J. Himalayan Ecol. Sustain. Dev. Vol 18 (2023) **ISSN 0973-7502**

Impacts of the Lower Subansiri Hydroelectric Project, Northeast India, and Implications for Other Imminent Projects

Ajoy Kumar Patir[1], Nazrana Begam Choudhury[2], Soma Roy Dey Choudhury[2], Rudraman Thapa[3] and Muhammed Khairujjaman Mazumder[4*]

[1] Department of Political Science, Dhemaji College, Dhemaji, 787057, Assam, India
[2] Department of Commerce, Assam University, Silchar, 788011, Assam, India
[3]Department of Political Science, Dibrugarh University, Dibrugarh, 786001, Assam, India.
[4]Department of Zoology, Dhemaji College, Dhemaji, 787057, Assam, India
The first two authors contributed equally.
*** Corresponding author Email:** khairujjaman1987@gmail.com.

ABSTRACT

Hydroelectric projects (HEPs) provide power, irrigation, and water supply, conserve water resources and have long been regarded clean and green. On the contrary, HEPs cause irreparable and permanent impacts on the ecology, hydrology and environment as a whole, and on the local people and their socio-economy. The large number of imminent mega HEPs in Northeast India have become concerns for the local denizens, sociologists and environmentalists. Lower Subansiri HEP of Arunachal Pradesh is one such mega 'under construction' hydel project of the region, and is one of the most controversial projects of India. The principal concern with the project is its location in the Eastern Himalaya global biodiversity hotspot and in a region undergoing orogenic and neotectonic developments. Furthermore, sociologists are concerned about the fate of the indigenous tribes whose identities and livelihoods are being threatened. The present study details the impacts of the project in terms of socio-economy, geo-politics and bio-physics. The impacts have been reviewed in detail, including estimation of carbon emission reduction credit and emission of greenhouse gases from the reservoir of the project. Further, we have calculated the Proximity index to estimate the impacts on the wildlife, while Seismicity index was calculated to assess reservoir-induced seismicity. Based on the analysis, we have provided recommendations for this and other imminent projects of the region.

Keywords: *Arunachal Pradesh; Assam; Biodiversity hotspot; Brahmaputra river; Greenhouse gases; Himalayas*

INTRODUCTION

With economic growth, urbanisation, industrialisation and population explosion in the developing economies of the world, the demand for power has greatly increased. On the other hand, the global urge for reducing carbon emission has diverted the focus towards greener energy sources, including hydropower (Moran *et al*., 2018; Choudhury and Dey Choudhury 2020a). Dams provide hydropower and irrigation, may conserve water resources and moderate floods (WCD 2000). Further, hydropower has long been considered clean and green. However, since last few decades, environmentalists have questioned the so-called cleanness and greenness of hydel projects since their reservoirs are reported to produce enormous quantities of greenhouse gases (Bastviken *et al.,* 2011; EPA 2012; Varis *et al*., 2012; IPCC 2013; Fearnside 2015). Furthermore, hydropower comes with enormous, irreparable and permanent damages to the environment (Tortajada *et al*., 2012; Moran *et al.,* 2018). Altered flow of rivers has ecological and hydrological impacts, and also leads to loss of biodiversity (Petts 1984; Lerer and Scudder 1999; Bunn and Arthington 2002; Petts and Gurnell 2005). Globally, dams have displaced over 80 million people, and the figure in India is between 16-38 million (WCD 2000). Another over 472 million have been affected in the downstream (Richter *et al*., 2010). This has resulted in internal displacement, landlessness, poverty, conflicts, and a higher pressure on the remnant environment (Cernea 1999; Brown *et al*., 2009; Moran *et al*., 2018). Unfortunately, only 15% of the 192 World Bank funded projects complied with the resettlement policy (McCully 2001). Scudder (2012) has reported that the socio-economic status of over 82% of these displaced people has deteriorated.

India is third, after USA and China, in terms of number of large HEPs, and 5th in the world in terms of production (IHA 2020). To meet its soaring demands and the increase in *per capita* power consumption, the Govt. of India is focussing on hydropower since last few decades, especially from the Himalayan and sub-Himalayan rivers of North and Northeast (NE) India (Menon *et al*., 2003). NE India has two major river systems: Brahmaputra and Barak. The Brahmaputra is a mighty river that originates in the Greater Himalayas, flows through Tibet (China), NE India and Bangladesh (Goswami 1985; Jain *et al.,* 2007). The river has over 100 major tributaries, most important being Subansiri, Lohit, Dibang and Jia-Bhoreli (Sharma 2004). The upstream reaches of the river and its tributaries have potential to be exploited for hydropower generation (CEA 2019). The total identified hydropower potential of NE India is over 63000 MW (CEA 2019), and thus the region is considered as the 'Future power-house of India'. At least 168 potential project sites have been identified in the NE Indian state of Arunachal Pradesh (Menon *et al*., 2003; GoI 2018). Hundreds of large and thousands of small hydel projects have been proposed, planned, or are under construction on different tributaries of the Brahmaputra river in the state of Arunachal Pradesh (Fig. 1).

Fig. 1. Map of Arunachal Pradesh highlighting major hydropower projects, including the Lower Subansiri Hydroelectric project (circled in red). Inset: Map of India highlighting Arunachal Pradesh. Map credit: Sanctuary Asia (Adapted from the map of the Department of Hydropower Development, Govt. of Arunachal Pradesh).

In addition to hydropower, the NE India is imbued with enormous biological diversity comprising of rare, endangered, threatened and endemic species of plants and animals (Chatterjee *et al.* 2006; Narwade *et al*., 2011; Choudhury 2013; Dalvi *et al*., 2013; Ghosh-Harirar *et al*., 2019). The region has a lush green vegetation cover from tropical evergreen to temperate forests, grasslands, wetlands, *etc.* (Fig. 2). The potential sites for construction of hydel projects fall in hilly mountainous areas which are ecologically sensitive, and prone to landslides and seismicity (Menon *et al.,* 2003; Singh and Kumar 2010). Furthermore, there are over 200 ethnic tribes dwelling here since ages, who have developed their own ways of life and livelihood with intricate dependence on their native environments (Menon *et al.,* 2003; Choudhury and Dey Choudhury 2020a). With dam-induced displacement of these people, their livelihoods are disrupted, and establishing them to other places leads to conflicts and disrupts social cohesion with other tribes (Menon *et al*., 2003; Chakraborty 2003). Recognizing these negative impacts, the US and European nations are now performing cost-benefit analysis of dam removal, and removing dams to revive ecological flow of the rivers, and to ensure water and food security (Purtill 2012; O'Connor *et al.,* 2015). On the contrary, the developing economies, like India, are aggressively constructing newer dams. In 2021, the global installed hydropower capacity increased by 26 GW, of which 80% was in China (IHA 2022). Current installed hydropower in China and India stand at 391 GW and 51.4 GW respectively. While China is set to increase pumped storage hydropower to 120 GW by 2030, India is planning for 96.5 GW. India has added 803 MW of hydropower in 2021, which is one of the largest additions (IHA 2022). Thus, it is extremely essential that the impacts of hydel projects are studied comprehensively.

