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Natural Resource Management and Sustainable Development in Northeast India

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ABSTRACT

Large dams are very important in water resource management, generation of hydroelectricity, irrigation and management of floods and are usually believed to be required in the achievement of development requirements in ecologically vulnerable and socially important regions like Northeast India, where the river systems are a source of significant social,cultural and ecological value. Therefore, the dam projects should harmonize between economic interests, environmental preservation, and the safeguarding of local and indigenous peoples whose livelihoods, cultures, and social lives are closely related to rivers. The inability to take such a course of action usually leads to ecological degradation, displacement and inequality, cultural erosion in society. Artificial intelligence (AI) has become a significant instrument in the design and control of big dams in recent years. The environmental impacts are measured using AI-based technologies like remote sensing technologies, predictive analytics, and real-time monitoring to control the water flows and manage the risks of disasters. Although these technologies are capable of sustainable management of resources, their employment also brings about some issues concerning governance, involvement and equity. As such, the current paper will discuss the role of large dams in sustainable and inclusive development and the applicability of modern technologies in environmentally friendly and socially equitable management of dams particularly in Northeast India. The research grounded on primary and secondary data; places more emphasis on the secondary data, which are newspaper reports, governmental and non-governmental data, policy documents, and published and unpublished research works. The paper comes up with the conclusion that effective implementation of advanced digital technologies with participatory governance and robust environmental protection is necessary to ensure that large dams can help in sustainable and socially inclusive development of Northeast India.

Keywords: Large Dams, Sustainable Development, Artificial Intelligence, Resource Management, Northeast India

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Introduction

Large dam projects have often been considered synonymous with modernisation and the development, especially in the post-independent nations, like India. They were considered as the drivers of economic growth, electricity generators, irrigation, flood control, industrialisation as well as development in agriculture (World Bank, 2000).

Jawaharlal Nehru viewed large dams as crucial symbols of India's post-colonial development and nation-building. He famously described dams as the "temples of modern India," arguing that they represented scientific progress, economic self-reliance, and collective welfare in a newly independent country. For Nehru, large river-valley projects were not merely engineering structures but social institutions meant to transform agrarian society by providing irrigation, electricity, and employment, thereby reshaping the relationship between nature, technology, and society (Nehru, 1954).

Dams in Northeast India are advocated as crucial for achieving developmental goals, energy security, and climate stability due to the region's high river density, with major rivers such as the Brahmaputra and Barak traversing vast areas. These extensive river systems are viewed as offering significant hydropower and water-management potential.(Government of India, 2014).

Although large dams have historically caused significant social, cultural and ecological impacts, they can be reoriented to deliver outcomes that are both sustainable and socially inclusive. In the context of Northeast India, this requires integrating technological innovation with participatory and environmentally sensitive governance. When dams are integrated with AI-based tools, participatory governance, robust environmental safeguards, and respect for indigenous knowledge systems, regional development can be achieved with minimal social and ecological disruption. (Chambers, 1997; Mol & Spaargaren, 2000).

The earlier literatureconstantly placed big dams as the key to national development as they were important in their input to the generation of electricity, increased irrigation and streamlined flood

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control (World Bank, 2000). However later studies shed light on the serious negative effects of dams such as community displacement, livelihood vulnerability, ecological destruction and exclusion of indigenous communities especially in the hazard-prone regions such as Northeast India (Cernea, 2000). Recent research indicates that the strategic use of technology can increase the sustainability of dam projects. Adaptive support mechanisms, including AI remote sensing and real-time monitoring, strengthen management of the environment, forecasting of risks and optimizing operation (Mol and Spaargaren, 2000). In the sustainable development and ecological modernisation contexts, the joint effort to harness technological inventions with the institutions that are inclusive can make large dams ethically responsible and transparent in the ecological aspects (Chambers, 1997).

