council, concerned Ministries—Ministry of Water Resources, Agriculture, Finance, Power & Surface Transport--and Departments of the Government of India—Central Water Commission, Geological Survey of India, India Meteorological Department and the Central Electricity Authority (Brahmaputra Board, undated). The Board is funded through a grant-in-aid by the Central Government.

Fig. 5.1: Jurisdiction Map of Brahmaputra Board



Source: http://www.brahmaputraboard.gov.in/NER/Organisation/organisation.html

Recently, a review of the Brahmaputra Board revealed that it was weak and powerless: its mandate for holistic development of the Brahmaputra sub-basin in India with regard to the land-use and natural resource management was missing. Several shortcomings have been identified:

1. Absence of a mandate for integrated river basin management leading to lack of multi-disciplinary approach to water management;
2. The State Governments' unsympathetic approach to the plans and programmes of the Board;
3. Overemphasis on flood and drainage works with nominal consideration to other ecosystemic issues;
4. Lack of competent engineering cadre;
5. Overemphasis on the State of Assam;
6. Lack of an inclusive approach while addressing stakeholders' concerns.

The strengthening of the institutional set-up for managing the Brahmaputra sub-basin in India was recommended by a Task Force under the Chairmanship of Chairman, Central Water Commission set up by the Ministry of Water Resources in August 2004; and a Nodal Group set up by Ministry of Water Resources in August 2011 under the Chairmanship of the Chairman, Central Water Commission. The Nodal Group suggested the working structure for the strengthened organisation.

This new proposal talks of a thorough restructuring of the existing Brahmaputra Board into a new entity to be called Brahmaputra River Valley [BRVA] ('Authority' for short). The Authority shall have a policy making Governing Council ('Council') and an Executive Board ('Board') which will be the executive agency. The Authority is vested with the responsibility of promoting IRBM in the Indian Brahmaputra sub-basin in a comprehensive manner. To render it more regulatory teeth, the Authority is envisioned as an autonomous, self-contained entity with a mandate for the development and management of all the water-related activities of the north-eastern region of India, keeping the entire Brahmaputra sub-basin in India as the unit for planning. It shall appraise and monitor water resources projects and take up implementation activities on a need basis or on the specific request of any State Government in the North Eastern Region. The terms of reference of the proposed Authority are the following:

- Integrated Multi-disciplinary basin Planning ensuring their implementation by member states;
- Investigation, Planning & Design, appraisal, clearance, monitoring and implementation of works in consultation with states;
- Promotion of sustainable water resources management;
- Integrated flood management, flood forecasting;
- Hydro-power development to the extent provided for national interest.

However, even such an institutional response might not be adequate, given the international trans-boundary nature of the Brahmaputra sub-basin. Moreso, because national-level approaches to basin management can address a portion of the basin, but can result in spatial inequity, which might not be conducive to address environmental security concerns. In contrast, there is the possibility of a bigger challenge to environmental security in the region arising out of this.

It is here that a mention of the UN Convention on the Law of Non-Navigational Uses of International Watercourses becomes relevant. The Convention was adopted by the United Nations on May 21, 1997, and pertains to the uses and conservation of all waters that cross international boundaries, including surface and groundwater. In the wake of increasing water demand in years to come, the UN document was drafted to conserve and manage water resources for present and future generations. Interestingly, the Convention took more than 17 years to come to force on 17 August 2014. While there is no doubt that after the Helsinki Rules of 1966, this Convention is regarded as the most important step in establishing international law governing water (Raj and Salman, 1999), the Convention has been ratified by just 36 states, with the majority of countries, especially a few key ones, remaining outside its scope. The controversy with the Convention is largely related to Article 7 of the document, entitled, "Obligation not to cause significant harm", which requires that member states who are "utilizing an international watercourse in their territories ... take all appropriate measures to prevent the causing of significant harm to other watercourse states" and compensate sharing states for any such harm (UN 1997). In the Brahmaputra sub-basin, two large basin nations, namely, India and China, are non-signatories (India abstained, while China opposed) to this Convention. There is no Convention that binds major actors in the Brahmaputra sub-basin to take into consideration downstream concerns.

As such, it is important that downstream concerns are taken into account to forge a better mechanism for human well-being and environmental sustainability at the scale of the river basin. Therefore, globally, the notion of IRBM has often been conceived of through the institutional vehicle of River Basin Organisation (RBO). RBOs often emerge as trans-boundary river basin authorities, generally with an autonomous stature, to manage the river basin in a holistic scale. The next sectionpresentssome global experiences of the basin-level governance structures and institutions. Lessons must be derived from these global best practices in in designing the structure of a trans-boundary river basin organisation for the Brahmaputra sub-basin.

5.3. Trans-boundary River Basins: global experiences in governance structures and institutions

The basin-level governance structures and institutional arrangements have emerged from the realisation that the river basin needs to be treated as the management unit from an administrative, as well as from an ecosystem perspective. Therefore, with Integrated River Basin Management (IRBM) treated as 'the most appropriate tool' to deliver IWRM at a basin scale, then river basin organisations (RBOs) are increasingly being promoted as the institutional mechanism for implementing IRBM. As a result, river basin organisations have become “a central component of … the framework that defines how water is managed at the river basin or strategic level” (Makin et al. 2004). Establishment or restructuring of river basin organisations has emerged as an integral component of contemporary water sector reforms globally, e.g., in South Africa, Brazil, the European Union, Nigeria, Indonesia, and the Netherlands, among other countries (Jaspers 2014).

The term 'river basin organisation' (RBO) has a broader connotation vested with various types of key responsibilities. There are also many ways of characterising river basin organisations. The Transboundary Freshwater Dispute Database (TFDD) of the Department of Geosciences, University of Oregon, provides the most comprehensive description on RBOs (Schmeier 2013a). Schmeier (2013a and 2013b), based on institutionalist approaches, have identified a number of institutional design factors for RBOs. She talks of the organisational set-up of RBOs from seven tenets: the membership structure; the functional set-up; reliance on international water law; institutionalisation and legalisation; organisational set-up; the Secretariat; and the financing of mechanism. The river basin governance mechanisms, according to Schmeier (2013 a) has five tenets—namely, decision-making mechanisms, data and information sharing mechanisms, monitoring mechanisms, dispute resolution mechanisms, and mechanisms for stakeholder involvement.

Dispute Resolution Mechanism

The prime reason for setting up RBOs is dispute resolution. Despite existence of RBOs disputes still emerged. Schmeier (2013) provides empirical evidence for the emergence of specific disputes alongwith the cooperation process. For example, in the Mekong River Basin, Laos' unilateral pursuit of the Xayaburi hydropower project spurred heated deliberations with its downstream neighbours, Cambodia and Vietnam. This jeopardised the work of the Mekong

River Commission (MRC) and placed in a dispute mode for more than two years. Similarly, the Netherlands' unilateral decision to shut the sluice gates near the mouth of the Rhine to combat salinity ingression to protect their agriculture was not taken kindly by upstream nations, namely, Germany and France. The contention of the upstream riparians was that the closing down of the sluice gates would obstruct the migration of salmon from the saline water to freshwater and can jeopardise achievement of joint goals defined under the ICPR's Salmon 2020 Program (ICPR 2004). In order to address this challenge, a number of RBOs have established dispute-resolution mechanisms.

Schmeier (2013a) reports that out of 119 basins, 63 of them have defined dispute-resolution mechanisms. Among the remaining 56 river basins, 31 do not have any dispute resolution mechanism, while for the remaining 25 institutions, data availability is insufficient to analyse their dispute-resolution mechanisms. Scheimer infers: "Such absence of pre-defined means for solving and mitigating disputes among member states can even further increase dispute intensity since in the case of an emerging disputes the mechanisms of addressing it need to be defined ad-hoc, providing disputing parties with even more reasons to disagree." Such lack of definition of dispute resolution mechanism creates a gap and is potentially problematic in river basins prone to high level disputes – examples being the Congo or the Jordan River Basin, none of which possess any transboundary dispute-resolution mechanism for addressing water-related disagreements.