In the present study, we analyse the impacts of the Lower Subansiri HEP (LSHEP) of NE India, which is an 'under construction' project, as our case. It is one of the largest and most controversial projects of India. But a comprehensive review on the impacts of the project is a long due. Using standard methodologies, we have estimated proximity index, seismicity index and carbon emission from the project. Since the nature of the environment and local socio-economy across most of the proposed project sites of NE India is largely same (Fig. 2), the findings of the present study may well implicate into other projects of the region, and may assist in decision-making.

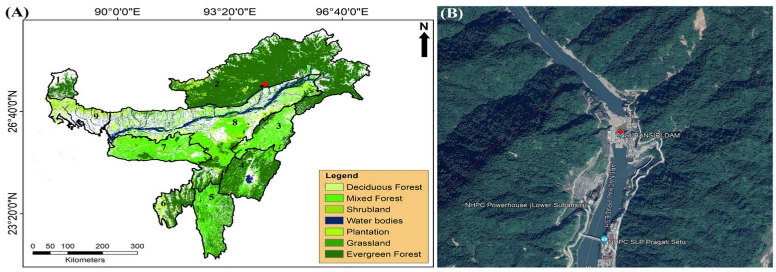

Fig. 2. (A) Vegetation map of the different states of NE India. It may be seen that most part of Arunachal Pradesh is evergreen vegetation. The location of the LSHEP is show as red rhombus. The states have been numbered as 1 - Sikkim, 2 - Arunachal Pradesh, 3 – Nagaland, 4 – Manipur, 5 – Mizoram, 6 – Tripura, 7 – Meghalaya, 8 – Assam and 9 – part of West Bengal. (B) Location of the dam site (obtained Google Earth Pro).

REVIEW OF LITERATURE

The geography

NE India is geographically located between 21°58″ – 29° 27″ N, 88° 00″ – 97° 24″ E, and covers an area of 2.75 lakh sq. km. The region encompasses the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim and parts of West Bengal. It shares international boundaries with China, Bhutan, Nepal, Myanmar and Bangladesh, making it a strategically important region of India (Choudhury 2013; Dikshit and Dikshit 2014). Excluding parts of Assam (Brahmaputra and Barak valleys), Manipur (Manipur valley), Tripura and West Bengal, rest of the region is hilly and mountainous, often snow-capped. Physiographically, the region may be divided into Himalayas (in the north), Hill ranges (in the east), Meghalaya Plateau, and Brahmaputra, Barak and Manipur valleys. The states of Arunachal Pradesh, Meghalaya, Nagaland, Sikkim, Manipur and Mizoram are largely hilly, and are criss-crossed by large rivers passing through deep gorges making them important sites for hydel projects. Most of these rivers flow through highly populated valleys of Assam. The state of Arunachal Pradesh receives high annual precipitation (about 3000 mm), and experiences tropical as well as temperate climate, with cool summers and cold winters. Thus, with its varied physiography, NE India is a treasure house of biological diversity (Choudhury 2013), and any mega hydel project has tremendous impacts on the wildlife.

Demography

The total population of NE India is around 45.6 million. Over 70% of the population lives in the plains, and about 80% of the population lives in rural areas (NEC 2015). Assam is the most populous state, having a density of 397 persons per sq. km., and Arunachal Pradesh has the least (17 persons per sq. km.) (Census of India 2011). There are over 200 ethnic tribes in the region, and the proportion of tribes in Arunachal Pradesh is 68.8%, as of 2011 (NEC 2015). Since all the major rivers in the region flow through the densely populated plains of Assam, the downstream impacts of the hydel projects of the hilly states on the plain dwelling Assamese people are profound. A map of population distribution in the NE Indian states is provided in Fig. 3.

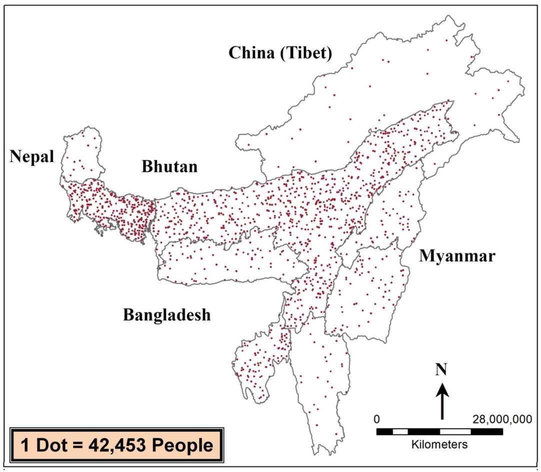

Fig. 3. Distribution of human population in the states of NE India, as per Census of India (2011).

Agriculture and GSDP

NE India lags far behind in socio-economic development, as the region is still industrially under-developed. Agriculture is the prime source of livelihood of the people (Dikshit and Dikshit 2014). There are two major agricultural practices in the region: Settled agriculture in plains and valleys, and *jhum* cultivation (a slash-and-burn type of shifting cultivation) in hilly areas (Choudhury and Dey Choudhury 2020a). Further, over 80% of the farmers have land holdings below 2 hectare, and a very small portion of the agricultural land is irrigated or mechanized (Karmakar 2008). The percent share of Agriculture to the Gross State Domestic Product in 2011-12 was 17.25% and 18.90% in Arunachal Pradesh and Assam respectively (NEC 2015). Since the farmers have smaller land holdings, without proper irrigation facilities, agriculture is largely dependent on rainfall and annual flood patterns. Thus, any displacement of the people and changes in flow regimes of rivers due to construction of dams badly affect livelihood of the people.

Forest cover and protected areas

As per the recent 'India State of Forest Report 2019' published by Forest Survey of India (FSI 2019), 65.05% of the total geographic area of NE India is forest covered. Between 2017 and 2019, there has been a decrease of 765 sq. km. of forest area, which has been attributed mainly to *jhum* cultivation. The forest cover is impressive, in terms of percent of total geographic area of the state: 62% in Arunachal Pradesh and 34% in Assam. A Land-Use Land-cover map of the region is provided in Fig. 2. There is an extensive network of national parks and wildlife sanctuaries, and two UNESCO World Heritage sites in the region. These conservation priority areas are the abodes of a plethora of wildlife (Choudhury 2013, 2018). Thus, NE India is included in two global biodiversity hotspots: Indo-Burma and Eastern Himalaya (Choudhury 2013).

