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The Threats and Opportunities of Linking Indian Rivers

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***Abstract*—India's National River Linking Project (NRLP) if executed as planned, would count among the largest water infrastructure proposals in the world. It aims to connect 30 major river basins through a huge network of new canals, dams, and storage reservoirs. The goal is to move water from areas with plenty of rain to dry, drought-prone regions. While the project is being showcased as the most logical solution to India's water woes, its long-term ecological impact is still open to debate. This paper studies both the opportunities and threats of the proposed project.**

***Index Terms*— rivers, water crisis, climate change, floods, desertification, canals, dams, reservoirs, water management, droughts, environment, biodiversity, ecology**

I. INTRODUCTION

India's water crisis is real. India supports 18% of the global population with just 4% of the world's freshwater resources. Lack of poor long-term planning, climate change, rapid increase in population, poor infra structure of water management, over-extraction of groundwater (accounting for 25% of global withdrawals), inefficient agricultural irrigation which consumer nearly 80% of India's freshwater, severe surface water contamination and lack of local ownership are some of main underlying reasons for the crisis (1,2,3).

India is the largest consumer of groundwater in the world. According to the United Nations World Water Development Report 2022, India is indeed the largest user of groundwater in the world. The country extracts roughly 251 cubic kilometers of groundwater each year, which is more than a quarter of the global total and surpasses the usage of the US and China combined Rampant borewell drilling and pumping are rapidly emptying aquifers, particularly in agricultural intensive states where there is no formal regulation of ground water extraction (4,5,6).

The maximum damage comes from increasing urbanisation and high-water demand and agricultural consumption. In the absence of foresight and long-term planning, Government policies and subsidies incentivize the farming of highly water-intensive crops (like paddy and sugarcane) even in low rainfall regions only adding to the problem (7).

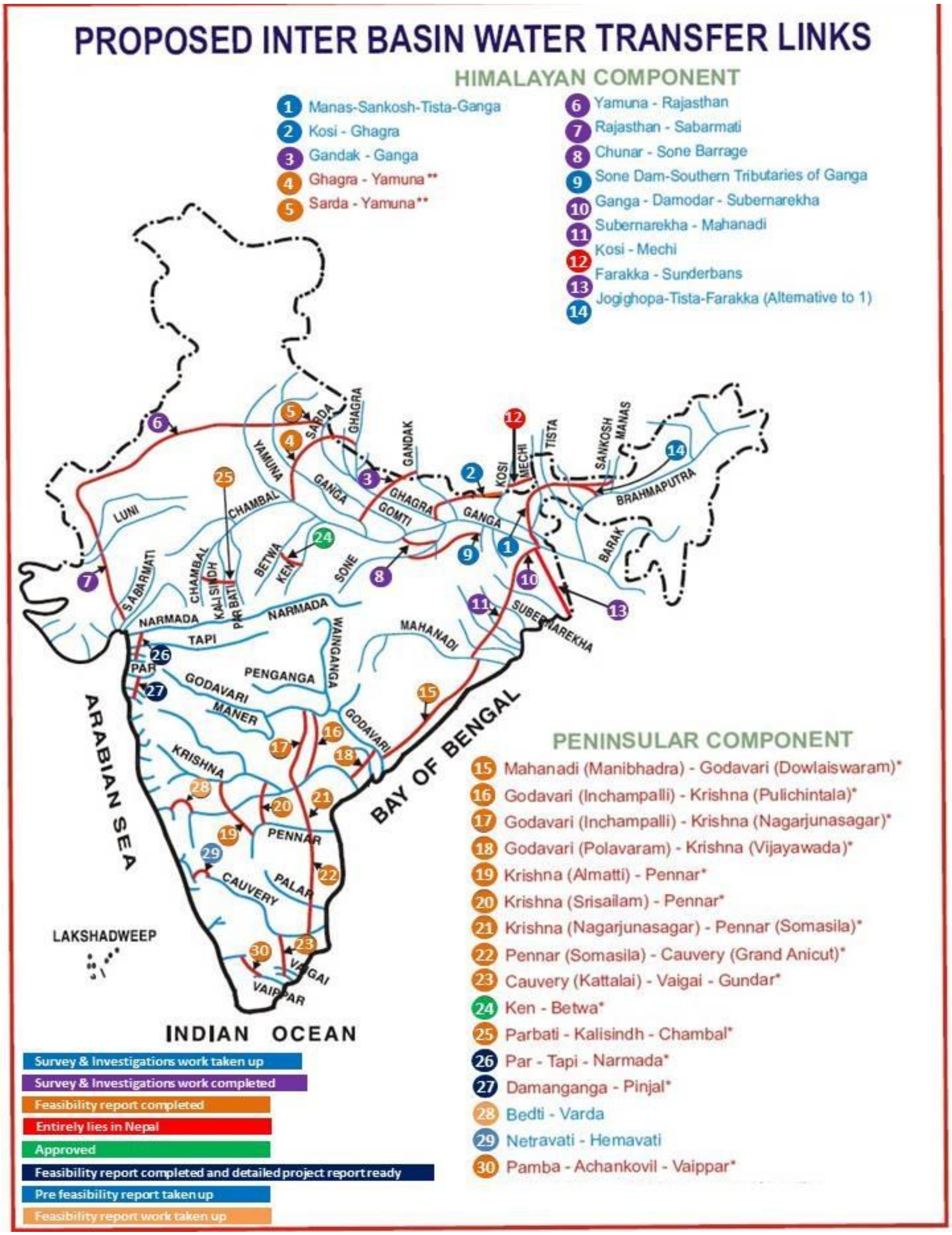
The demand for water in the urban areas of India is rising exponentially. By 2030, India's water demand is expected to be twice the available supply, and many cities will face severe shortages. NITI Aayog's report, titled "Composite Water Management Index," published in 2018, mentions that 21 major Indian cities, including the national capital, Delhi, IT hub Bengaluru, and coastal city Chennai, will run dry of groundwater by 2020, affecting around 100 million people. If left unchecked, urbanization, industrialization, and poor water management will have widened the demand-supply deficit, making sustainable water management a necessity rather than a choice. Urbanization further disrupts natural aquifer recharge due to the proliferation of impervious surfaces like roads and buildings, reducing infiltration capacity. Reports from the Centre for Science and Environment (CSE) and insights on the India Water Portal highlight major gaps in the country's treatment capacity pointing out that only about 28 percent of the urban wastewater and sewage generated is treated in India. The remaining 72 percent flows untreated into local rivers, lakes, and open land (8,9,10,11,12,13,14). India is also bracing the vagaries of Climate Change with shifting, delayed monsoons, and extreme heatwaves cause erratic rainfall, leading to frequent cycles of drought and localized flooding (15).