For those basins equipped with dispute-resolution mechanisms, it can be distinguished between three mechanisms of dispute-resolution: 1) dispute-resolution directly by the RBO; 2) dispute-resolution in a bilateral manner among disputing member states of the RBO; and 3) dispute-resolution by third parties (e.g., international donors, international courts or arbitration panels).

Benefit-sharing mechanism

Bach et al (2014) infers that there are generally two common features for success for a transboundary institutional set-up, and that is grounded in benefit sharing. MRC (2014) reviews cases of benefit sharing in eight international river basins. Their analysis shows that generally transboundary benefit sharing is grounded on the principle of a win-win outcome, underpinned by an appropriate legal framework. The two features of benefit sharing as reported by Bach et al (2014) are classified as:

I. A mutual benefit in the developments – Examples abound on this. In the La Plata Basin, bilateral projects, such as the Salto-Grande between Argentina and Uruguay, are based on equity and accrual of equal benefits. Again, in the Columbia River, central investments are made by upper riparian countries against an agreed payment process from lower basin countries. By contrast, the Ganges water treaty has no economic incentives to bind the parties together, making it an agreement that relies on political goodwill and 'neighbourliness'.

II. A customised legal framework: A wide range of agreements have been used to underpin benefit-sharing arrangements. La Plata has an overall treaty binding all the riparian countries together in a manner similar to the Mekong Agreement. The agreement also has scope for bilateral agreements for specific benefit sharing, such as the Salto Grande between Argentina and Uruguay.

Organisational Structure of RBOs

In terms of organisational structure, RBOs generally rely on a three-tier set-up, consisting of a high-level decision-making body, an intermediate body to operationalise political decisions, and a secretariat that provides administrative services for the day-to-day affairs (Schmeier 2013a). High-level decision making bodies take the form of Councils or Commissions, comprising the ministerial-level representatives of the RBO's member states. They provide an overall guidance to the RBO, and undertake policy and long-term strategic decisions on water resources governance in the respective basins. The Comité de Ministres of the CICOS, the Commission of the International Commission for the Protection of the Rhine River (ICPR), the Conseil des Ministres of the NBA, or the Council of Ministers of the ZRA are a few examples (Schmeier 2013a).

TFDD reveals that as many as eight RBOs possess an even higher level organisational body, taking water resources governance issues up to the Heads of State and Governments' level. This is, for instance, the case with the Autorité de Développement Integré de la Région du Liptako-Gourma (ALG)'s Conférence des Chef's d'Etat, the Meeting of Presidents of the OCTA, or the Assembly of Heads of State and Government of the VBA (Schmeier 2013a).

At the intermediate level, Committees most often consist of high-ranking government officials with technical expertise from the respective ministries in the RBO's member countries. Examples include the Management Committee of LTA, the Joint Committee of the MRC, the Basin Steering Committee of the Okavango River Basin Water Commission (OKACOM), or the Technical Committee of the ZAMCOM. According to the TFDD, a large number of RBOs (39) possess such intermediate technical bodies, by acknowledging the importance of linking political decisions to technical knowledge. This is an important aspect of these RBOs where hydro-diplomatic regimes are based on holistic hydrological knowledge base.

In some other cases, RBOs often employ Expert or Working Groups, consisting of technical experts from the member countries to arrive at technically informed pathways to achieve politically given goals and objectives. Such organisational bodies are most common among European RBOs such as the Working Groups of the International Scheldt Commission (ICBC), the Expert Groups of the ICPDR, or the Working Groups of the International Commission for the Protection of the Oder (ICPO). RBOs in other parts of the world have, in some cases, established similar mechanisms for bringing together technical expertise from the member countries in order to inform water resources governance decisions at the RBO level and develop the respective activities. Examples include the Working Groups of the Lake Victoria Fisheries Organization (LVFO), the Technical Expert Committees of the NBA or the Working Groups of the Orange-Senqu River Commission (ORASECOM).

The Secretariats play a critical role in the implementation of agreed-upon water resources governance strategies, and are the executive bodies in the context of the RBOs. This is in line with the general role of Secretariats in institutionalised international politics or any other association (Schmeier 2013a). As such, a majority of the RBO Secretariats fulfill some sort of administrative and secretarial functions. RBOs without Secretariats tend to be RBOs of limited institutionalisation. Further, the RBO Secretariats' functions vary considerably across the population of RBOs, ranging from the mere provision of administrative and financial services to the execution of full-fledged project implementation activities including their monitoring and reporting or the engagement in scientific research and data analysis and provision (Schmeier 2010). In many cases, the RBO Secretariat supports the overall vision, mission, and short-term objectives of supporting the overall goals and objectives by engaging in the strategic planning and the development of programs and projects (Schmeier 2013a).

5.4. Organisation for the Governance of Trans-boundary Brahmaputra sub-Basin

With this background, the transboundary river sub-basin organisation for the Brahmaputra is proposed, keeping in view not only the lessons derived from the best practices across the world, but more importantly, the specific needs of the sub-basin. It is clear that the Brahmaputra sub-basin is not a “water scarce” region, where one really needs to think of future water demand from within the sub-basin as a major factor creating environmental and social stress. The stressor or the pressure point might be in the way the water might be used. The fountainheads of the pressure points creating the management challenges are anthropogenic in nature. Floods have always been looked at as “damages”; hydropower potential has been looked at as a harbinger of development but initiating transboundary problems; interlinking of rivers are clear supply-side interventions without considering long-run social-ecological implications. In all these cases, there is a clear lack of ecosystems perspective as discussed earlier. The fragmented approach to development at certain fractions of the basin will not serve the desired purpose, and could be more damaging over time. Therefore, a holistic approach can be taken by the transboundary river organisation, whose dominion can be defined from Korbo in Arunachal Pradesh (where Yarlung-Tsangpo enters India) to near Goalundo (where the mainstream merges with the Ganges) in Bangladesh.

This institutional set-up is proposed to be known as Organisation for Governance of the Lower Brahmaputra Sub-basin (OGLOBS). It is proposed that this be a trans-national body, autonomous in character, and with responsibilities to chalk the guidelines for water systems management, create the master-plans for basin-level development, and with powers to impose penalty on those players who do not adhere by the set guidelines. The powers can be vested to this Organisation on the basis of an Agreement by the three nations of the lower Brahmaputra sub-basin, i.e., Bangladesh, Bhutan, and India. Therefore, these three nations can be called the member nations of the OGLOBS.

Objective of the Organisation

The OGLOBS can define its objective as the promotion of Integrated River Basin Management (IRBM) within the lower sub-basin considering the various needs of the various actors. The

OGLOBS needs to keep the river in the designated area in good ecological state, harmonise the uses and development of flood management, fishery, hydro-power, agriculture, forestry, navigation, industry, household, and various other uses of water of the member nations, ensuring environmental security and human well-being in the region. While floods and hydropower projects should be the most important management issues for work for this Organisation, environmental protection from the threats of deforestation and pollution of the rivers by agriculture, industry, and urban centres, also need to become major themes of their work in the future. Therefore, any national-level river basin project on the Brahmaputra will have to go through the scrutiny of the OGLOBS, so that the critical concerns of downstream and the social-ecological systems are well taken into consideration and potential disputes and conflicts can be avoided.

Institutional Responsibilities

As listed by Bandyopadhyay (2016) for the institutional responsibilities of an RBO, OGLOBS needs to have the following responsibilities:

- Create processes and practices for water governance at various spatial levels, from the sub-basin level to the local administrative units based on ideas of integrated river basin management (IRBM);
- Create institutional processes and practices for generation, storage and dissemination of quantified and detailed data on diverse aspects of the hydrological cycle as relevant for the sub-basin;
- Promote interdisciplinary research on water systems and periodic updating of the knowledge base of governmental officials and water policy makers, especially on the management challenges identified in the earlier chapter;
- Promote innovations in water technologies, including technologies for de-pollution of water systems;
- Create institutional mechanisms for the formulation of laws and policies based on inter-disciplinary knowledge for utilisation and conservation of water systems giving highest priority to public interest and participation in decision making processes;
- Create institution processes offering easy but informed mechanisms for resolution of disputes and conflicts at diverse spatial levels, especially the ones that are trans-boundary in nature.