Lower Subansiri Hydroelectric project

Subansiri river is the largest tributary of the Brahmaputra river. It originates in the Himalayas in Tibet (China), flows southward into Arunachal Pradesh passing through deep gorges of Upper and Lower Siang districts, and finally into Brahmaputra valleys of Assam wherein it traverses through Dhemaji, Lakhimpur and Majuli districts, before emptying into Brahmaputra river (Goyal *et al*., 2018). As per CEA (2019), 22 hydel projects of more than 25 MW potential have been identified in the Subansiri basin. Originally, a large project was planned on the Subansiri river, which has now been divided into three: Upper, Middle and Lower Subansiri HEPs (Menon *et al*., 2003; Vagholikar and Ahmed 2003). The LSHEP is being constructed by the state-run agency National Hydropower Corporation Ltd. (NHPC). This project is located at Lower Subansiri district of Arunachal Pradesh, near the border of Assam (Fig. 1). The project is a 2000 MW, concrete gravity dam of 116 m height, and shall generate power using eight Francis turbines each of 250 MW capacity (Baruah *et al*., 2009). The catchment area of the dam is 34900 sq. km. and storage capacity is 1365 mcm. The clearance of Cabinet Committee (Economic Affairs, Govt. of India) was accorded to the project on 9th September, 2003 at Rs. 6608.68 crore. Stage I clearance of LSHEP was granted in 2000, and stage II clearance in 2001. The environmental Clearance was accorded on 16 July, 2003. The environmental clearance of the project was challenged in the Honourable Supreme Court of India, and the judgement of the court came in 2004 which directed the NHPC to ensure that the downstream river section is not silted. Subsequently, the project work started in 2005. This delay in the commissioning of the project has raised its cost to 19,992.43 crores by 2020. The project work has not completed so far, and as per NHPC, the commissioning of the turbines shall be completed by 2024 (Fig. 4A).

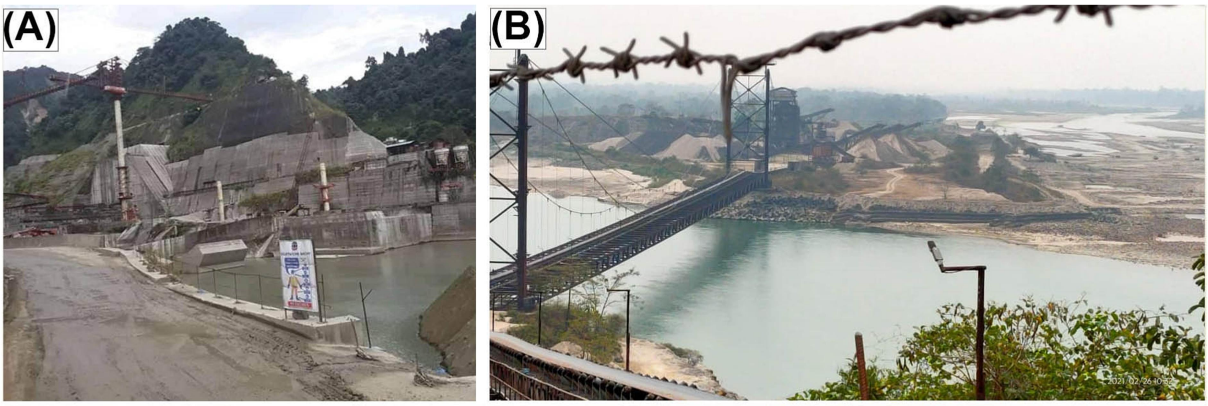

Fig. 4. Photographs pertaining to the Lower Subansiri hydroelectric project: (A) The project site with constructions; and (B) The stone quarry just downstream of the project site which affects elephants.

Mising tribe and the LSHEP

Mising is an ethnic tribe of North Assam branch of Tibeto-Burman language speakers of Mongoloid race who migrated to India from the North-west China through Tibet. They originally settled in the Siang and Dibang valleys in the ancient times, and now occupy mainly the plains and lower hills along the north bank of Brahmaputra (Patir and Thapa 2020). *Misings* are riverside people who are socio-economically associated with rivers, and the Subansiri river basin is one of their primary abodes. The river is the lifeline of these people as it provides water for domestic and agricultural uses. Further, it is a medium of transportation of goods, and livelihood based on fisheries, and sand and stone excavation (Pegu 2005). The population of the *Mising* community is mainly concentrated in the Dhemaji, Lakhimpur and Majuli districts of Assam (Patir and Thapa 2020). Since this area falls immediately downstream to the LSHEP site, *Misings* would be the worst hit downstream community following commissioning of the LSHEP.

METHODOLOGY

We have searched several research databases including Web of Science, Google Scholar, Scopus Index Journals, NCBI PubMed, Elsevier Science Direct, Springer, Sciverse and Research Gate to find related articles. We focused on research articles, review articles, books, book chapters, Govt. reports, policy papers of various agencies including World Bank and Asian Development Bank, news reports, etc. Relevant keywords including “Hydropower”, “Cost-benefit Analysis of hydel project”, “Impacts of dams”, “Northeast India”, “Hydropower in India”, “Hydropower in Northeast India”, “Lower Subansiri hydel project”, “Subansiri river”, “Biodiversity of Northeast India”, “Chinese dams on Brahmaputra river’, etc. were used to search the databases. Further, the global databases on hydropower such as International Hydropower Association and World Commission on Dams were also used to retrieve relevant data. Once the primary articles were selected, their reference sections were consulted to identify more articles / documents.

A total of 136 articles/documents have been included in this review, which includes 16 articles on the impacts of dams in general, 4 on cost-benefit analysis of hydel projects, 7 on impacts of LSHEP, 2 each on Mising community, Subansiri river and its biodiversity, 22 on biodiversity of NE India, 13 on dams of NE India, 3 on Chinese dams, 12 on water and hydropower of Southeast Asia, etc. The articles/reports were analyzed systematically for identifying the impacts of the LSHEP, and relevant data was used to calculate proximity and seismicity indices. The review also discussed future directions for mitigating the impacts of the project based on the specific nuances of the project.

Proximity index

HEPs and their reservoirs may affect conservation priority areas, including National parks and wildlife sanctuaries. The impacts may be direct through inundation, or may be indirect by causing disturbances to the wildlife and the environment. Thus, closer a hydel project to a conservation priority area, greater is its impacts on the wildlife and the environment (Brown *et al*. 2009). To measure the magnitude of impact of the LSHEP on conservation priority areas, Proximity index was calculated, as per Integrated Dam Assessment Modelling (IDAM) tool (Kibler *et al*. 2012), using the following formula.

$$\mathbf{P}_{index} = \sum_{i=1}^{n} \left(\frac{1}{d_i}\right)$$

Here, '*di*' is the minimum distance between the footprint of the project and the conservation area (in km), and '*n*' is the number of such conservation priority areas. The index provides an idea of the impacts of a project on the wildlife.

Seismicity index

Seismicity index is a vital parameter for decision making with respect to construction of dams and reservoirs, especially in regions with high neotectonic and orogenic activities (Talwani 1997; Brown *et al.,* 2009), like NE India. It is known that reservoirs of hydel projects may induce seismicity, called reservoir-induced seismicity (RIS), which depends on three vital parameters, *viz.* the maximum height/depth of the dam ($h_{max\ res}$), the maximum reservoir volume ($vol_{max\ res}$) and the minimum distance of the reservoir from active faults (*d)* (Talwani 1997; Gupta 2002; He and Tsukuda 2003; Kibler *et al.,* 2012). As per the IDAM tool (Kibler *et al*., 2012), seismicity index of the LSHEP was calculated using the following formula.

$$\text{Seismicity index} = h_{\max \text{res}} \times vol_{\max \text{res}} \times \frac{1}{d}$$

Carbon emission reduction credits

Recent studies have questioned the greenness of hydel projects since reservoirs of the projects have been identified to be sources of emission of greenhouse gases (GHGs) (Barros *et al.,* 2011; Varies *et al.,* 2012; Varun *et al.,* 2012; Moran *et al*., 2018). Emission of GHGs depends on surface area of the reservoir, climatic conditions and reservoir age (Barros *et al.,* 2011; Varun *et al*., 2012). Thus, whether or not a hydel project may be accorded the credit for reducing carbon emission depends on the reservoir surface area and power output, which is measured as Power density (Brown *et al*., 2009). As per the IDAM tool, a hydropower project with power density below 4 Watt/m^2 is in-eligible for carbon emission reduction credits, while those with power density of more than 10 Watt/m^2 are regarded to have negligible project emissions (Kibler *et al*., 2012).

