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# Tsangpo Hydropower Dam: Is it Devastation on River Ecosystem and Downstream Riparian Community?

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**Abstract:** Energy use is the main challenge for achieving the carbon emission reduction target. Rapid development and increase share of renewable energy use has taken as the main strategic driver for achieving this goal. The most populated, biggest economy, energy user and carbon emitter China, has committed to global community to reduce their emissions and focused on renewable energy sources. Tibet Plateau for being geologically vast hydropower potential, China has aimed, approved several dams in this region which one of them already been constructed on Tsangpo River. This study has investigated the socio-economic and environmental impacts of this dam on lower riparian countries and how this dispute could be settled. The study found imminent adverse impacts on socio-economic and ecological conditions of lower riparian countries and illustrated the urgent 'joint impact assessment', 'negotiation', 'integrated river basin management' and 'collaborative institutional framework' for settling this trans-boundary conflict. This study will be helpful to understand and develop an idea to the policy makers for visualizing impacts of this dams and importance of urgent management initiatives.

**Key words:** Dam · Trans-boundary River · Impacts · Lower Riparian · Basin Management

## INTRODUCTION

Energy is considered as the main driver for economic development and its global production and use has been increased in a significant trend. The energy demand in China has been increasing since late 1970s for rapidly evolving industrialization and economic activities [1]. The huge energy demand pushed on this most populous and biggest economy and recognized as the largest energy producer, user and carbon dioxide ($CO_2$) emitter (23.43% of global total) to the present world. Consequently, energy challenge has appeared as the bottleneck for China's sustainable economic development [2]. On the other hand, India is the fourth largest economy and was in third position for both energy use and $CO_2$ emission (5.7%) in 2014 [3]. The ongoing population growth and economic development will accelerate this energy demand and emission in the next few decades [4]. Green house gases (GHGs) emissions into the atmosphere especially $CO_2$, $CH_4$ are considered as the main cause of global climate change [5] which is the most crucial environmental problem for present world [6]. In this vein, it has already taken the global concern and global community has converged and aimed to reduce 50% emissions by 2050 [7]. Hence, energy use from renewable sources has been encouraging as the green and alternative source of fossil fuels. As a result, renewable energy use has been evolving globally and shares in total primary energy system (TPES) also increasing day by day. For instance, the estimated share of renewable energy was 19% of global TPES in 2012 [8].

Hydropower is ranked in first position as the largest practicing renewable energy source and dominant share in TPES globally which accounts for 15.8% of total electric energy and amounted as the 78% of all renewable energy in 2011[9]. China is rich in hydraulic resource and ranks first in the world for hydroelectric power generation. In 2011, renewable energy contributed 7%to the China's TPES in which 6% was come from hydropower [10].India's energy demand as well generation also increased concurrently. Himalayan steep river gradient and high seasonal run-off are posing numerous potential and ideal conditions for hydroelectric power generation [11]. As a result, India has also emphasized on hydroelectricity and taken '50,000 MW Initiatives' with aiming to increase its share from 25-40% of the TPES [12].

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Although hydroelectric power is fostering the economic development as the major renewable and low emission energy source but at the same time poses inevitably adverse impact on river ecosystem especially on the downstream river [13]. It is crucial for damaging environmental resources e.g., water and land as well arising conflict about re-allocation [11]; create obstacle on natural flow and connectivity those lead to inundation of adjacent low-land, sediment deposition, alteration of ecological niche, habitat destruction, water quality degradation [14, 15]. Consequently, loss of river ecosystem, conflicts on local resource utilization and/or depletion are taking public concern increasingly for ecosystem restoration and local communities' livelihood [16, 17] and transforming into socio-economic and environmental constraints for hydropower development.