The effective functioning of OGLOBS will depend on the availability of recent knowledge and quantitative scientific data on the movement of water along all the links within the hydrological cycle, as relevant for the sub-basin. Hence, the Organisation needs to emerge as an institution with appropriate authority for generation, storage and dissemination of data at various levels. Presently, data are collected and made available for some limited aspects of the hydrological cycle, like stream flow or the depth of the groundwater table. A much wider data base and conceptual framework is needed for shaping the interdisciplinary approach in the new institutions for IRBM (Bandyopadhyay 2016).

Financing of the OGLOBS

The OGLOBS can be financed by the three member nations, and international donor agencies. Initially, a corpus grant from the three governments can be provided, along with the grants for capital expenditure. Further, international donors may come forward to offer grants-in-aid to the OGLOBS for Operations and Maintenance.

Composition and Organisational Structure

This study proposes a tentative composition with the organisational structure. As stated earlier, this will require more research, and some initial discussion can begin with this structure. The organisational structure presently proposed is three-tiered.

Council: There should be a Council of Ministers from the three nations that will define the vision and mission of the RBO, and chalk out the broad contours of its work over the future. This Council will consist of Ministers of Water Resources, and Ministers of Environment and Forests, and Ministers of Earth Sciences, from each of the three nations.

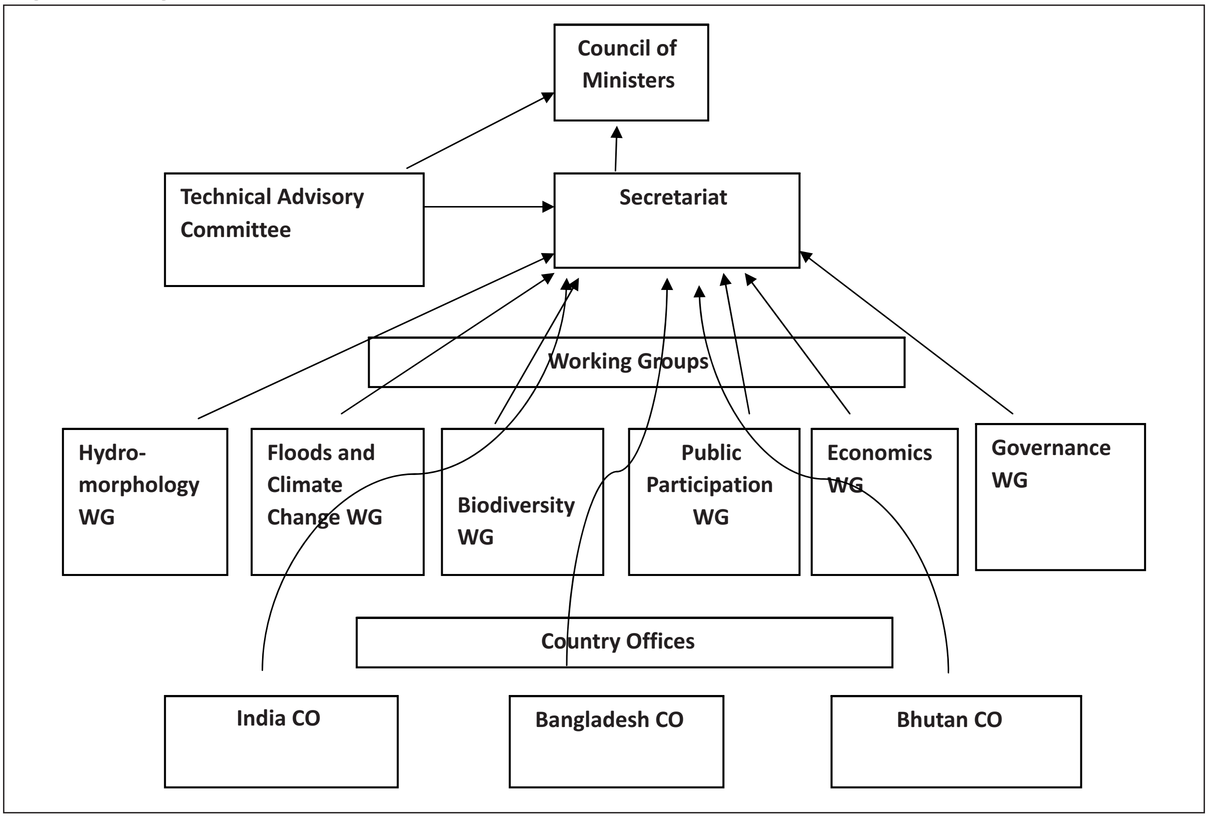
Secretariat: The Secretariat will serve as the executive body of the OGLOBS. It should report to the Council. The Secretariat is supposed to play a critical role in the implementation of the water resources governance strategies. Therefore, the Secretariat will not only provide administrative and financial services, but will also be responsible for execution, monitoring, and reporting of full-fledged project implementation activities. As such, this body will also participate in scientific research and data analysis. The Council would decide on the location of the Secretariat in between the three nations. Therefore, the Secretariat's location may either be permanent, or may be rotated between the three countries.

Technical Advisory Committee: A Technical Advisory Committee can be constituted to advise the Council as well as Secretariat on various technical issues related to floods, engineering, ecological sciences, economics, social sciences, fluvial geomorphology, eco-hydrology, hydro-meteorology, computer sciences and analytics, social issues, and related disciplines. This Committee will comprise, among others, senior technocrats, social scientists, senior academicians, and NGOs. The Advisory committee can act as formalised organisation involved in planning and providing advice on water resource management matters.

Working Groups: There will be Working Groups dedicated to working in various domains. These groups will report to the Secretariat directly. These expert working groups can be: Hydro-morphology Working Group, Flood and Climate Change Working Group, Biodiversity Working Group, Public Participation Working Group, and Governance Working Group. This is a tentative list and can be expanded.

Country offices: The country offices of the OGLOBS need to be set up for getting more micro-level information of the sub-basin, and understanding the ground realities better. These offices will also report to the Secretariat. Here the local politicians, and ministers of federal states, or representatives of local governments need to be involved. Further, competent local level officers need to be recruited. These country offices may create a network of hydro-meteorological observatories in upstream parts of all major tributaries. As an example, in India, such observatories need to be formed from Luhit to Teesta for monitoring high flows in the monsoon period. While these information should regularly be sent to the Secretariat, a strategy for mitigation of flood damages, including structural interventions, while ensuring ecosystem processes and services in the downstream areas can be worked out by the OGLOBS.

Fig. 5.2.: Organisational Structure of the Proposed OGLOBS



5.5. Summing up

It is clear that existing institutional mechanisms are insufficient not only in addressing current management challenges, but also those that might emerge in the future in the wake of the concerns posed on the Hindu Kush Himalayan water towers by forces of global warming and climate change. Adherence to the present institutional responses will result in short-term solutions in most cases, and will be confined to national boundaries in all cases. There is no doubt that the present management challenges (e.g., hydropower, water transfer) have emerged due to economic interests prevailing within national boundaries (or even within federal states), with minimum downstream ecological considerations. The future ecological implications of such projects remain unclear, and further, they can affect human society through ecosystems-livelihoods linkages. As such, quite a few of these human interventions like hydropower have already sown the seeds of conflicts within federal states of a nation. If livelihoods are affected, they can even lead to social conflicts, and hostilities in hydro-politics between nations. Therefore, business-as-usual has become untenable, and should give way to newer institutions like the OGLOBS.