IMPACTS OF THE LSHEP

The impacts of the LSHEP have been categorised as biophysical, socio-economic and geopolitical, which are discussed in the succeeding sub-sections.

Bio-Physical impacts

Submergence of forest land and Proximity index

The LSHEP submerges 70 km of the Subansiri river course in the upstream. The project submerges 4035.56 hectare of land in Assam and Arunachal Pradesh, of which 4030 hectare is forest land. The submergence area includes 42 hectare of the Tale Valley wildlife sanctuary, and parts of Tale Valley reserve forest (RF), Tale RF, Panir RF, Jiadhal RF and Kamla RF in Arunachal Pradesh, and Subansiri RF in Assam (Vaholikar and Ahmed, 2003) and 475 hectare of community forest land. All these forestland comprise of evergreen and mixed forests of the Eastern Himalayas (Choudhury 2013).

The LSHEP directly submerges six conservation priority areas at the project site and upstream. Thus, as per the calculations based on IDAM tool (Kibler *et al.* 2012), the overall proximity index of the LSHEP was found to be infinity (∞). This implies that the project has colossal impacts on these conservation priority areas, and would therefore have detrimental impacts on the biodiversity thriving therein. Furthermore, there would be impacts in the conservation priority areas in the downstream. The Bordoibam-Bilmukh Bird sanctuary (Assam) is located at 18 km downstream from the project site. The sanctuary is an important habitat for resident as well as migratory birds, which will be threatened by the project once operational.

Impacts on Biodiversity

The NE India is included in two global biodiversity hotspot areas: Eastern Himalaya and Indo-Burma (Myers *et al.,* 2000; Mittermeier *et al.,* 2011). Thus, the diversity of mammals, birds, reptiles, amphibians, plants, and others, both aquatic and terrestrial, in the region is high. The project site of the LSHEP and its submergence areas of 4030 hectare are parts of evergreen forest tracts of the Eastern Himalaya biodiversity hotspot (Choudhury 2013). These forests are home to several IUCN redlisted fauna, including Endangered species such as Bengal tiger, Dhole, Bengal slow loris, Fishing cat, Black musk deer, Hog deer, *etc.*; and 'Vulnerable' species include Asiatic black bear, leopard, clouded leopard, Gaur, Capped langur, Binturong, Sambar, Takin, *etc*. Some of the other threatened animals found here are Marbled cat, golden cat, Assamese macaque, Large Indian civet, Malayan giant squirrel, *etc.* (Choudhury 2013, 2016, 2018). The submergence area is a critical habitat of several threatened and endemic amphibian and reptilian species (Ahmed *et al*., 2009; Varadaraju 2018). The submergence area is a part of the 'Subansiri Important Bird area' and thus avifauna of the area is also promisingly diverse, some of which are Rufous-necked Hornbill (Vulnerable), Steppe eagle (Endangered), Himalayan vulture (Near threatened), Blyth's Tragopan (Vulnerable), Great Hornbill (Vulnerable), Bengal florican (Critically

Endangered) (Choudhury 1998), White-winged wood duck (Endangered), *etc.* (Choudhury 1996, 1997, 1998, 2007). All these animals are protected in India under Wildlife (Protection) Act, 1972.

Dr. Anwaruddin Choudhury, an eminent naturalist of NE India, reported that the forest area along the border of Assam and Arunachal Pradesh, including the project site of LSHEP, is a part of the contiguous habitat of the Endangered Asiatic elephant (Choudhury 1999, 2004; Williams *et al.,* 2020). The constructions of the LSHEP, its approach roads, settlements and townships, so far, are affecting the elephants and their migration, which is surmised to exaggerate human-elephant conflicts (Choudhury 1999, 2004, 2013).

The downstream bio-physical impacts of any hydel project or dam are largely on the aquatic life. This is because of the dam-induced alterations in flow regimes, river depth, water current, sediment flux and physico-chemical water parameters (Abell 2002; Bunn and Arthington 2002). Such changes devastate the ecology and hydrology of the downstream river channel, which consequently affects the aquatic biodiversity (Oliver 1974; Moran *et al.,* 2018). The Subansiri river is an important habitat of the Endangered Ganges river dolphin (Anderson 1879; Wakid *et al.* 2010), which is the state aquatic animal of Assam, and national aquatic animal of India (Mazumder *et al*., 2014). The dolphin inhabiting section of Subansiri river is just 12 km downstream of the project site. Thus, the project-induced altered flow regimes would make the upstream reaches shallow thereby devastating their habitat and extirpate the entire resident dolphin population (Baruah *et al*. 2012; Wakid *et al*. 2010). In addition, researchers have reported over 204 species of fishes from the lower Subansiri river, including Golden mahseer - an Endangered migratory fish species (Das *et al*. 2013; Bakalial *et al*. 2014). Similar impacts of dams and barrages on aquatic life and the dolphin has been surmised from the Barak (Choudhury *et al*. 2019) and the Ganges river (Sinha and Kannan 2014). Since the Subansiri river contributes about 10% of the flow of the Brahmaputra river, the dam-induced altered flow regimes would also affect the dolphins and other aquatic life in the Brahmaputra river substantially (Goyal *et al.* 2018).

For the construction of the LSHEP, a large stone quarry has been set up in the downstream river bank (Fig. 4B). Furthermore, quarrying of boulders and sand has resulted in disturbances in the river, affecting siltation, sedimentation, and aquatic bottom fauna. These activities of the dam developers are in violation of the 2004 verdict of the honourable Supreme Court of India. In addition, about 70 km of road has been constructed so far, and about 1500 workers are currently working at the project site. During the construction, a large tract of the forest has already been cleared, and the commissioning of the dam would submerge another huge chunk of primary forest (Vagholikar and Ahmed 2003). These have resulted in deforestation and anthropogenic disturbance in this critical wildlife habitat, threatening continuous existence of the biodiversity.

In addition to the aquatic life, the downstream valley of the Subansiri river is home to some of the splendid wildlife species, including Bengal florican (Critically Endangered), Asiatic wild water buffalo (Endangered), Asiatic elephant, the Great

Indian One-horned rhino (Vulnerable), *etc.* (Choudhury 2013, 2018). Some of the noteworthy avifauna found here includes 'Critically Endangered' species like Oriental White-backed vulture; 'Endangered' species like Greater Adjutant stork, and migratory birds, including Bar-headed goose, Ruddy Shelduck, Gadwall, Mallard, Eurasian Wigeon, Red-crested Pochard, Common Pochard, Tufted duck, Ferruginous duck, Great crested Grebe, Black Stork, Great Cormorant, Common Kestrel, Peregrine Falcon, Black-eared Kite, Osprey, Himalayan Vulture, Griffon Vulture, Eurasian Marsh Harrier, Pied Harrier, Northern Lapwing, Grey-headed Lapwing, Pacific Golden Plover, Common Sandpiper, *etc*. (Choudhury 2000; Grimmett *et al.,* 2011).