Large dams in Northeast India are deeply intertwined with the lives of indigenous and local communities, whose relationship with rivers is shaped by Indigenous Knowledge Systems (IKS) that emphasize ecological balance, seasonal rhythms, and community-based resource management. Traditionally, rivers are viewed not merely as economic resources but as cultural and spiritual entities, guiding practices of agriculture, fishing, and flood adaptation. Sociologically, large dams often disrupt these knowledge systems by altering river flows, displacing communities, and marginalizing local voices in decision-making (Cernea, 2000; Scudder, 2005). However, technology-enabled management systems offer new possibilities for making dam management more socially and environmentally sustainable. By integrating AI-based hydrological modelling, flood forecasting, and sediment management with IKS-derived insights on local ecology and river behaviour, dam operations can become more adaptive and participatory.

This study has an empirical basis made of primary and secondary data. Primary data is based on unstructured interviews with the stakeholders, most of the information are secondary data, inclusive of newspaper articles, websites and published or unpublished research.

The Region

The Northeast India is a culturally and geographically diverse area, which consists of eight states namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura all found at the far east of the nation, with long international boundaries with

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Bangladesh, Myanmar, China, Bhutan, and Nepal. This area also possesses a wide variety of landscapes such as the great Brahmaputra and Barak river basins, deep valleys, hills and thick forests, which determines its ecology, all their livelihoods and settlement patterns. It is one of the most ethnically heterogeneous regions in India with more than 200 different ethnic groups and languages where many tribal communities like the Bodo, Deori, Mising, Khasi, Garo or many others preserve rich cultural traditions, agriculture, festivals and crafts that signify strong attachment to the natural environment. The Northeast culture identities are also closely related to land, water and lives of the community that includes festivals such as Bohag Bihu which brings different groups together and has agrarian rhythms that are associated with riverine and valley cultures(MHA, n.d.).

Discussion

Rivers in Northeast India occupy a central place in Indigenous Knowledge Systems (IKS), where culture, ritual, and subsistence practices are deeply embedded in riverine ecology. Ethnographic studies show that tribes such as the Mising, Bodo, Adi, Apatani, Garo, Mizo etc. perform festivals and rituals that are closely synchronized with river cycles, rainfall patterns, and agricultural seasons. Festivals like Ali-Aye-Ligang (Mising) and Bwisagu (Bodo) are linked to sowing seasons shaped by the Brahmaputra's flood regime, while rituals during Dree (Apatani) and Solung (Adi) seek to appease river and nature spirits to prevent floods and ensure ecological balance (Goswami, 1998; Doley, 2015). The Kopili River holds ritual significance in marriage practices among indigenous communities, where its waters are symbolically used for purification and blessings, reflecting the deep integration of river ecology with social institutions and cultural identity. These cultural practices reflect a worldview in which rivers are perceived as living entities rather than exploitable resources, reinforcing norms of restraint, collective responsibility, and adaptive strategies such as stilt housing and seasonal mobility. Scholars argue that such ritual–ecological linkages function as informal systems of environmental governance rooted in tradition, which are increasingly challenged by large dam interventions that alter river flows and disrupt community–river relationships (Gohain, 2010; Vagholikar & Das, 2010; Baruah, 2012).

However, large dams have been an important component in the developmental process of India, most notably in irrigation, creation of hydropower and flood management. Dam construction has

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closely been associated with state-led modernisation and economic development since independence that is based on the scientific and technological approach (World Bank, 2000).

In Northeast India, the dams play a more important role, because rivers predominate, there is large potential of hydropower generation, and frequent flooding also occurs. The Brahmaputra and Barak rivers are also considered as the important resources of the regional development, energy security, and climate variability adaptation (Government of India, 2014; Baruah, 2012). The major endeavours have been the Lower Subansiri Hydroelectric Project, LSHEP, the Ranganadi Hydroelectric Project and the proposed Tipaimukh Dam etc.