The objective of this Chapter has been to sketch the broad contours of the development of a River Basin Organisation over the Brahmaputra sub-basin. More discussion and research are called for. In the case of the Brahmaputra sub-basin, the issues are complex not only because of the very nature of hydro-political relations between the nations, but also because of a complicated and not yet properly understood social-ecological interactive system, as well as the complex management challenges.

As such, the setting up of a transboundary RBO of the scale of the OGLOBS is not a simple task. A review of the institutional structures of various operating RBOs reveals that there had been complex and sustained negotiation processes through which they finally took shape and are working successfully. Further, there needs to be some basic ethics involved in the process of their making. The primary imperative is the building of trust and confidence amongst all the nations of the basin. Trust-building efforts are primarily political in nature and can only be a positive outcome of many other processes apart from the fields of geo-politics (Jaspers 2014). It would be the output of long history of interactions and socio-economic and cultural bondages present amongst the basin countries (Jaspers 2014, Scheimer 2013a). Presently, given improvements in the Bangladesh-India and Bhutan-India relations, the success of setting up such an institution seems more attainable. Bhutan and Bangladesh have also been contemplating hydropower trade lately. It is generally felt that it needs more efforts from the large and economically stronger country to arrive at a cooperative mechanism and form such an organisation. There is no doubt that India has to perform a leadership role.

The most important starting point is information dissemination among the stakeholder nations. The need for developing a time-bound deliberative process has long loomed large. It cannot be overemphasised that there is a need for a detailed knowledge base about the water resource potentials of the basin as initially endowed with the member states, to get a proper estimate of human demands and demand management steps, and eventually have an inter-state cooperation with equitable sharing, thereby balancing development with conservation needs of the sub-basin. Organisations stand on trust, after all, and while there is no doubt that a harmonised cooperative regime for the Brahmaputra sub-basin could be achieved through a structure like OGLOBS, trust and political will among the nations is key to achieving the protocols, agreements, and a legislative arrangement to develop together to fit into the mandate of integrated river basin management.

Finally, an organisation like OGLOBS is going to be an important step towards achieving some of the Sustainable Development Goals (SDGs). In Chapter 1, this study gave an overview of the developmental paradox of "ample water, ample poverty" plaguing the Brahmaputra sub-basin. This paper argues that the prevalence of such a paradox is driven by a lack of a proper and holistic ecosystems perspective in water management. The broader policy challenge in the region is related to poverty. A more informed water management regime that will understand the critical ecosystem services of water in terms of providing sustainable food security in the region, clean water and sanitation, sustenance aquatic ecosystems, can help in the long run in achieving the SDGs.

References

Acreman, M. and M.J. Dunbar "Defining Environmental Flow Requirements: A Review", *Hydrology and Earth System Sciences* 8(5) (2004):861-876.

Adamson, D. "Buying Paper and Giving Gold: The Murray Darling Basin Plan", Working Paper No. M13_3, Risk and Sustainable Management Group Working Paper Series. Schools of Economics and Political Science, The University of Queensland, 2013.

Alam, U., O. Dione, and P. Jeffrey "The benefit-sharing principle: implementing sovereignty bargains on water", *Political Geography* 28(2) (2009): 90–100.

Alcamo, J., P. Doll, F. Kaspar and S. Siebert *Global Change and Global Scenarios of Water Use and Availability: An application of Water GAP1.0*. Kassel: Center for Environmental Systems Research (CESR), University of Kassel, 1997.

Alier, J.M. "Environmental Justice and Economic De-growth: An Alliance between Two Movements", *Capitalism Nature Socialism* 23(1) (2012): 51-73.

Allan, J. A. "The political economy of water: reasons for optimism but long term caution", *In Water, Peace and the Middle East: Negotiating Resources in the Jordan Basin* edited by Allan, J. A. and J. H. Court London: Tauris Publishers, 1996.

Amarasinghe, U. A. *Spatial Variation in Water Supply and Demand across the River Basins of India*, 2003, mimeo.

Amarasinghe, U. A., L. Mutuwatta and R. Sakthivadivel *Water Scarcity Variations Within a Country: a case study of Sri Lanka*, Research Report 32, Colombo: International Water Management Institute, 1999.

Anonymous *The Dublin Statement* (Geneva: WMO).

ASE Establishing *a futures market in Water Availability Risk*, Discussion Paper, Australian Stock Exchange, 2006.

Aylward, B., J. Bandyopadhyay, J. C. Belausteguigotia et al "Freshwater Ecosystem Services" in *Ecosystems and Human Well-being: Policy Responses* edited by Kanchan Chopra et al., Vol. 3: 215-55Washington: Island Press, 2005.,.

Bach H., P. Glennie, R. Taylor, T. Clausen ., F. Holzwarth., K. Jensen K., A. Meija. & S. Schmeier *Cooperation for Water, Energy and Food Security in Transboundary Basins under Changing Climate*, Lao PDR: Mekong River Commission, 2014. .

Bandyopadhyay, J. "Water Management in the Ganges-Brahmaputra Basin: Emerging Challenges for the 21st Century" *Water Resources Development*11(4) (1995): 411-42.

Bandyopadhyay, J. "Adoption of a New and Holistic Paradigm is a Pre-condition for Integrated Water Management in India" in *Water Security and Management of Water Resources* edited by G. Saha Kolkata: National Atlas and Thematic Mapping Organization, 2004.

Bandyopadhyay, J. : *Water, Ecosystems and Society: A Confluence of Disciplines*. New Delhi: Sage Publications, 2009.

Bandyopadhyay, J. "Deciphering Environmental Flows", *Seminar* 626 (2011):50-53..

Bandyopadhyay, J. "Water Science in India: Hydrological Obscurantism", *Economic and Political Weekly*, 47(16) (2012): 45-47.

Bandyopadhyay, J. "New Institutional Structure for Water Security in India", *Economic and Political Weekly*, 51(15) (2016): 15-17.

Bandyopadhyay, J. and N. Ghosh "Holistic Engineering and Hydro-diplomacy in the Ganges-Brahmaputra-Meghna Basin", *Economic and Political Weekly* 44 (45) (2009): 50-60.

Bandyopadhyay, J. and N. Ghosh "China-India hydro-politics: Rescue facts from drowning", *Economic Times*, April 16, 2016.

Bandyopadhyay, J. and S. Perveen "Interlinking of Rivers in India: Assessing the Justifications" *Economic and Political Weekly*, 39 (50), (2004): 5308-16.

Bandyopadhyay, J. and S. Perveen "Interlinking of Indian Rivers: Questions on the Scientific, Economic and Environmental Dimension of the Project" in Interlinking Rivers in India: Issues and Concerns edited by M. Q. Mirza, A. U. Ahmed and Q. K. Ahmad. Abingdon: Taylor and Francis, 2008.

Bandyopadhyay, J. "Securing the Himalaya as the Water Tower of Asia: An Environmental Perspective", *Asia Policy*,16, (2013): 45-50

Bandyopadhyay, M. K. *Ganga-Farakka Barrage Project and Rural Economy of India* Kolkata: Uppal Publishing House, 2012.

Beach, H.L., J. Hammer, J.J. Hewitt, E. Kaufman, A. Kurki, J.A. Oppenheimer, and A.T. Wolf. *Transboundary Freshwater Dispute Resolution: Theory, Practice, and Annotated References*. New York: United Nations University Press, 2000.

Bhaumik, S. "India floods: Thousands flee homes in Assam", http://www.bbc.com/news/world-asia-india-23237130, July 9, 2013 (retrieved on April 24, 2016).

Biswas, A.K., O. Varis, and C. Tortajada eds. *Integrated Water Resources Management in South and Southeast Asia*. New Delhi: Oxford University Press, 2005.

Boelee E ed. *Ecosystems for water and food security*. Nairobi: United Nations Environment Programme, 2011.).