Zhang, Xu [18]studied environmentally feasibility of hydropower dam on Lhasa River by China and found the extensive damage on surrounding environment such as change in river morphology, ecosystem etc. Gao, Li [19] also conducted an environmental impact assessment on this River and found it as a fragile ecosystem for being potential source for hydropower generation. There are different studies on the other deployed dams by China also found the posing environmental damage on River ecosystem such as alteration of bio-physicochemical parameters of water [20]; prevent breeding some aquatic biodiversity [21]; change in abundance and composition of phytoplankton [22]; change in nutrient concentration [23]; more than 50% sediment trapped and deposit for dam in Yangtze River that creates variations among food chain and nutrient cycles of microbial communities [24]. Furthermore, changes in downstream riparian and upland vegetation by Three Gorges Dam [25]; as well as changes in buffer zone of wetlands, grasslands, farmlands, water and landscapes of Yellow River [26]. Wang, Fang [27] analyzed the impacts of dam on Jiulong River and found the significant ecological losses on that region e.g., biodiversity loss, water quality degradation etc. The similar study by Erlewein [11] on Himalayan Sutlej River dam also showed the diverse effects on downstream several tributaries. He found the upcoming consequences are drying up river bed; dying up tributaries and shrinking the stretch flow as well affect the hydro morphological, biological, ecological and microclimatic characteristics [28]. In addition to ecological and environmental consequences, it has also undesirable impact on human habitation and livelihood in the dam zones. Li, Zhang [22] found the parallel displacement of local communities in contrast to increasing dam development along with emerging different social problems such as loss of land and job. China has already dammed on all major River streams in Tibet and has taken an ambitious project to generate 38,000 MW on Yarlung Tsangpo River which is known as Bramaputra to the down riparian countries India and Bangladesh. The first dam of approved six dams was begun to construct in November 2010 at Zangmu River station that is situated approximately 2000 meter before entering into India. After constructing this world's biggest dam, the downstream countries will socio-economical and environmentally suffer terribly [29].

This study is aimed to see this socio-economic and environmental impacts of dam construction on 'Tsangpo or Bramaputra' on the downstream riparian communities, and prospects of trans-boundary water management for overcoming this geopolitical dispute. The structure of this study has developed based on some specific research questions. These questions were developed from knowledge of other constructed dams and environmental consequences. The most important and crucial questions are: how upstream Tsangpo hydropower dam will affect the downstream ecosystem and the riparian community? Is it essential to raise concerns from India and Bangladesh and how international concerns could be achieved? How this trans-boundary concern might be solved? *And* is it possible to solve by geopolitical negotiations or needed international collaboration?

The structure of this article is basically based on three major sections. In the first section, it is sketching the assumptions of different devastations by this dam in socio-economic and environmental point of view. In the second section, it is demonstrating the concerns, conflicts and impediments for this trans-boundary river basin management. Finally, it is critically reflecting on possible settlement of this dispute and recommending an assimilated mechanism for management.

**Study Area:** Tibet is the source of origin of 10 major international rivers those are flowing to the 11 downstream countries and supporting livelihood to 500 million Asian people in which 250 million from China alone [30]. Yarlung Tsangpo is the longest (2,900 Kilometers) one of these major rivers. This study is a conceptual impact assessment mainly based on the secondary data and extensive literature review of recently constructed a hydropower dam on this River by China. Its origin is from Himalayan Angsi Glacier at Northern part of Tibet and drains approximately an area of 530000 $km^2$through crossing four different countries China (50.5%), India (33.6%), Bangladesh (8.1%) and Bhutan (7.8%) [31]. Most of the riparian people are dependent on this river basin for their livelihood.

Table 1: Most relevant literatures and their major findings

| Author(s) | Assessment Tool(s) | Major findings and Remarks |
|---|---|---|
| Gain and Giupponi [32] | Comprehensive dynamic risk assessment based on physical, social, economic, institutional and ecological dimensions | • Water scarcity will slightly increase and affect the socio-economic factors.<br>• Not modeled trans-boundary governance aspects. |
| Zhang, Xu [18] | Environmental Impact Inventory based on ecosystem and downstream ecological process alteration | • Assessing and comparing environmental and economic feasibility of a hydropower plant.<br>• Soil erosion and fertility loss, pollution, sedimentation, aquatic and terrestrial faunal and floral habitat destruction, water quality degradation.<br>• Effect on downstream flow reduction. Both environmentally and economically feasible in global context.<br>• Need to incorporate policy-making processes and further study. |
| Li, Zhang [22] | Multi-scale Evaluation Method on three spatial plant, river and watershed scales | • Alteration and destruction of ecosystems due to pollution, sedimentation, inundation, soil erosion.<br>• Cause for Net Primary Productivity, $CO_2$ fixation, fish and human habitat loss. |
| Hennig, Wang [34] | Evaluation and comparison of small and large hydropower projects (SHP & LHP) based on socio-economic and environmental consequences | • Adverse impacts on local and downstream socio-economic and environmental aspects.<br>• Regional outcry, tension and conflict. |
| Yang and Chen [35] | Comprehensive Evaluation and Valuation Index System for River ecosystem services | • Positive effects for mitigating $CO_2$ and $SO_2$ emission<br>• Adverse impacts on river ecosystems, human health due to sedimentation, land acquisition, water contamination, biodiversity loss |
| Franchi, Carosi [36] | Sampling based statistical analysis and comparison of fish community composition in the upper and downstream river after and before the dam construction | • Fish communities were radically decreased after dam construction.<br>• Decreased fish communities, water temperature and increasing threat to existing communities |