The LSHEP that is located along the Subansiri River on the border of the Assam-Arunachal Pradesh is one of the largest hydropower projects in India, and it has an estimated capacity of 2,000 MW. It is estimated to enhance energy security in the region, reduce dependence on fossil fuel and fuel economic development. Regulated releases of water might also limit the threat of floods and develop irrigations downstream (Government of India, 2014). However, this project has been controversial. Among the issues that have been raised by the stakeholders are ecological effects, sedimentation, seismic risks, and repercussions of sudden releases of waters to Assam population (WCD, 2000; Baruah, 2012). Another hydropower project in the area is the Ranganadi Hydroelectric Project in Arunachal Pradesh which was commissioned in 2001. Although positively providing a contribution in provision of electricity and development of infrastructure, it has caused a change in the river flow regimes and downstream flooding thus raising some concerns over the issue of transparency and environmental sustainability. The proposed Tipaimukh Multipurpose Dam is on the border at Manipur and Assam along the Barak River that is meant to provide hydropower and flood management services. The supporters believe the dam would help in the supply of energy and to check floods in the Barak valley (Government of India, 2014).

For the Lepcha tribe of Sikkim, Teesta River and its tributaries are sacred and form part of their cultural and spiritual life, especially in the Dzongu region. In Lepcha culture, rivers, forests, and mountains are not seen merely as economic resources but as living entities connected to ancestors, myths, and rituals, reflecting strong indigenous ecological knowledge. Arora shows that large hydel projects on the Teesta ignore this traditional knowledge and cultural relationship

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with nature, treating the river only as a source of electricity and revenue.Vibha Arora (2006; 2012) highlights that the large dam projects in the Northeast of India are not simply technical structures; they are closely connected with identity, indigenous heritage. Arora claims that resistances to dams are usually based on fear of being marginalised politically, disruption of ancestral river-based social networks, rather than being only a basic objection to development. Therefore, dam projects often become centers of societal tension. Arora statesthat conflicts can be mitigated long side the validity of the dam projectsby comprising ethnographic histories, reflecting on rivers' cultural and symbolic roles, and encouraging the dynamics of participatory governance.

Baruah (2012) also mentioned that since the region has huge hydropower potential, the development efforts of state organizations have focused on the exploitation of river systems like the Brahmaputra, Barak, Teesta, and Subansiri to help with national and regional development objectives. Meanwhile, researchers believe that the results of such projects underscore the necessity of more inclusive and context-sensitive planning of development instead of the denial of the infrastructure-based growth.

Other scholars, such as Menon (2009), argue that recognizing customary land rights and indigenous resource-use systems within development policy can enhance social equity while still promoting development.

The Northeast region is rich ecologically and seismically and it is due to this that stringent environmental regulations are required. As it can be observed in literature on projects such as Lower Subansiri and Tipaimukh, the threats of environmental aspects (like changes in river flows, stress on biodiversity and downstream effects) can be overcome with better basin-level planning, cumulative impact assessment and adaptive management approaches (Gohain, 2008; Dutta and Sarma, 2012). Instead of dismissing dams, researchers propose to adopt scientifically sound and biodiversity-based EIAs with a combination of ecological interdependence and long-term sustainability (Vagholikar, 2011).

It has already mentioned that rivers in North East India also have a great symbolic and spiritual importance as well as livelihood to the indigenous people of the area. The research in the North East India provides an example of how cultural continuity and identity issues of concern in

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communities have enriched the discourse of development by prefiguring social aspects of sustainability (Arora, 2009; Arora and Kipgen, 2012). Such thinking promotes development strategies that do not devalue the cultural tradition and instead involve the local knowledge systems that enhance a low level of confrontation and promotes social acceptance (Bhagbati, 2013).

Notably, community mobilization and resistance against some dam projects have been a positive contribution towards democracy. Instead of hurdles to development, the movements have led towards the learning of policies by identifying gaps in impact assessment, down stream risk management and institutional accountability (Baruah, 2012).

The more recent literature is inclined towards assuming a balanced way of development, that balances hydropower development with indigenous culture, environmental protection, rural involvement, and regionality (Joy, Mahanta, and Das, 2014; Arora & Kipgen, 2012). According to such an approach, large dams can be discussed as potentially useful developmental tools because including them in the governance structure, formulating the ethical policies, and adhering to ecological boundaries are the key factors to their successful operation in the long run.