Booth, K. *Theory of World Security* Cambridge: Cambridge University Press, 2007.

Bora, A.K. "Fluvial Geomorphology", in *The Brahmaputra Basin Water Resources* edited by Singh, V.P., N. Sharma, C. Shekhar, and P Ojha, 139-95.Boston: Kluwer Academic Publishers, 2004.

Bouhia, *H. Water in the Macro Economy*.Aldershot: Ashgate, 2001.

Briscoe, John and R.P.S. Malik *India's Water Economy: Bracing for a Turbulent Future*. New Delhi: Oxford University Press, 2006.

Bulletin of the American Geographical Society. Explorations on the North-East Frontier during 1911-12-13 by Colonel S. G. Burrard. *Bulletin of the American Geographical Society* 47(4) (1915):, 259-264.

Burrand, C. S. Explorations of the North-East Frontier during 1911-12-13.

Buzan, B. and O. Wæver *Regions and Powers: The Structure of International Security Cambridge*: Cambridge University Press, 2003.

Chalecki, E. "Environmental Security: A Case Study of Climate Change", Paper Presented at the *2002 Biennial Conference on Enhancing Regional Security*. Asia-Pacific Centre of Security Studies, Honolulu HI, 2002.

Chowdhury, M.H.K. and A. Hussain "Aridity and Drought Conditions of Bangladesh. Tropical Droughts (Meteorological Aspects and Implications for Agriculture)", *Journal of WMO Program on Research in Tropical Meteorology*, 73-80. New Delhi, India, 1981.

Coates, David, Richard Connor, Lisa Leclerc, Walter Rast, Christine Schumann and Michael Webber "Water Demand: what drives consumption?" in *UN World Water Development Report* 1, Part 1:44-

69 Paris: UNESCO, 2012. .

Cooley, H., J. Christian-Smith, P. H. Gleick, L. Allen and M. J. Cohen *Understanding and Reducing the Risks of Climate Change for Trans-boundary Waters*. Oakland: Pacific Institute in collaboration with UNEP, 2009.

Crow, B. and N. Singh "Impediments and Innovation in International Rivers: The Waters of South Asia", *World Development*, 28 (11), (2000): 1907-25.

Crow, B., A. Lindquist and D. Wilson *Sharing the Ganges: the Politics and Technology of River Development*. Dhaka: Sage Publications and University Press Bangladesh, 1995.

D'Souza, R. "Water in British India: The Making of a 'Colonial Hydrology'", *History Compass*, 4(4), (2006): 621-8.

Dalby, S. "Climate Change: New Dimensions of Environmental Security", *RUSI Journal* 158(3), (2013): 34-43.

Dalby, S. "Framing the Anthropocene: The Good, the Bad, and the Ugly", *The Anthropocene Review*, 3(1), (2016): 33-51.

Danda, A.A, G. Sriskanthan, A. Ghosh, J. Bandyopadhyay, and S. Hazra *Indian Sundarbans Delta: A Vision*, New Delhi: World Wide Fund for Nature-India, 2011.

Das, D. C. *Agricultural Landuse and Productivity Pattern in Lower Brahmaputra valley (1970-71 and 1994-95)*. Ph.D. Diss., Department of Geography, North Eastern Hill University, Shillong, 2000.

Datta, B. and V.P. Singh "Hydrology" in *The Brahmaputra Basin Water Resources* edited by Singh, V.P., N. Sharma, C. Shekhar, and P Ojha 139-95, Boston: Kluwer Academic Publishers, 2004.

Delli-Priscoli, J. and A. T. Wolf *Managing and Transforming Water Conflicts*. Cambridge: Cambridge University Press, 2009.

Desai, N "Appraisal and Approval of Irrigation Projects", personal communication.

Dhaka Tribune "Flood situation worsens in northern district", July 11, 2013.

Dollo, M., P. K. Samal, R.C. Sundriyal and K. Kumar.. "Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalaya, India". *Journal of American Science* 5(5), 2009: 44.

Dutta, A. K. *The Brahmaputra*. New Delhi: National Book Trust. 2001. .

Dyson, M, G. Bergcamp and J. Scanlon (Eds) , *Flow: the essentials of environmental flows* Gland: IUCN. 2003.

EEA *Environmental indicators: Typology and overview*. The Netherlands: TNO Centre for Strategy, Technology and Policy, 2003.

EEA *Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe*, Technical Report no. 11/2007, Copenhagen: European Environment Agency, 2007.

Eidem, N. *Enhancing Social-Ecological Resilience in the Colorado River Basin*. Ph.D. Dissertation, Oregon State University, 2012.

European Commission Common implementation strategy for the Water Framework Directive(2000/60 EC); Groundwater Risk Assessment; Technical report developed on the basis of the Guidance Document 2004. Available online: http://www.eurogeologists.de/images/content/panels_of_experts/hydrogeology/081F8d01.pdf (accessed on 15November 2014).

Falkenmark, M., J. Lundqvist and C. Widstrand "Macro-scale water scarcity requires micro-scale approaches: aspects of vulnerability in semi-arid development". *Natural Resources Forum*, 13(4), (1989): 258–267.

Falkenmark, M., L. Gottschalk, J. Lundqvist, and P. Wouters "Towards Integrated Catchment Management: Increasing the Dialogue between Scientists, Policy-makers and Stakeholders", *Water Resources Development*, 20(3), (2004): 297-309.

FAO *Ganges-Brahmaputra-Meghna river basin*. *Rome:* Food and Agricultural Organisation, 2011.

Feitelson, E. and J. Chenoweth "Water poverty: towards a meaningful indicator", *Water Policy*, 4(3), (2002): 263–281.

Fischhendler, I., A. T. Wolf, and G. Eckstein "The Role of Creative Language in Addressing Political Realities: Middle-Eastern Water Agreements." In: *Shared Borders, Shared Waters*. Leiden, CRC Press/ Balkema edited by Megdal, S.B., et al, 53-74. Delft: Taylor & Francis Group in cooperation with UNESCO-IHE...

Fisher, F, A Huber-Lee, I Amir, S Arlosoroff, Z Eckstein, M Haddadin, S Hamati, A Jarrar, A. Jayyousi, U Shamir, H Wesseling, A Salman and E Al-KarabliehLiquid Assets: *An Economic Approach for Water Management and Conflict Resolution in the Middle East and Beyond*. Washington DC: RFF Press, 2005.

Flessa, K.W. "Ecosystem services and the value of water in the Colorado River delta and Estuary, USA and Mexico: Guidelines for mitigation and restoration". *International Seminar on Restoration of Damaged Lagoon Environments*, 79-86. Matsue, Japan, 2004.

Förare, J. (ed.) (2008): *Water and Food* (Stockholm: The Swedish Research Council Formas).

Gain, A.K., W.W. Immerzeel, F. C. Sperna Weiland, and M. F. P. Bierkens "Impact of climate change on the stream flow of the lower Brahmaputra: trends in high and low flows based on discharge-weighted ensemble modelling", *Hydrology and Earth System Sciences*, 15, (2011): 1537-45.

Gazmuri, R. "Chilean Water Policy Experience" paper presented at the *Ninth Annual Irrigation and Drainage Seminar*, Agriculture and Water Resources Department Washington DC: The World Bank, 1992.

Ghosh, N. "A new look at Integrated Water Resources Management (IWRM) from the perspective of Scarcity Value of Water Resources", *Journal of Resources, Energy and Development*, 5 (1), (2008): 27-48.

Ghosh, N. "Challenges to Environmental security in the Context of India-Bangladesh Transboundary Water Relations", *Decision*, 42 (2), (2015): 27-48.

Ghosh, N. "Little need for India to worry over Chinese plans on Brahmaputra", http://www.abplive.in/blog/little-need-for-india-to-worry-over-chinese-plans-on-brahmaputra. December 4, 2015 (retrieved on June 25, 2016).