The Subansiri is a braided river, and forms a large number of *Chapories* (riverine islets, sandbars and tracts) during lean season, while several of them are perennial. These *Chapories* are the lifeline for several wildlife species, providing refuges, and grazing and nesting grounds (Choudhury 2013). With the dam in operation, the natural and annual flood cycles, sediment flux, and hydrology and ecology as a whole, will be disrupted. This would badly impact the aquatic as well as terrestrial biodiversity in the downstream river basin, wetlands, valley and the *Chapories*. Thus, it may be argued that the impacts of the LSHEP on the wildlife in the upstream, at project site as well as downstream are a serious concern.

Seismicity, landslide, flood and erosion

Large HEPs have the potential of causing RIS. There are about five active faults in the Eastern Himalaya that fall within a radius of 5 km of the LSHEP (Rajendran and Rajendran 2011; Borgohain *et al.,* 2017; Pandey *et al.,* 2018). The Miri thrust and Kumon Fault run across the reservoir area of the LSHEP (see Deb and Baro 2022 for the tectonic map). The project site has thus been questioned by experts to be out of place for such a huge structure (Saikia 2019). The gross storage capacity of reservoir of the project is 1470 million cubic meter, and the maximum reservoir height is 116 m from the river bed (Vagholikar and Ahmed 2003; Baruah *et al.*, 2009). As such, the seismicity index of the project was calculated to be 34.104. Thus, the LSHEP may induce seismicity to a large extent due to seepage of water through the active faults, and any catastrophic seismic-burst would be likely. In addition to RIS, the region (being in seismic zone V) experiences frequent earthquakes (Pandey *et al.* 2018; Rajendran and Rajendran 2011). Devastating earthquakes of magnitudes over 8.5 have occurred in 1897 and 1950 in NE India (Das 2004). Similar impacts of earthquakes and RIS have been surmised for other proposed HEPs of NE India (Choudhury and Dey Choudhury 2020a, 2021), the consequences of which would be catastrophic for the downstream.

The great earthquake of 1950 (magnitude 8.7), in Arunachal Pradesh have caused landslides in the hill course of Subansiri and Brahmaputra rivers, causing blockages and natural reservoirs (Ben-Menahem *et al.,* 1974). In next 4 years, these reservoirs burst to release enormous quantities of water, sand, boulders and muck. This resulted in devastating floods accompanied by deposition of the debris in riverbeds and valleys, thereby braidening the river, decreasing its width and depositing silt in the agricultural fields. Furthermore, these events led to changes in courses of the river and river bank erosion

(Priyanka *et al*., 2017; Bilham and England 2002; Rajendran and Rajendran 2011). The erosion and siltation affected the downstream people in Subansiri basin, mainly the *Mising* community people, who lost their lives, livelihoods and agricultural fields (Kingdon-Ward 1955; Dikshit *et al*., 2020). A devastation of higher magnitude is being feared if any such major earthquake occurs following commissioning of the LSHEP.

The recent incidence of glacial lake outburst flood (GLOF) in October 2023 from the South Lhonak lake in Sikkim (India) is a glaring example. The GLOF released water which gushed down at a speed of 15 m/s with a height of 15-20 feet. The water washed away the largest hydel project of Sikkim, Teesta III, a 1200 MW, 60 m high run-of-river dam, and a 200 m long bridge connecting the powerhouse. Also, the GLOF damaged the downstream 'under construction' Teesta V hydel project. The resultant devastation caused due to the flash floods includes another 10 bridges, the National Highway 10, and a lot of other infrastructures, a cost of billions and miseries to the human. Such GLOFs and floods due to seismic activities and RIS would be threats for the LSHEP as well, making it the biggest man-made hazard for NE India, mainly Assam.

One of the major problems with the rivers of the Brahmaputra basin is the riverbank erosion. The Subansiri river cuts off its banks, engulfing agricultural and homestead lands, and leading to miseries for the riparian people. This is further exaggerated by channels migration and braidening of the river (Gogoi and Goswami 2014). Large areas of land of the Majuli (the largest riverine island) are lost every year. In 2004 itself, the loss due to flood in Assam was estimated at INR 771 crores. Between 1999 and 2004, the average annual loss due to flood has been estimated at US$163 million (NHC 2006). Further, due to river bank erosion, annual average loss of land in Assam is estimated at 8000 hectare, and over 4.27 lakh hectare of land has already been eroded which is about 7.4% of the geographic area of the state (Water Resources, Govt. of Assam, 2023). An estimated area of 386000 hectare has been eroded since 1954 (NHC 2006).

The present average discharge of the Subansiri river is 450 cumecs in lean season. However, when the dam becomes operational, it will fluctuate between 6 cumecs (for 20 hours when water will be stored in the dam) and 2560 cumecs (when all the turbines become operational during power generation) (Wakid *et al.*, 2010). With the operational LSHEP, the daily fluctuations in discharges would undoubtedly exacerbate riverbank erosion in the Subansiri basin, and would have detrimental impacts in the downstream, adding to the miseries of the people. This would also affect the flood preventive structures including embankments, sand bags, *etc*., which are installed along river banks by the Govt. of Assam. In 2020, incessant rains have already caused damages to the guard walls of the project (The Sentinel 2021), while landslides have caused damages to the project in October 2023 (Singh 2023).

It is quite known that dams hardy moderate floods, although they claim so. For instance, the Ranganadi HEP on Ranga river in Arunachal Pradesh causes floods in the downstream Lakhimpur district of Assam frequently (Mathew 2017; Saikia 2017). Thus, it is evident that the LSHEP would be one of the largest hazards of the region, and the downstream people of Assam valley would be under perpetual threat of floods, erosion, *etc*.

Carbon emission reduction credits and emission of greenhouse gases

With installed capacity of 2000 MW and reservoir surface area of 33.5 million m^2, the power density of the LSHEP was found to be 59.7 W/m^2. At this power density, the project is eligible to be credited for carbon emission reduction (Kibler *et al.* 2012). This may be regarded as a positive impact of the dam. However, as noted by Choudhury and Dey Choudhury (2020b), power output is affected by amount of stored water, precipitation, reservoir depth, and the efficiency of operation. Siltation of the reservoir is a common concern with most of the HEPs of NE India which affects output, as observed for the Gumti HEP Tripura, NE India (Bhaumik 2003). With siltation and decrease in storage capacity, although the power generation capacity is reduced, the surface area remains same. Dr. Anwaruddin Choudhury has commented that "*India's hydro-electric projects generally operate at around half their installed capacity*" (Sanctuary Asia 2021). In such circumstances, the power density would decrease, and consequently the credibility of HEPs for carbon emission reduction would be lost (Choudhury and Dey Choudhury 2020b).