Using the Ecological Modernisation Theory (EMT), the issues of big dams do not require the stop of the development. Rather, these problems can be solved with the help of technological innovation, regulatory reforms, and sustainable management practices. Instead, they insist on embracing hi-tech technology, institutionalization, and improvement of governance on the environment (Mol & Spaargaren, 2000).

The initial phase of dam development in Northeast India, such as the Subansiri Lower Dam in Assam, the Gumti Dam in Tripura, the Ranganadi project in Arunachal Pradesh, and the Ithai Barrage on the Loktak Lake in Manipur—revealed serious deficiencies in environmental impact assessment and post-construction monitoring. These shortcomings intensified ecological stress and triggered social opposition due to displacement, livelihood loss, and inadequate consultation with affected communities. Such experiences have underscored the importance of incorporating local knowledge systems and meaningful community participation in planning processes in order to achieve development that is both socially responsive and ecologically sensitive (Menon, 2009; Vagholikar& Das, 2010; Gohain, 2010).

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Recent strategies, though, have been in the direction of the green and responsive management. An example of an EMT approach is the use of AI-based hydrological modelling, satellite tracking, and real-time data which is a combination of scientific knowledge and technologies aimed at reducing environmental risks but maintaining the goals of development (Government of India, 2018).

The challenges and the opportunities of EMT are described in such projects like the Lower Subansiri Hydroelectric Project. In the beginning of the project, it was facing resistance because of downstream effects and safety issues. In the long term, improvement in the design and environmental management, as well as data-driven risk management has shown that the ecological issues can be resolved by technological advancements and institutional learning without necessarily leaving large infrastructure (WCD, 2000; Baruah, 2012). The theory introduces ecological Modernisation Theory (EMT) which accentuates adaptive strategies and institutional reform rather than conflict, which promotes sustainable development in society by embracing technology and participatory governance. The prominent element in such reformation is artificial intelligence (AI) because it enables efficiency, more predictive, as well as resilient water management. Deep learning and Machine learning and, which are types of AI tools, analyze high-volume datasetsproduced by sensors and satellites to predict outflows, inflows, and reservoir levels and improvethe operational decision processesand water managementin real time (Lee and Kam, 2023). The combination of remote sensing and AI improves flood and drought forecasting, and managers can prevent environmental pressure due to its timely response (Fatima and Rahim, 2025). AI has a high potential of being used in sustainable water management in Northeast India, where the rivers like Brahmaputra and Barak are highly variable and prone to floods. Real-time forecast scenarios and scheduling adjustments of reservoirs and early warning systems can help decrease the ecological load and increase security in the society (JoWREM, 2024). The combination of AI with the Internet of things, as well as satellite surveillance will allow checking the level and quantity of water any time and make the work of the dams more sustainable and environmentally friendly (UNESCO, 2025). The combination of AI, data analysis and environmental sensors can help turn the conventional dam management approach to be more efficient and predictive. This approach integrates technological innovation with local wisdom and ecological ethics to advance inclusive and socially responsible development goals.

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Conclusion

The insight of dams as social institutions points to the complexity of the relationship between the planning, operation and effects of the dam and the local communities, traditions and environmental relations. Drawing on Ecological Modernisation Theory, this paper demonstrates that strengthened governance frameworks, informed technological choices, and enhanced institutional capacity can play a decisive role in addressing challenges related to large dams and society. The AI-related tools, such as real-time monitoring, predictive hydrologic modelling, and adaptive reservoir management, can restructure the dam functioning to connect with the environment protection and social inclusion (Lee and Kam, 2023; UNESCO, 2025). These technologies have the potential to enhance socio-ecological resilience, reduce ecological risks and assist in sustainable management of water when combined with participatory governance and the local knowledge. Back to sociological assumptions, it alludes to the fact that development, technology and environmental management can all exist together in a mutualistic relationship. When managed with socio-technical empowerment, ecological awareness, and social purpose, major dams in Northeast India can transcend sources of conflict. They can then function as instruments of sustainable development that integrate community well-being, environmental stewardship, and inclusive governance. Combining AI innovation and culturally sensitive governance has provided a solution to equitable, adaptive and environmentally responsible management of the large dams.

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