Ghosh, N. and C. S. Shylajan "Coastal Mangrove Ecosystems, Fishermen's Welfare and Anthropogenic *Externalities: Compensatory Payments* through Mangrove-Fishery Linkages" in *Biodiversity and Quality of Lifeedited* by N. Sengupta and J. Bandyopadhyay , 294-315 New Delhi: Macmillan Publishers, 2005.

Ghosh, N. and J. Bandyopadhyay "A scarcity value based explanation of trans-boundary water disputes: the case of the Cauvery River Basin in India", *Water Policy*, 11 (4), (2009a): 145-67.

Ghosh, N. and J. Bandyopadhyay "Methods of Valuation of Water Resources: A Review", *South Asian Water Studies*, 1(1), (2009b): 19-50.

Ghosh, N. and S. Rachuri "Pricing the Fluid Mosaic: Integrated "Inclusive Valuation" of Water from the Scarcity Value perspective", *India Infrastructure Report*, 337-50. New Delhi: 3i Network and Oxford University Press, 2011.

Ghosh, N. and S.E. Khan: *Situation Analysis on Environmental Security*, Ecosystems for Life: A Bangladesh-India Initiative, IUCN, International Union for Conservation of Nature, 2012.

Ghosh, S. and S. Dutta "Impact of climate change on flood characteristics in Brahmaputra basin using a macro-scale distributed hydrological model", *Journal of Earth System Science*, 121 (3), (2012): 637–657.

Gilmartin, D. "Imperial Rivers: Irrigation and British Visions of Empire," in *Decentring Empire: Britain, India and the Transcolonial World* edited by Kennedy, D. and D. Ghosh, 76-103New Delhi: Orient Longman, 2006. .

Gleick, P.H. "Water and Conflict: Fresh Water Resources and International Security", *International Security*, 18 (1), (1993): 79-112.

Goswami, D. C. "Brahmaputra River, Assam, India: Physiography, Basin denudation and Channel Aggradation", *Water Resource Research American Geophysics Union*, 21, (1985): 959-978.

Goswami, D. C. *Himalayan Catchment and the Hydrologic Regime of Brahmaputra River, India: Selected Case Studies*. 2001 Available at www.cig.ensmp.fr.

Goswami, D. C. "Management of water resources of North-East India: Need for an integrated regional plan", 2005. mimeo.

Goswami, D. C. "Managing the Wealth and Woes of the River Brahmaputra", *Ishani* (Guwahati), 2(4), (2008).

Goswami, D. C. *Story of the Brahmaputra,Geological Society of India*, 2014.

Goswami, D.C. and P.J. Das "The Brahmaputra River, India: The eco-hydrological context of water use in one of world's most unique river systems", *Ecologist Asia*. 11(1), Special issue on large dams in North-east India -- rivers, forests, people and power. (2003): 9-14.

Grafton, R.Q., G. Libecap, S. McGlennon, C. Landry, and B. O'Brien "An Integrated Assessment of Water Markets: A Cross-Country Comparison", *Review of Environmental Economics and Policy*, 5(2), (2011): 219-239.

Hall, J. V. and D.C. Hall "Environmental resource scarcity and conflict", in *The Political Economy of War and Peace* edited by Wolfson, M. Boston: Kluwer Academic Publishers, 1998.

Hassing, J., N. Ipsen, T.J. Clausen, H. Larsen and P. Lindgaard-Jørgensen *Integrated Water Resources Management in Action*. The United Nations World Water Assessment Programme. Paris: UNESCO, 2009.

Hazarika, S. "Waters of Despair, Waters of Hope", *Seminar*, 550 (2005)

Hitzhusen, F. J. *Economic Valuation of River Systems* Cheltenham: Edward Elgar, 2007.

Homer-Dixon, T. F. "On the threshold: environmental changes as causes of acute conflict", *International Security*, 16(2), (1991): 76–116.

Homer-Dixon, T. F. "Environmental scarcities and violent conflict: evidence from cases", *International Security*, 19(1), (1994): 5–40.

ICIMOD. *The Himalayan Climate and Water Atlas:Impact of Climate Change on Water Resourcesin Five Of Asia's Major River Basins*. Kathmandu: ICIMOD, 2015.

Immerzeel, W.W. "Historical trends and future predictions of climate variability in the Brahmaputra basin", *International Journal of Climatology*, 28, (2008): 243-54.

Immerzeel, W.W., L.P.H van Beek, and M.F.P. Bierkens "Climate change will affect the Asian water towers", *Science*, 328 (5984), (2010): 1382–1385.

INCCA *Climate Change and India: A 4x4 Assessment. A Sectoral and Regional Analysis for 2030s*. Indian Network for Climate Change Assessment, Ministry of Environment & Forests, Government of India, 2010.

Islam, Shafiqul and Lawrence Suskind *Water Diplomacy: a negotiated approach to managing complex water networks*. New York: RFF Press, 2013).

Jarvis, T., M. Giordano, S. Puri, K. Matsumoto, and A.T. Wolf "International Borders, Ground Water Flow, and Hydroschizophrenia". *Ground Water*, 43(5), (2005): 764-770.

Jaspers, F. *Towards Integrated Water Resources Management: International experience in development of river basin organisations*, Khartoum: United Nations Environment Programme, 2014.

Jian, J., P.J. Webster, and C.D. Hoyos "Large-scale controls on Ganges and Brahmaputra River discharge on intra-seasonal and seasonal time-scales", *Quarterly Journal of Royal Meteorological Society*, 135 (639), (2009): 353–370.

Jiang, C., L. Zhang, D. Li, and F. Li "Water Discharge and Sediment Load Changes in China: Change Patterns, Causes, and Implications", *Water*, 7, (2015): 5849-5875.

Jobson, S. *Water Stressed Regions: The Middle East & Southern Africa – Global Solutions*. Occasional Paper No. 16, Water Issues Study Group, School of Oriental and African Studies (SOAS), 1999.

Kagalou, I, I. Leonardos, C. Anastasiadou, and C. Neofytou "The DPSIR Approach for an Integrated River Management Framework. A Preliminary Application on a Mediterranean Site (Kalamas River -NW Greece)", *Water Resource Management*, 26 (6), (2012): 1677-92.

Kripalani, R., J. Oh, A. Kulkarni, S. Sabade, and H. Chaudhari "South Asian summer monsoon precipitation variability: coupled climate model simulations and projections under IPCC AR4", *Theory of Applied Climatology*, 90 (3–4), (2007): 133–159.

Kuenzer, C., I. Campbell, I., M. Roch, L. Leinenkugel, T. VoQuoc, and S. Dech (2013): "Understanding the Impacts of Hydropower Developments in the context of Upstream-Downstream Relations in the Mekong River Basin", *Sustainability Science*, 8 (4), 565-84.

Lawrence, P., J. Meigh, and C. Sullivan "The Water Poverty Index: an international comparison", *Keele Economics Research Papers*, 19, 2002.

Levitt, J. "Water: Conflict and Cooperation over Israel's Jordan Valley", *The Algemeiner*, March 3, 2014. http://www.algemeiner.com/2014/03/03/conflict-and-cooperation -over-water-in-israels-jordan-river-valley/ (accessed on November 16, 2014).

Linnansaari, T., W.A. Monk, D.J. Baird, and R.A. Curry *Review of approaches and methods to assess Environmental Flows across Canada and internationally*. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/039, 2013.

MA (Millennium Ecosystem Assessment). Ecosystems and human well-being. Washington, DC: Island Press, 2005.

Martinez-Santos, P., M.M. Aldaya, M.R. Llamas *Integrated Water Resources Management in the 21st Century: Revisiting the paradigm*. CRC Press, 2014.

Mattas, C., K.S. Voudouris, and A. Panagopoulos "Integrated Groundwater Resources Management Using the DPSIR Approach in a GIS Environment: A Case Study from the Gallikos River Basin, North Greece", *Water*, 6 (4), (2014): 1043-68.