Although HEPs are regarded clean and green, recent studies have reported most tropical and boreal HEPs as producers of large quantities of GHGs (Guérin *et al.,* 2008; Varies *et al*., 2012). The stored waters of HEPs serve as point sources of emission of GHGs, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Guérin *et al.,* 2008; Varis *et al.,* 2012; Deemer *et al.,* 2016). Choudhury and Dey Choudhury (2020b) estimated the annual emission of CO_2, CH_4 and N_2O were found to be 48910 tonnes/year, 1675.2 tonnes/year and 52.2 tonnes/year respectively, making the total emission 106340.9 tonnes CO_2 equivalents/year. The total annual emission of the three GHGs by the LSHEP was estimated in CO_2 equivalents, as proposed by Deemer *et al*. (2016) and Varis *et al.* (2012). Emission of CO_2 and CH_4 by the LSHEP was estimated using emission rates suggested by others (Varis *et al*., 2012; Guérin *et al*., 2008). However, studies on actual production of GHGs from LSHEP or other HEPs of the region are wanting.

Soil fertility and hydrology

The high soil fertility of Subansiri and Brahmaputra basin in Assam are mainly contributed by the annual flood cycles of the rivers which bring in mineral-rich soil and sediments (Rasul 2015). It may be mentioned here that the daily flow of the Subansiri shall fluctuate between 2% and 600% of the normal flow, as water would be impounded for 20 hours and released for power generation in 4 hours (Vagholikar and Das 2010). Once the LSHEP becomes operational, the annual sedimentation would be affected, ultimately affecting the soil fertility, water table and flow regimes, the impact of which would be seen far downstream. Khan *et al*. (2005) have studied the hydrological impacts of the Tipaimukh multipurpose HEP (Manipur, NE India) and surmised that the commissioning of the HEP would result in flooding, aggradation / degradation of river beds, and affect the downstream channel morphology, and watershed in general. However, similar studies on the LSHEP or other HEPs of NE India are wanting. It may be mentioned here that the immediate downstream of the Subansiri river in the plains of Assam is highly fertile and a large section of the downstream people are dependent on agricultural activities, including cultivation of mustard, vegetables, paddy, *etc*. Some of the hydrological impacts of the project have been mentioned by Baruah *et al.* (2009).

Socio-economic impacts

One of the greatest impacts of any large hydel project is on the socio-economy of the local people. Construction of large hydel projects causes displacement of the local people at dam sites. Most often, these people are primarily dependent on their environment for their livelihood (Tortajada *et al.,* 2012; Biswas 2012). NE India is home to more than 200 tribes, most living in hilly terrains, and largely dependent on their environment for their livelihood. Further, being unskilled, their displacement from their homeland will lead to loss of their livelihood, ethnicity and cultural heritage (Egre and Senecal 2003; Menon *et al*., 2003; Chowdhury and Kipgen 2013).

Loss of livelihood

At project site: The LSHEP would inundate 960 hectare of forestland in 2 inhabited villages (*viz.* Gengi and Siberite) in Arunachal Pradesh, comprising of 38 *Gallong* tribe families (Vagholikar and Ahmed 2003). Like any other such project site of NE India, these indigenous tribal people perform *jhum* in the hilly terrains. They cultivate vegetables, crops, *etc.* in *jhum* fields, and terrace and wet rice cultivation along river banks. In addition, these people collect forest products like wild vegetables, thatch, fodder, medicinal plants, firewood, wild fruits, *etc*. from forests (Vagholikar and Ahmed 2003). The forests also serve as grazing grounds for the domestic cattle, especially *Mithun* (a semi-domestic cattle species and State Animal of Arunachal Pradesh) (Choudhury 2013). The NHPC is offering 1 hectare of land per family as compensation for agricultural land, in addition to 200 sq. m. for homestead, animal-shed and granary. This is clearly disproportionate (Vagholikar and Ahmed 2003). Furthermore, these displaced families with lack of any education, technical or vocational training, are more likely to continue to follow their indigenous livelihood practices in their new area of rehabilitation. This would increase anthropogenic pressure at the new site and remnant forestland.

In the downstream: Three species of the migratory mahseer fishes are found in the Subansiri river, while another over 200 are found in the river (Das *et al*., 2013). The mahseer fishes migrate upstream in monsoon for breeding, which would be affected by the LSHEP. In a similar incidence, diversion of Ganges river by Farakka barrage in West Bengal (India) has led to about 99% reduction in migration of the fish Hilsa (Sinha *et al*., 1996). In addition, the natural water flow, flooding and discharge inundate the floodplain wetlands (*beels)* in the lower Subansiri basin. These water bodies are important breeding grounds for fishes, and fishes migrate between rivers and wetlands for spawning. Thus, the un-natural water discharges caused by dams would have severe impact on the spawning of the fishes, and their abundance would decrease (Mazumder *et al*., 2014). With decrease in fish abundance, the fisheries-based economy of the local people in the Subansiri basin would also be badly affected. *Misings* are the predominant people living in the downstream plains and are dependent on fishing for their livelihood (Pegu 2005; Patir and Thapa 2020), which would be affected once the project is commissioned.

Impacts on agriculture and animal husbandry: The *Mising* and other people of the lower Subansiri basin in Assam perform deep water rice cultivate in the monsoon and flood-recession agriculture in winter season (Patir and Thapa 2020). These activities are largely dependent on natural water cycles of the river for the want of modern irrigation facilities. Further, the natural water flow and floods provide fertility to soil, recharge groundwater and wetlands. Thus, it is feared that the LSHEP would have detrimental consequences on the agriculture-based economy of the people of lower Subansiri basin in Assam, and thereby threaten their livelihood sources. Animal husbandry is another important livelihood source for these people, which includes cattle, pig, goat, buffalo, etc. The local tribes and others let their cattle grazes in agricultural fields as well as *chapories* during lean season. Commissioning of the LSHEP would affect flow regimes of the river and thus sufficient fodder would not be available for the grazing herds (Vagholikar and Das 2010). This would invite overgrazing on the remaining land, cause over-exploitation and competition, affecting animal husbandry.

Threats to life and infrastructures

Dam-induced floods and flash floods are hardly predictable, and people do not get enough time to respond to the same. With a huge hazardous dam a few kilometres upstream, the lives and properties of the downstream people shall always be at stake. Since the Himalayas is still undergoing orogenic and neotectonic transformations with earthquakes being frequent (Valdiya 2003), any seismicity-caused dam burst would take a huge toll on human lives. When such mega hydel projects are constructed in areas with highest seismicity, zone V, the very purpose of identifying different earthquake zones is rendered meaningless. Such incidences would result in loss of lives of the downstream people mainly of Dhemaji, Lakhimpur and Majuli districts. A bigger crisis would be dam burst or GLOF, if so happens. This might damage several infrastructures on its way, including Gogamukh town, office of the *Mising* Autonomous Council (Gogamukh, Dhemaji), a large number of schools and colleges, administrative offices, roads, *etc.* Alteration in water flows and discharges would affect embankments and erosion-protective measures (including sand bags) installed along the Subansiri river in Assam. River bank erosion is a recurrent hazard for the residents of Assam living along Subansiri river (Sentinel Digital Desk 2020a), which would be exaggerated by the LSHEP. The estimated human population in Lakhimpur, Dhemaji and Majuli districts of Assam is over 1.4 million, of which about 5.2 lakh are *Misings* (Patir and Thapa 2020; https://www.indiacensus.net/states/assam).
Their lives and properties would be in danger of dam-induced floods and dam bursts.