**Study Methodology:** This study is built on the literature review of the scholarly literature on the socio-economic and environmental impacts of dams and water diversion on Tsangpo River by its downstream riparian countries. The literature review encompasses peer-reviewed articles (i.e., empirically based research papers and literature reviews) published within last 5 years (shown in Table 1). The similar studies interrelated with the impacts of water dams and diversions were also incorporated to properly address the impacts on riparian communities. The study is divided into two parts. Firstly, impacts to lower basin were conceptualized by identifying and eliciting the most relevant literatures, their methods and major findings. The similar investigative studies and assessment tools were used to see the social, ecological and physical vulnerabilities [32], environmental impact inventories for primary and secondary impacts on downstream basin [18], social sustainability [33] and necessity of urgent concern for this trans-boundary river basin management. Finally, an integrated management framework has been developed based on scrutinizing the hindrances, findings and recommendations of relevant studies.

This database driven review study is suffering from some limitations. For examples, this study is not covering any practical field works and analyzing any datasets. The reviewed all potential relevant journals might not be indexed in the selected database. Among these some are opinion articles quoted from approach papers those might not be authentic from scientific points of view. Besides, the impacts are more distinctive so many articles published in languages other than English which were not considered. As well, to consecutive support the article, used different notion and quotation from local newspapers those might not be able carry scientific appeal. Furthermore, this article only focused, assessed and scrutinized the socio-economic and environmental impacts on its sharing riparian countries and communities not considered the economic benefits of hydroelectric power generation those are the major limitations of this study.

## RESULTS

The origin of Yarlung Tsangpo is at high altitude and geologically complex area made a power flow to the downstream with a decreasing altitude that also reason for high potential for hydropower development [37]. The series of dam construction by China (Zangmu 510 MW dam, Dagu 640 MW, Jiexo and Ziacha 320 MW dam those already been approved in 12th FY plan,

2011-2015) and Arunachal Pradesh (e.g., Lower Subansiri Dam) have raised concerns for not only interrupting downstream natural water flow and adverse impacts on socio-economic and environmental impacts of lower riparian Bangladesh but also China and India [38]. This study has assessed different impacts based on previous relevant study and revealed the major reasons why Bangladesh, India and China should to be concerned. The reasons are classified into environmental, economic and social aspects and illustrated in context to vulnerable country.

**Environmental Aspects:** *Bangladesh*is the lower riparian country of Brahmaputra River which natural flow is incredibly important for irrigation, biodiversity, fisheries resources, navigation and inhabiting intrusion of saline water into the fresh water ecosystems. But the construing hydropower dam at upper Brahmaputra (Tsangpo) and water development activities for reducing flood hazards by India will pose a tremendous threat to the livelihood of lower riparian community as well ecosystem. The upstream dam and water diversion will reduce both surface and ground water flow as well insufficient management and control will lead to river bank erosion, siltation and severe flooding in Bangladesh [39]. Watts [40] reported that hydro morphological change in Brahmaputra will accelerate the siltation, low land inundation, damage of river bank, change in river course, decreasing soil moisture, water shortage for agricultural, industrial, domestic use, fishery, salinity intrusion, intensification of dissertation, damage mangrove forest, loss of navigation etc. Giupponi, Giove [41] has developed a framework based on the IPCC (2014) report and Gain and Giupponi [32] used this framework to assess the impacts on Lower Brahmaputra River Basin. They found the risk of water scarcity during the dry season which might be exacerbated due to climate change [31]. Shahid [42] also found the severe water scarcity for irrigation during the dry season that also found in support to the frequent droughts in western part of Bangladesh during the last decade [43, 44].