Maxim L., J. Spangenberg and M. O'Connor "The DPSIR framework for Biodiversity Assessment", *Ecological Economics*, 69 (1), (2009): 12-23.

Meigh, J. R., A.A. McKenzie, and K.J. Sene "A grid-based approach to water scarcity estimates for eastern and southern Africa", *Water Resources Management*, 13(1), (1999): 85–115.

Menon, M. and K. Kohli "From Impact Assessment to Clearance Manufacture", *Economic and Political Weekly* 44(28), (2009): 20-23.

Menon, M., N. Vagholikar, K. Kohli and A. Fernandes "Large Dams in the North East: A Bright Future?" *The Ecologist Asia*, 11(1), (2003): 3-8.

Middleton, Nick *Rivers: A Very Short Introduction*.*Oxford*, Oxford University Press, 2012.

Mipun, B.S. *Impact of Migrants and Agricultural Changes in the Lower Brahmaputra Valley : A Case Study of Darrang District*. Ph.D. Thesis, Department of Geography, North Eastern Hill University, Shillong, 1989.

Mirumachi, N. *Transboundary Water Politics in the Developing World*. London: Earthscan, 2015.

Mirza, M.M.Q. "Global warming and changes in the probability of occurrence of floods in Bangladesh and implications", *Global Environmental Change*, 12 (1), (2002): 127-138.

Mitchell, B. (ed.) *Integrated Water Management: International Experiences and Perspectives*. London and NewYork: Belhaven Press, 1990.

Mohile, A D "India's Water and Its Plausible Balance in Distant Future" unpublished paper, 1998 (as cited in NCIWRDP (1999), *Integrated Water Resource Development: A Plan for Action*, MoWR, New Delhi, p 29).

Molle, F. and P. Mollinga "Water poverty indicators: conceptual problems and policy issues", *Water Policy*, 5(5–6), (2003): 529–541.

MoWR *Draft National Water Policy 2012* New Delhi, Ministry of Water Resources, Government of India, 2012.

MoWR *Assessment of Environmental Flows* New Delhi, Ministry of Water Resources, Government of India, 2015

Myers, N. "Environment and Security". *Foreign Policy*, 74 (1), (1989): 23-41.

Myers, N. "Environmental Security: What's New and Different?" Paper presented *at The Hague Conference on Environment, Security and Sustainable Development*, The Peace Palace, The Hague, The Netherlands, 9 - 12 May 2004.

Myers, N. "Environmental Security Concerns: Sources", in, eds., *Energy and Environmental Challenges to Security* edited Stec, S. and B. Baraj. Springer-Verlag, 2008.

OECD "OECD Environmental Indicators: Development, Measurement and Use", Reference Paper, Paris: Organisation for Economic Cooperation and Development, 1994.

Ohlsson, L. 1998: *Water and Social Resource Scarcity*. Rome: FAO, 1998.

Pervez, M.S. and G.M. Henebry "Assessing the impacts of climate and land use and land cover change on the freshwater availability in the Brahmaputra River basin", *Journal of Hydrology: Regional Studies*, 3, (2015): 285-311.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg "The Natural Flow Regime: A paradigm for River Conservation and Restoration", *BioScience*, 47 (11), (1997): 769-84.

Prabhu, S. *Chairman, Task Force on Interlinking of rivers: Press report, The Dinamani, Coimbatore Edition dated 17.4.2003*, 2003.

Pramanik, M.A.H. *Natural Disasters*. Article prepared for Bangladesh Space Research and Remote Sensing Organization (SPARRSO). Dhaka, Bangladesh, 1991.

Pranavananda, Swami *Kailash Manasarovar*, 1949

Rahaman, M.M. and O. Varis "Integrated water resources management: evolution, prospects and future challenges", *Sustainability: Science, Practice, & Policy* 1(1), (2005): 15-21.

Rahaman, M.M., O. Varis, and T. Kajander "EU Water Framework Directive Vs. Integrated Water Resources Management: The Seven Mismatches", *International Journal of Water Resources Development*, 20(4), (2004): 565-575.

Rahman, M.R. "Impact of Riverbank Erosion Hazard in the Jamuna Floodplain Areas in Bangladesh", *J. Sci. Foundation*, 8(1&2), (2010): 55-65,

Raj, K. and Salman, S.M.A. "International Groundwater Law and the World Bank Policy for Projects on Transboundary Groundwater", *In Groundwater: Legal and Policy Perspectives: Proceedings of a World Bank Seminar* edited by Salman, S.M.A. New York: World Bank Publications, 1999.

Rashid, H. and M.A.H. Pramanik : *Visual Interpretation of Satellite Imagery for Monitoring Floods in Bangladesh*. Springer-Verlag New York Inc. U.S.A., 1990.

Raskin, P., P. Gleick, P. Kirshen, G. Pontius, and K. Strzepek *Water Futures: Assessment of Long-range Patterns and Problems*. Stockholm: Stockholm Environment Institute, 1997.

Rasul, G. "Why Eastern Himalayan countries should cooperate in transboundary water resource management", *Water Policy*, 16(1), (2014): 19-38.

Richards, A. and N. Singh "Two Level Negotiations in Bargaining over Water", in Parthasarathy, T., B. Dutta, J.A.M Potters, T.E.S. Raghavan, D. Ray and A. Sen (eds.) *Game Theoretical Applications to Economics and Operations Research*, Boston: Kluwer Academic Publishers, 1997.

Rockström, J., M. Falkenmark, T. Allan, C. Folke, L. Gordon, A. Jägerskog, M. Kummu, M. Lannerstad, M. Meybeck, D. Molden, S. Postel, H.H.G. Savenije, U. Svedin, A. Turton., and O. Varis "The unfolding water drama in the Anthropocene: towards a resilience-based perspective on water for global sustainability", *Ecohydrology*, 7, (2014): 1249-61.

Rodriguez-Labajos, B., R. Binimelis, and I. Monterroso "Multi-level driving forces of biological invasions", *Ecological Economics*, 69, (2009): 63-75.

Rowley, G. "The tragedy of the common waters: towards the deepening crisis within the Jordan Basin", Paper presented at *Congres International de Kaslik*, Liban, 18–20 June, 1998.

Ruchay, D. "Living with water: Rhine river basin management" *Water Science and Technology* 31(8), (1995): 27-32

Rudra, K. *The Encroaching Ganga and Social Conflicts: The Case of West Bengal*, Independent Broadcasting Associates, Littleton, MA, 2004.

Sadoff, C. and D. Grey "Beyond the river: the benefits of cooperation on international rivers", *Water Policy*, 4 (5), (2002): 389–403.

Saikia, A.J. "Ecology, Flood and the Political Economy of Hydro-Power: The river Brahmaputra in the 20th century", Occasional Paper Series, NMML, New Delhi, 2014.

Salameh, E. "Redefining the water poverty index", *Water International*, 25(3), (2000): 469–473.

Salman, S. M. A. And K. Uprety *Conflict and Cooperation on South Asia's International Rivers: A Legal Perspective*. Washington DC: The World Bank, 2002.

Sarma, J.N. "An Overview of the Brahmaputra River System", in Singh, V.P., N. Sharma, C. Shekhar, and P Ojha (eds.) *The Brahmaputra Basin Water Resources*, 139-95. Boston: Kluwer Academic Publishers, 2004.

Schmeier, S. "Governing International Watercourses: Perspectives from Different Disciplines: A Comprehensive Literature Review", *Hertie School of Governance Working PaperNo. 53*, 2010.

Schmeier, S. "The Institutional Design of River Basin Organizations – Introducing the RBO, Institutional Design Database and its main Findings", Transboundary Freshwater Dispute Database (TFDD) Working Paper, Corvallis, OR, USA, 2013a.

Schmeier, S. *Governing International Watercourses: The Contribution of River Basin Organizations to the Effective Governance of Internationally Shared Rivers and Lakes*, London: Routledge, 2013b.