Loss of social cohesion

Displacement and re-settlements of dam-affected people in nearby areas lead to inter-community disputes and loss of social cohesion with other such tribes (Brown *et al.* 2009; Chowdhury and Kipgen 2013). The project site of LSHEP, its upstream areas and the downstream basin is home to several indigenous tribes, including *Adi, Boro, Kachari, Sonowal, Deori, Mising*, etc. There are several incidences of land-related disputes among these tribes along the Assam-Arunachal Pradesh border which often led to casualties. The LSHEP-induced displacement would exacerbate the conflicts and compromise the social cohesion.

As per govt. sources, an estimated area of 3.86 lakh hectare of land has been eroded since 1954, affecting over 90,000 families and 2500 villages (NHC 2006). The socio-economic status of these affected people, popularly called *Char* area dwellers has been devastated due to such erosions, making them landless, homeless, and without livelihood sources. This has badly affected social cohesion of these affected people with other communities (Kumar and Das 2019; Saikia 2021). As mentioned in previous sections, the LSHEP would have tremendous impacts on the flow regimes of the river in the downstream, which would exaggerate erosion of the riverbank. As a consequence, more and more land, and people, would be affected, and thus the existing socio-economic crisis would be exacerbated.

Geo-political and administrative concerns

The sub-standard EIA

The Environmental Impact Assessment (EIA) reports of most of the proposed and under construction hydel projects of NE India have been questioned by experts from various backgrounds. The renowned naturalist Dr. Anwaruddin Choudhury has commented on the EIA of several large HEPs, and stated that, "*It is shocking that mega hydel projects in the northeast are being granted clearances based on such reports. How can we decide the fate of some of the country's most important wildlife habitats based on sub-standard impact assessment studies?*" (Choudhury 2002). The EIA report of the LSHEP lists 55 species of fishes, while the river is home to more than 200 (Bakalial *et al*., 2014), and the report assessed only 7 km of the river section in the downstream. The Govt. agency, Zoological Survey of India, in its EIA, reports that the vast reservoir of the dam *"will be happy haunt for aquatic creatures"*, which is scientifically unsound. It is well-known that aquatic organisms living in lotic systems have specific needs and adaptations for such ecosystems, and would be extirpated if left to such lentic ecosystems (*i.e.* reservoirs). Further, these reservoirs would facilitate invasion of exotic species, like *Clarias gariepinus,* which would outcompete the native species. Very strangely, the EIA reports only 10 species of mammals from the submergence area, and excludes species like Asiatic black bear. Again, the EIA wrongly records an 'Endangered' species *Manis crassicaudata*, which is not yet recoded from the area, while strange non-existent species such as 'nutchh' 'mastheis' finds mention in the report. The EIA records 13 birds, which is again strange. The submergence area is an IBA, and over 300 species of birds are recorded so far (Choudhury 2007). The listing of amphibians is also very poor, as the project records only three. The EIA report makes vague un-scientific statements like *"the animals in the sanctuary (Tale Valley) are not dependent on the river Sipu and no animal is reported to come down to the banks of the river Sipu to drink water".* Other flaws with the report are lack of assessment of downstream impacts in terms of ecological, hydrological and socioeconomic impacts. Importantly, despite the fact that the Subansiri has its origin in the Greater Himalayas and is largely glacier-fed, the EIA report did not assess possibility of GLOF, neither does the report assess RIS.

Who is 'project affected'?

One of the major issues with the HEPs of NE India is that the downstream people are not recognised as 'project affected' (Kant 2003). However, in practice, impacts of such a hydel project on the downstream river ecology and socio-economy are equally enormous, and the threats are more severe (WCD 2000; Brown *et al*., 2009; Tullos *et al*., 2009). Thus, the downstream people of Dhemaji, Lakhimpur and Majuli have not been considered as project-affected, and legitimate steps to safeguard their needs, concerns and livelihoods is warranted. Furthermore, the five numbers of public hearings conducted for the project, one in Assam and four in Arunachal Pradesh, in 2001, are widely questioned with respect to their transparencies (Vagholikar and Ahmed 2003).

Protests against the LSHEP

Recognizing the tremendous impacts on the LSHEP on the environment and socio-economy in the downstream Assam, several organisations, notably KMSS, AASU, TMPK, *etc.* have been protesting against the project since it was notified in early 2000s. There have been several litigations in courts and tribunals (Vagholikar and Ahmed 2003). In April 2004, the Supreme Court of India ordered that the NHPC should ensure that no siltation of the downstream Subansiri river is caused, and the excavated materials should not be dumped into the river or national parks / sanctuaries or surrounding forests. However, as per the locals, these orders were not complied by the NHPC. Due to protests by KMSS, AASU and TMPK, a technical experts committee involving experts from Gauhati University, Indian Institute of Technology (Guwahati) and Dibrugarh University, was constituted. The final report of the committee came in 2010, which highlighted the various impacts of the hydel projects. By 2010, the previous street protests turned into 'large scale anti-dam movements' in Assam, and the construction works stopped in 2011. Amidst the protests, a MoA was signed by NHPC with the Govt. of Assam in 2019, following which the construction works resumed in the same year. By 2020, the eight turbines reached the project site, and the project is likely to start operation soon (Sentinel Digital Desk 2020b). The conflicting issues with the LSHEP is that the people of Assam are at risk of floods, dam burst-induced miseries and loss of livelihood, in addition to environmental and hydrological consequences, without having any share or profit from it.

Trans-boundary concerns

China is planning several dams on different trans-boundary rivers in Tibet, including dams on upstream reaches of Subansiri and Brahmaputra near Arunachal Pradesh border (Keerthana 2021). One such HEP, the Zangmu hydropower project of 510 MW capacity has already been commissioned in 2015 (Dasguta 2015), and another 50 m high project of 60 GW capacity is under construction on the Great Bend of the Brahmaputra river in Medog, Tibet (Donnellon-May 2022). In such a case, Chinese dams may affect water flow and thereby the productivity of the LSHEP and other upcoming HEPs. Further, sudden release of water from such dams due to incessant precipitation or GLOFs may cause breaches in the HEPs of NE India, and cause flash floods leading to loss of infrastructures and lives of millions. On the other hand, similar is the concern of Bangladesh with the NE Indian dams (Huda and Ali 2018; Osmani 2017).

RECOMMENDATIONS

The discussions above on the impacts of the LSHEP reveal that the project has irreparable consequences on the environment, and on lives and livelihood sources of millions of people, especially in the downstream. Unfortunately, since the project is abounding commissioning, there exist minimal scope for recommendations and suggestions. Nevertheless, to minimize human miseries and losses to environment, the following suggestions are provided. Further, we have provided recommendations keeping in view the other upcoming and proposed HEPs of NE India.