This basin in *Indian* portion i.e., Arunachal Pradesh hosts very rich biodiversity and ecologically hot spot but now suffering its aquatic and forest biodiversity and ecosystem, fishery and their breeding ground as well reducing livelihood of local people from disastrous effects of constructed upper hydro-dam [45]. The similar concern has arisen in Assam state of India for changing its green topography into dried sandy floodplains for upper water diversion, road construction and sand deposition. The consequences might be exacerbated for being world's one of the most seismic and landslide vulnerable zone [46].

The effects could be worsen in *China*'s Tibetan Plateau for its powerful geological stresses, occupying more than 100 active landslips can cause devastating floods to millions of people, destruction of all communication channel, emerging natural hazards, depriving rivers from flow by cutting ways and lead to become desert. As Yarlung Tsangpo is nourishing huge biodiversity of this region will also be threatened due to dam construction. (Page 4) found the declining ecosystem, trees dying and forest depletion, continuous burning of forest for farmland are leading to soil erosion and landslides, extinction of biodiversity, fragmenting ecosystems and destroying food chains that will ultimately be fatal injury to the Tsangpo River ecosystem. Alison Reynolds of International Tibet Network gave a statement in 2013 with anxiety for being interrupted their safe and stable water supply by the upstream dam. Lafitte (2014), an Australian scholar has written an investigative book "Spoiling Tibet" where he come up with some harmful impacts of these dams construction in Tibet such as destroying migratory fish species, aquatic biodiversity, triggering earthquake etc. In 2008, the 7.8 magnitude earthquake in Wenchuan, China was killed 80,000 people which cause was reported as for near dam project. International Plateau Research inferred that glacier landmass of Tibetan Plateau has decreased by 7% by the last 5 decades as well high temperature has been recorded in 2009. Geologists and environmentalists are assuming to be an interconnection between these increasing warming phenomenon with dam construction.

**Economic Aspects:** The flow and timing have critical economic importance on downstream countries. Bangladesh is an agronomic country which contributes 12.64% of national GDP in 2014 with providing around 50% employments [47]. Geologically, it is highly dependent on trans-boundary flows of three major Rivers namely Ganges-Brahmaputra-Meghna and their numerous tributaries [37] for agricultural production, aquaculture, forest resources, biodiversity etc and supporting livelihood to millions of people. Brahmaputra contributes its 67% of annual flow from upstream countries [48].But, the weak or reduced flow rate of Brahmaputra is intensifying the extensive sediment deposition in river bed, riverbank erosion and severe flooding to the riparian community [49].Brahmaputra is playing inevitably important role on Bangladesh for economic activities and

environmental balance that could tremendously impacted by upper hydropower and middle water diversion activities [50]. Consequently, depleting soil moisture has been observed with 40% salinity increase in northern 21 districts of Bangladesh are leading to desertification. In addition, removing nutrient-rich silt due to dam will hamper the agricultural production. Islam [50] also quoted that more than 10.2 million acres of northern cultivable land may turn into arid land. As a result, due to water scarcity, huge area of agricultural will be converted into fallow land and dry land those will lead to food insecurity in this region [32]. Besides, lower ground water table and scarcity will also be severe condition due to withdrawal for irrigation in contrast to low infiltrating rate for low surface flow. The siltation, erosion and surface flow reduction will extensively allow saline water intrusion in surface water that hamper agricultural production and aquaculture alongside into the coastal shallow aquifer and affect the pure drinking water system [51].

India is the middle riparian country, exceedingly dependent on Brahmaputra River for agricultural cultivation which contributing 50% of its total national GDP and 70% of employment [52]. Further, India's 30% of total surface water comes from Brahmaputra as well 41% hydropower is generating from this river flow. Brahmaputra basin is posing 7.7 million acres cultivable landmass for India which 1.5 million acres are directly dependent on irrigation with potential 4.2 million acres for future. Their expansion and intensification of irrigation channels will impose a pressure of 50000 to 60000 cusecs for withdrawal from Brahmaputra [53]. In Assam, there are thousands of hectors farmlands were buried by sand deposition due to river course change in 2011. Besides during rainy season, almost 30,000 people were affected due to the lack of water overload control in 2008 [46]. Besides, in 2008, 94% of water in Bhutan was used for agricultural production and highly dependent on Brahmaputra River basin as major water source [54].