Seckler, D., U.A. Amarasinghe, D. Molden, D., R. De Silva, and R. Barker *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues*, Research Report 19. International Water Management Institute, Colombo, 1998.

Sharma, B., U. Amarasinghe, and A. Sikka "Indo-Gangetic River Basins: Summary Situation Analysis", *Mimeo*, 2008

Shi, Y., X. Gao, D. Zhang, and F. Giorgi "Climate change over the Yarlung Zangbo–Brahmaputra River Basin in the 21st century as simulated by a high resolution regional climate model", *Quaternary International*, 244 (2), (2011):159–168.

Shrivastava, R.J. and J.T. Heinen "Migration and Home Gardens in the Brahmaputra Valley, Assam, India". *Journal of Ecological Anthropology* 9, (2005): 20-34.

Singh, K. People of India:Vol.XIV- Arunachal Pradesh. Kolkata: Seagull Books, 1995.

Singh, K. People of *India: Vol.XV- Assam: Part 1*. Kolkata: Seagull Books on behalf of Anthropological Survey of India, 2003.

Singh, V. P., N.C. Sharma, C. Shekhar, and P. Ojha *The Brahmaputra Basin Water Resources*. *Springer*, 2004.

Sivanappan, R.K. "Inter-Linking Of Indian Rivers-Need And Importance", *Journal of Indian Water Resources Society*, 32 (3-4), (2012): 40-46.

Smakhtin, V., C. Revenga and P. Döll "A Pilot Global Assessment of Environmental Water Requirements and Scarcity", *Water International* 29, (2004): 307-317.

Song, X. and B. Frostell The DPSIR framework and a pressure-oriented water quality monitoring approach to ecological river restoration. *Water*, 4 (3), (2012): 670–682.

Srinivasan, R., T.S. Ramanarayanan, J.G. Arnold, and S.T. Bednarz "Large area hydrologic modeling and assessment: Part II Model application", *Journal of American Water Resources Association*, 34 (1), (1998): 91–101.

Stucker, D. *Linking Natural Capital, Rural Livelihoods, and Conflict: Toward Governance for Environmental Security and Peace in Tajikistan*, Masters' Dissertation University for Peace, headquartered in Ciudad Colón, Costa Rica, 2006.

Subramanian, A., B. Brown, and A. T. Wolf . "Understanding and overcoming risks to cooperation along transboundary rivers", *Water Policy*, 16(5), (2014):824-43.

Sullivan, C. "Calculating a Water Poverty Index", *World Development*, 30(7), (2002): 1195–1210.

TEEB : The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, London: Routledge, 2010.

Tullos, D. D., E. Foster-Moore, D. Magee, B. Tilt, A. T. Wolf, E. Schmitt, F. Gassert, and K. Kibler "Biophysical, socioeconomic, and geopolitical vulnerabilities to hydropower development on the Nu River, China", *Ecology and Society*,18(3), (2013): 16.

Turton, A. R. *The Hydropolitics of southern Africa: the Case of the Zambezi Basin as an area of potential co-operation based on Allan's concept of virtual water.* Ph.D. diss. University of South Africa, 1997.

Turton, A. R. and L. Ohlsson "The turning of a screw: Social resource scarcity as a bottle-neck in adaptation to water scarcity", Occasional Paper No. 17, Water Issues Study Group, School of Oriental and African Studies (SOAS), University of London, 1999.

UN "Convention on the Law of Non-Navigational Uses of International Watercourses" United Nations, 1997. Retrieved on June 29, 2016 from http://legal.un.org/ilc/texts/instruments/english/conventions/8_3_1997.pdf.

UNEP : *GEO4: Global Environment Outlook – Environment for Development*. Nairobi:United Nations Environment Programme, 2007.).

UNEP *Freshwater Under Threat: South Asia* Nairobi: UNEP, 2008.

UNEP *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*. Paris: UNEP, 2011.

Valvis, A. "Environmental security and trans-boundary water management: Political and economic dimensions of river Evros "mis-management", *The 5th Biennial Hellenic Observatory PhD Symposium on Contemporary Greece & Cyprus*, June 2-3, 2011.

Veilleux, J.C., M. Zentner, and A.T. Wolf "The Relationship Between Freshwater Resources, Socio-Cultural Dynamics, and Geopolitical Stability", USGIF Monograph Series #1: Challenges of Socio-Cultural Dynamics for Global Security. Chapter 3.2, 2014.

Verghese, B. G. *Waters of Hope*. Dhaka: University Press, 1990.

Vorosmarty, C.J., C. Pahl-Wostl and A. Bhaduri "Water in the anthropocene: New perspectives for global sustainability", *Current Opinion in Environmental Sustainability*, 5, (2013): 535-38.

Wang, Z. Z. Li, M. Xu, G. Yu *River Morphodynamics and Stream Ecology of the Qinghai-Tibet Plateau*. CRC Press, 2016.

Ward, M. "The Exploration of the Tsangpo River", *The Alpine Journal*, (2000): 124-32.

Webster, P.J., and J. Jian "Environmental prediction, risk assessment and extreme events: adaptation strategies for the developing world", *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369 (1956), (2011): 4768–4797.

Westing, A. H. (Ed.) *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*, Oxford: Oxford University Press, 1986.

Wiebe, H. "River Flooding and Erosion in North East India: Exploratory Consideration of Key Issues", http://siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/Background_Paper_4.pdf (accessed on October 13, 2016)

Wolf, A. T. "Conflict and cooperation along international waterways", *Water Policy*, 1(2), (1998): 251–265.

Wolf, A. T. "Shared waters: conflict and cooperation", *Annual Review of Environmental Resources*, 32, (2007): 241–269.

Wolf, A. T., J. Natharius, J. Danielson, B. Ward and J. Pender "Ínternational River Basins of the World", *International Journal of Water Resource Development*, 15(4), (1999):387-427.

Wolf, A. T., S. Yoffe, and M. Giordano "International waters: identifying basins at risk", *Water Policy*, 5(1), (2003): 31–62.

WWF *The Ecological Effects of Mining Spills in the Tisza River System in 2000. World Wide Fund for Nature*, 2002.

Yu, W. *Benefit Sharing in International Rivers: Findings from the Senegal River Basin, the Columbia River Basin and the Lesotho Highlands Water Project. Washington:* The World Bank, 2008.

Zeitoun, M., and N. Mirumachi "Transboundary water interaction I: reconsidering conflict and cooperation", *International Environmental Agreements: Politics, Law and Economics*, 8(4), (2008): 297-316.

This Report conceptualises a framework for Integrated River Basin Management (IRBM) for promoting environmental security at the scale of the Brahmaputra sub-basin, which is part of the Ganges-Brahmaputra-Meghna basin and spread over Bangladesh, Bhutan, China and India. Unlike other river basins, the challenge with the Brahmaputra sub-basin does not arise from the Malthusian creed of physical scarcity, but from the developmental paradox of "ample water, ample poverty". Through a modified Drivers-Pressures-State-Impacts-Response (DPSIR) framework, the report attempts to understand the four-fold management challenge of the sub-basin in the form of floods, hydropower projects, proposed water transfer projects entailing the interlinking of rivers, and the concerns of global warming and climate change. Most of these challenges emerge from a lack of an ecosystem perspective in basin management. While presenting a conceptual framework for IRBM with institution being its cornerstone, and ecological economics being an important disciplinary pillar, the Report conceives of Organisation for Governance of the Lower Brahmaputra Sub-basin (OGLOBS), for promoting IRBM. An institutional structure for OGLOBS is presented in the process.

ORF OBSERVER RESEARCH FOUNDATION

Ideas · Forums · Leadership · Impact

20, Rouse Avenue Institutional Area, New Delhi - 110 002, INDIA
Ph. : +91-11-43520020, 30220020. Fax : +91-11-43520003, 23210773
E-mail: contactus@orfonline.org
Website: www.orfonline.org