- **Minimizing disasters:** The implementing agency should perform detailed modelling studies on the hydrological impacts of the project, and mitigate the same accordingly. Modelling study should include any dam break with full reservoir storage, and estimate the flow, speed and height of water in the downstream. This would identify the magnitude of the damage such events may cause, and help work out mitigation measures. Based on the studies, water level in the reservoir should be maintained such that if released by dam burst it should not exceed last recorded flood level in the downstream. The project managers should share information with downstream administration about incessant precipitations and release of water from the dam well in advance. Alarm systems should be installed in the downstream, which should inform the riparian people as far downstream as is affected. It is extremely essential that the upstream river basin and glacial lakes be monitored using GIS modelling studies, to mitigate possible GLOFs or flash floods, and avoid circumstances like that of South Lhonak lake of Sikkim.
- **Minimizing losses to livelihood:** Dr. Anwaruddin Choudhury commented that *"......... the downstream impacts on livelihoods and the natural habitats of riverine ecosystems are severe."* (Sanctuary Asia 2021). The downstream people of Assam who would be affected by the project should also be recognised as 'project affected'. The people living immediately downstream may be rehabilitated to a different suitable location with due and legitimate compensation. The 'project affected' people of both project site and downstream Assam should be provided with vocational training and financial support for alternate livelihood options. The people may be provided training on pisciculture, sericulture, weaving, *etc.*, as suggested for other HEPs of the region (Choudhury and Dey Choudhury 2020b).
- **Maintaining river ecology and impacts on wildlife:** In the downstream, the ecological flow of the river should be maintained so much as possible to minimize impacts on biodiversity, sediment loading, siltation, etc. This may be done by reducing storage. Dr. Anwaruddin Choudhury has commented that *"....... small and medium dams are far better options to mega dams that submerge large, biodiverse valley forests, thus destroying the very biodiversity we know to be critical to moderating our*

climate." (Sanctuary Asia 2021). Minimizing storage would reduce submergence of the RFs as well. Ray and Sarma (2011) have suggested that the diurnal variation of downstream flow should be minimized to reduce impacts on the environment.

- **Research:** The EIA report of the LSHEP has been questioned by experts as it was largely erroneous and ignored important flora and fauna. Dr. Choudhury commented that *"A good EIA would diagnose problems to the advantage of the project promoters too.....*" (Sanctuary Asia 2021). For instance, the GLOF in the Teesta river of Sikkim washed away Teesta stage III and V projects, costing thousands of crores of money invested by the implementing agency. Had the EIA been appropriate, such impacts may have been mitigated. Further, it is necessary that hydrological and geo-morphological modelling studies should be done, and socio-economic studies should be done. Without such studies, large hydel projects like LSHEP should not be commissioned in the Himalayan region.
- **Cost-benefit analysis (CBA):** It is known that the benefits of constructing dams are often shown in exaggeration, while costs are under-rated. It is essential that judicious CBA be performed for all the planned and proposed HEPs of NE India, including every aspect of socio-economy, bio-physics and geo-politics, as suggested (Brown *et al*. 2009). It may be mentioned here that developed economies have started performing CBA of removing dams, while we are yet to do such analysis for constructing dams in the first place.
- **Regional cooperation:** It is essential that the South Asian countries should have a healthy cooperation with respect to food, water and energy, as suggested by Rasul *et al*. (2021). This is because, while Nepal and Bhutan have surplus hydropower, countries like India, Pakistan, Bangladesh and Afghanistan are energy deficient. Within India, north and NE India have surplus hydropower potentials, while other states are deficient. Thus, in order to efficiently harness the hydropower potentials for all the South Asian countries, it is pertinent to have regional cooperation among all the countries (Huda 2013, 2017; Huda and McDonald 2016; Huda and Ali 2018; Vaidya *et al*., 2021; Tortajada and Molden 2021). As per the study by Asian Development Bank, through regional cooperation and trade, South Asia could save about $100 billion over 2020–2040 (Wijayatunga *et al.,* 2015; Timilsina and Toman 2016, 2018; Tortajada and Molden 2021).
- **Stakeholder participation and external mediation:** Protests and litigations at local, national and international forums result in delayed implementation of hydel projects, increasing project cost, as is the case with LSHEP (Saikia 2019). Thus, it is essential that local people, local and global experts of ecology, hydrology, geology, sociology and economy should be involved in the decision-making process. For effective implementations with respect to socio-economy and environment, and for regional

cooperation for conflict-free trade and water sharing, external mediations and funding are useful. Thus, it is suggested that international agencies including United Nations Organisation, World Bank, Asian Development bank, *etc.* should be involved in development of HEPs in NE India, as suggested by others (Biswas 2012; Wijayatunga *et al*., 2015; Huda 2017; Huda and Ali 2018; Timilsina and Toman 2016, 2018).

- **Conserving water and land resources:** Due to the ensuing global warming and climate change, the food and water security across the globe, and especially in the developing economies, is under threat. In such a juncture, it is the need of the hour that the water, land and biological resources are conserved, managed and utilized in a sustainable manner (Misra 2014; Ostad-Ali-Askar *et al*. 2018; Javadinejad *et al.* 2021; Talebmorad *et al.* 2021). Thus, rather than exploiting the freshwater resources, like rivers, for economic growth, focus should be diverted to their conservation.
- **Constitution of Joint river commission (JRC):** There is an urgent necessity that JRCs are formed between at least three riparian nations, China, India and Bangladesh, with involvement of international agencies such that conflicts are better resolved and a basin-wide management plan be worked out.

CONCLUSION

Developmental infrastructure of any magnitude has its due bio-physical, socio-economic and geo-political impacts. In the case of a hydropower projects, these impacts are irreparable and permanent. The present analysis of the impacts of the LSHEP of NE India reveals that the project has detrimental impacts on the environment, which includes the biodiversity, hydrology, ecology, and geo-morphology. The project would affect sediment flux, riverbank erosion, landslides and water quality in the Subansiri river basin. Likewise, the project has a spectrum of socio-economic impacts, including threats to social cohesion, livelihood, impacts on agriculture, fisheries and animal husbandry, which may ultimately result in poverty and social unrest. Furthermore, there are geopolitical concerns, which may lead to trans-boundary tensions with China and Bangladesh. The most important bio-physical impacts unveiled from the analysis include the threat of dam-burst, GLOF and seismicity, and loss of biodiversity. Under such circumstances, a mega hydel project would be a devastating threat and hazard, especially for the downstream residents. While proper research, cost-benefit analysis, and regional cooperation are the needs of the hour, it is not to be forgotten that a trans-boundary rivers need a basin-wide understanding and management for ecology, hydrology and geology. Since the present study focuses the different aspects of impacts of a hydel project in NE India, the *dam developers* should take cognizance of the same, and perform the requisite research before planning any such project. It should be noted that thousands of such dams are being decommissioned by developed countries in view of restoring ecology of the rivers. Let us not repeat their mistakes, and rather focus on conservation of the water and land resources of NE India.

Funding source: The present study has not been funded by any organisation.

Declaration of interest: None

Compliance with Ethical Standards

We declare no conflict of interest in publishing the article. The study involves no human participant or animals. The study has not been funded by any organisation.

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