**Social Aspects:** The dynamism of this river is not only associated with long run length and numerous tributaries but also cherishing diverse cultural, social, political aspects. This river has assimilated almost 220 different languages and dialects belonging to Indo-Aryan, Austric and Sino-Tibetan language families [49]. Assam is an important 'ethnological transition zone' between northeastern region of India with Bangladesh, Tibet, Bhutan and Myanmar. There are more than 166 separate tribes, 160 scheduled and over 400 sub-tribal communities are in Northeastern region. These communities are very poor, directly or directly living on agriculture and forest resources that will severely affected by the upstream water flow. Ali and Das [55] found the different pull and push factor for migration where loss of land and livelihood is one of them those in combined could lead to collapse of culture like Maya, Harappan etc.Lewis [56] mentioned that decreasing tourists' interest in Tibet Plateau due to damaging natural beauty and destruction of ancient culture which was one of their popular destination before.

**Conflicts and Hindrance to Management:** Combating with energy crises and $CO_2$ emissions by hydroelectric power has been questioned for its other adverse impacts those might be direct and indirect impediments for achieving whole sustainable development goals. The Himalayan trans-boundary river systems are inextricably connected to the South Asian regional geopolitical aspects for being environmentally, culturally and socio-economically important for lower riparian countries.

The investigative study by Siwakoti [57] of International Rivers, found different geopolitical issues, inequalities in power; economy and proportion of dependency are involved in water disputes in this region for last six decades. Firstly, he identified the 'dependency ratio' as the most crucial geo-political aspects for South Asian trans-boundary Rivers to the downstream co-riparian countries. Secondly, history of hostile relationship among them after divided into three independent countries in almost all circumstances.

The absence of regional water sharing treaty or law is another major reason of conflict for Himalayan trans-boundary Rivers. The biggest and powerful riparian countries, China and India are not interested in the multilateral negotiations, international laws and regulations and/or regional treaties or frameworks for a unilateral action. For instance, China voted against the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UNCIW) in 1997 and India abstained with rejecting the third party's involvement, Bhutan absented itself where Bangladesh endorsed this law [58]. This lack of multilateral treaties and respect to international water sharing principles for governing the Bhramaputra River basin has been escalating the regional conflicts by establishing hydropower dam and inter-basin water transfer. The application of only technocratic principles for examining river hydrological systems is also impediment to assess the potential impacts on downstream riparian countries. For instance, Zhang Boting the deputy general secretary of the China Society

for Hydropower Engineering confirmed to The Guardian in May 2010 that research has been carried out on Motuo Dam

> *"……..This dam would be potential to 38 GWh hydropower plant and could abate 200 million tones of $CO_2$ emissions that would be over a third of entire UK's emissions"[40].*

But, he avoided to talk about siltation by engineering principles is cause to future navigation, ecosystem and livelihood loss. In this perspective, Peter Bosshard of International Rivers expressed a sterling comment about Tsangpo dam:

> *"…….A large dam on the Tibetan plateau would amount to a major, irreversible experiment with geo-engineering. Blocking the Yarlung Tsangpo could devastate the fragile eco-system of the Tibetan plateau, and would withhold the river's sediments from the fertile floodplains of Assam in northeast India and Bangladesh".*

Therefore, evaluation and assessment process only based on engineering spirit and narrow or partial approach without ecological or environmental aspects is not enough to calculate damage of this basin as well overall long-term sustainability.

## DISCUSSION

This study based on several socio-economic and environmental impact assessments has found the both short-term and long-term potential impacts to the upper riparian China, middle riparian India and lower riparian Bangladesh by hydropower dam on Tsangpo River. It has revealed that the severity or risk of impacts has increased with increasing the river length of flow to the downstream.

Northern part of Bangladesh has already been suffering for scarcity of Ganges River water in summer due to upstream diversion by Farakka dam and Brahmaputra will exacerbate the risk more for agricultural production. There are huge amount of arable land will diverted to arid land of agronomic country, lot of people will lose their livelihood and struggle for food. The weak water flow will inhibit to transport nutrient-rich silt but huge sand deposition will destroy its navigation system and water reservoirs. Apart from food insecurity and lose of livelihood, this riparian community also suffer from devastating flood due to insufficient controlling tools and techniques for upper dam management during the heavy rainfall and shrink up water reservoir. Further, ecosystem will be more vulnerable for both scarcity of fresh water and intrusion of saline water. The aquatic and forest diversity will adversely be affected by saline water that cause to destroy their food chain, niche, feeding and breeding places. Besides, the lower surface flow leads to low infiltration rate and cause to introduce saline water intrusion in shallow ground water that affects the pure drinking water and tube-wells irrigation. India's Arunachal Pradesh is also vulnerable to this hydropower dam. Assam has already been struggling to protest all sort of upper dams by India and China because of being highly vulnerable to floods and dependent on the upper natural water flow. Socio-culturally diverse this region is dependent on agricultural production and forest resources those will severely impacted by upstream diversion. China is also endangered by this dam itself because of geological formations. For being a seismically active region, it is highly vulnerable to earthquake, landslide and mudslides.

The comprehensive and unilateral action plan has been suggested by regional experts for the resolution of Brahmaputra river basin problem. Since, there is no existing legal framework or law related to water sharing of this river, so it should be foremost and forthcoming initiatives among these countries [59]. Dolma [30] suggested using the multilateral bargaining tool in diplomacy for solving the geopolitical and security concerns. As well, comprehensive socio-environmental and economic monitoring with flow sharing data could be included in jointly operational processes. But, apathy on UNCIW or internal trans-boundary water sharing principles and 'no harm rules' by both upper and middle riparian countries has appeared as the main impediment for unilateral actions [60]. In that case, Liu [59] proposed to apply the conceptual methodological framework 'benefit-sharing' which described by McIntyre [58] to be consisted of 'environmental flows', 'ecosystem services' and 'eco-compensation' for facilitating cooperation. These concepts illustrate the understanding of ecological and environmental aspects; equitable sharing and allocation of cost, protecting ecosystems; social, economic, cultural and spiritual valuations as well as guidelines for financial activities by means of inter basin cooperation.

Undoubtedly, technocratic knowledge is the key component of river basin management. But, the management framework and monitoring should not only based on technocratic knowledge but also all other such

as social, cultural, economic, spiritual, environmental aspects. The engineering activities are needed to impose for calculating silt deposition in both upstream and downstream channels, equitable allocation of flow and maximum utilization. In this circumstance, journalists may play a vital role by analyzing, criticizing and gathering public opinions for valuing and justifying the concerns from all groups, sectors and countries [57]. He also suggested to develop an inter river basin management framework that would be adhered to local and international principles and laws and governed by joint institutional mechanism rather than existing bi-lateral treaties. For this purpose, he urged to policy makers and planners for not to be pertained under the powerful countries but work through democratic procedure with considering the comprehensive workforce by establishing bureaucratic, technocratic and political mechanisms. As well, long term co-riparian basin management; short term administrative and institutional along with multi-level representative committee in the transnational legislative mechanism for mediation and arbitration could be applied for 'equal', 'equitable' and 'reasonable' with human rights and environmental considerations for trans-boundary water management. Rahaman and Varis [61] proposed 'Integrated Brahmaputra River Basin Management' may apply for achieving Millennium Development Goals (MDGs) and food security as well as conflict resolution and water resource management in this region. In this sense, international cooperation and coordination along with strengthening regional relationship and institutional capacities, regional cooperation, integration among different sectors, stability are also equally important for conflict resolution and peaceful management of transnational Brahmaputra River basin. The developed conceptual framework based on different relevant studies and suggestions is given in Fig 1.

The proposed conceptual IBRBM framework in Fig 1 has developed based on relevant literatures, studies and recommendations. It is illustrating a comprehensive approach for a unilateral action by establishing multilateral working groups. A group from each riparian country will form together only for one 'Multilateral Joint Commission (MJC)' which will take the responsible for the entire basin management.

The entire execution mechanism of MJC is divided into three individual phases from impact assessment to long time management. It starts with *pilot phase* which consists of assessing pre-, during and post project impacts assessment in consideration with socio-economic, environmental cultural aspects. It is also important to resolve or exclude historical hostility, economic and power inequality as well other geopolitical issues for accelerating the monitoring and evaluation tools effectively. As the JMC is aimed to execute unilateral actions, hence participation of different expert groups (might be in inside or from outside of JMC) need to be ensured during *action phase*. It is not only for participation and collaboration among different groups but also a technique to communicate for achieving goals. For example, decision makers may think to formulate findings into national policies, journalists convey for mass communication, engineers to develop technocratic guidelines, local NGOs to build awareness and capacity to laypeople etc. Consequently, eco-compensation, equal share and benefits, human rights etc. to the riparian communities and countries might be achieved more easily. The long time *implementation mechanism*, is the most important phase to achieve sustainability but very comprehensive and complex for comprising socio-economic, political, administrative and management systems [62]. The implementation process should be based on legal frameworks by compiling with national and regional polices, regional treaties, institutions, monitoring and decision-making cells. The relevant national policies (e.g., water, fisheries, livelihood, agricultural, environmental etc.) could be included for local environmental and ecosystems protection, livelihood improvement and benefits. The combination of different types of institutions such as local, international, formal, informal, micro, macro, societal, economic, environmental and/or political institutions might be considered into this process. In this proposed framework, formal institutions are refereeing inter-governmental bodies or agencies wherein formal are local NGOs or relevant local water management groups those are working for development and sustainability. For example, Bangladesh Water Development Board (BWDB) and River Research Institute (RRI) are formal institutes in Bangladesh working from top to bottom level (national to village level). Besides, Bangladesh Agricultural Working Peoples' Association (BAWPA), WaterAid, Association for Realization of Basic Needs (ARBAN), Uttoron, Local Pani Parishads etc. are working for water rights development in local level.

In India, central Ministry of Water Resources (MOWR), Ministry of Agriculture (MOA), Central Water Commission (CWC) etc. river boards and commissions such as Brahmaputra Board, Upper Yamuna River Board, Ganga Flood Control Commission etc., and community based organizations e.g., Pani Panchayat, Phad might be considered for comprehensive local institutional

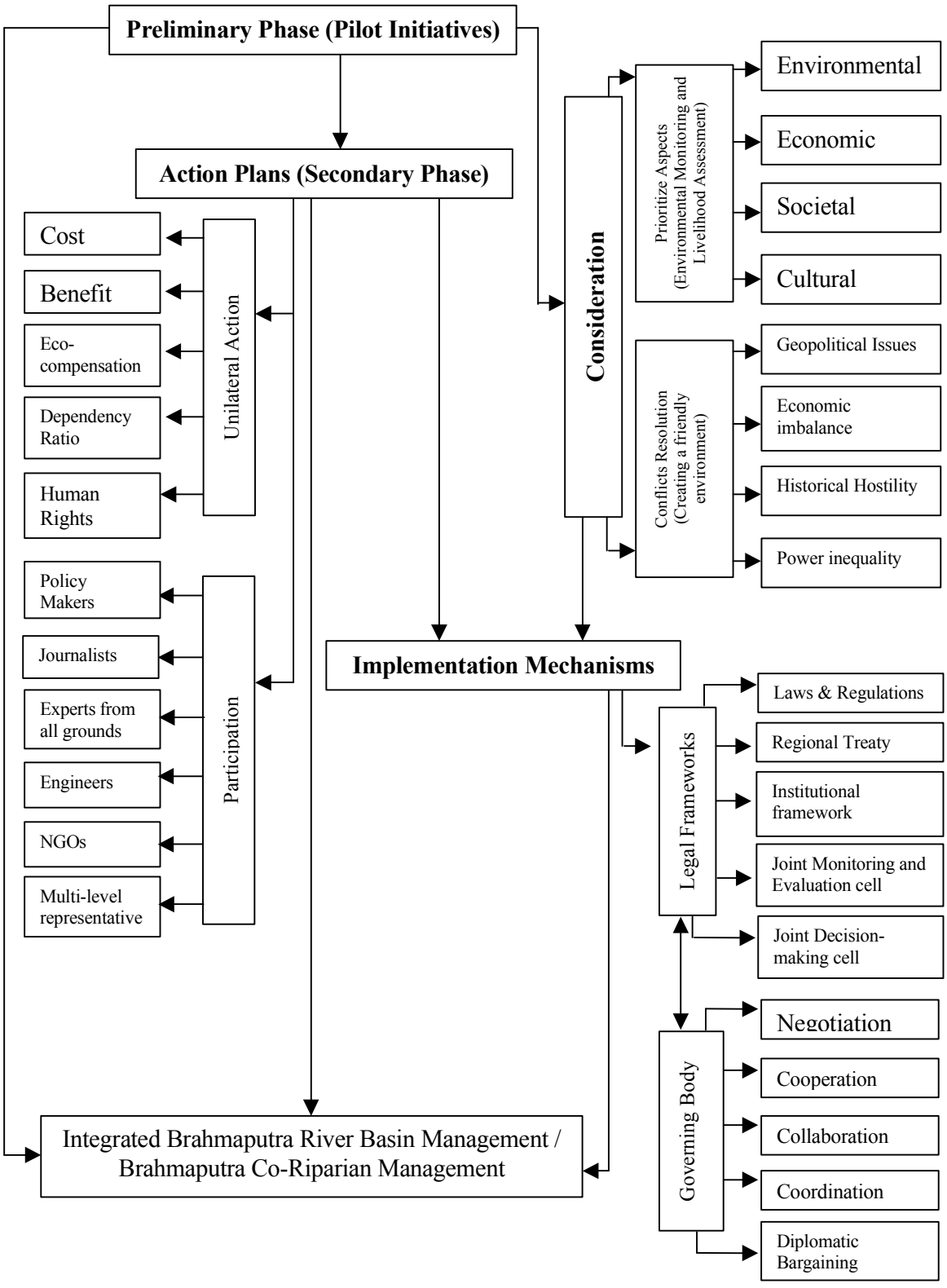


Fig. 1: Proposed conceptual 'Integrated Brahmaputra River Basin Management (IBRBM)' framework

framework development [63]. Local institutions may play a key role for investigating local situation. It would be helpful to assess the impacts in community level through the participatory method because the difficulties and complexities are exacerbated exponentially with increasing the scale of areas i.e., districts to national levels [64]. The representative institution will represent their existing and proposed mechanism for basin water development and management. The joint governing body will implement the framework based on the considerations and legal frameworks through the multilateral negotiation, coordination, collaboration, cooperation and diplomatic bargaining for achieving the Integrated Brahmaputra River Basin Management.

## CONCLUSION

Global growing population, industrialization, agricultural and other economic activities have been leading to increase energy demand as well major cause for $CO_2$ emissions. As China and India are the major emitters of $CO_2$, they have committed to global community to reduce their emissions and move to green economic development. But being biggest populated and economy, energy structure is the main impediment for achieving their $CO_2$ reduction target. In this vein, they emphasized on the renewable energy sources and developing rapidly day by day.

Tibet is known as the 'water tower' of Asia for being source of most of the major Himalayan Rivers and playing an important role for socio-economic and environmental aspects to all upper, middle and lower riparian ecosystems and communities. The origin of Tsangpo River is at high altitude and gradually decreasing with steeper mountainous flow to the downstream countries and named as Brahmaputra in India and Jamuna in Bangladesh. The geological characteristics and high flow steeper flow rate are providing a unique potentiality for hydropower generation on this River basin. China the upper riparian country, already approved a series of dams for on this river flow and one of which already constructed.

Since all of the sharing countries are more or less are inextricably connected to this river basin and vulnerable to its any changes, therefore the on-going concern need to be taken in accounts for regional peaceful economic development. Although the proposed IBRBM is more comprehensive, complex and interconnected with different aspects but it might be the best initiative for sustainable management. The top-down implementation technique with different groups' participation will increase the mutual understanding, trust, collaboration, knowledge sharing those may help to achieve goals timely and effectively. Formation of local institutional representative groups might be time consuming and very difficult part of this framework. It would be better to take this responsibility by relevant governmental institutions to form an effective local institutional body with ensuring participation of all relevant groups. Furthermore, all proposed unilateral action framework, multilateral negotiation, regional integration, strengthening institutional capacity, environmental and ecological aspects in engineering activities, unbiased policy making and integrated river basin management need to be in consideration. Therefore, it is urgent to revise the hindrance for coming up with resolution of the conflicts for the sake of that sustainable development.

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