India has to plan for a major surge in the demand challenge: by 2050, 1.67 billion people will need water to support an economy that is rapidly urbanising, industrialising, and consuming more food, a demand that the current supply cannot sustainably meet and the situation is only likely to worsen. In India, approximately 89 percent of water is used for agriculture, and the efficiency of water use in irrigation is among the lowest in the world. Second, there is a supply problem. Of the 4000 billion cubic metres (bcm) of annual precipitation the country receives, only about 1123 bcm can be utilised, owing to inadequate storage facilities, a limited distribution network, and high evapotranspiration in semi-arid regions. The Central Ground Water Board (CGWB) has assessed 26 percent of groundwater blocks in India as over-exploited, critical, or semi-critical—directly correlated with the country's most productive agricultural areas. Third, there is a quality crisis. Fluoride contamination affects more than 85 million people; arsenic contamination is a problem in the Gangetic Plains; and in most states, polluted, untreated wastewater is discharged into rivers and aquifers without adequate controls (16,17,18).

It was this urgency that led to the conception of the plan to interlink Indian rivers. The interlinking of India’s rivers is not a new idea. The idea of linking rivers to equalize water surplus and deficit is not new. From the Romans to Mesopotamia to India, rulers and visionaries have attempted to bend rivers to their will and lead water to barren lands.It is rooted in late nineteenth- and early twentieth-century canal projects to irrigate land in the Indus, Ganga, and Yamuna river valleys, projects which produced wide-ranging effects in river basin ecosystems, agricultural production, rural power, and relations between farmers and the state. It also laid the foundation for state control over water and the centralization of decision making on water resources that continued into the post-independence period. (17,18).

In the midst of the post-independence dam building era, the idea of designing a river linking scheme for the whole country carried this aim further into national water policy through the National Perspective Plan for Water Resources Development. The National Perspective Plan, prepared by the Ministry of Irrigation (now the Ministry of Water Resources) and the Central Water Commission, was published in 1980. In 1982 the National Water Development Agency (hereafter NWDA) was established as a society under the Ministry of Irrigation to implement the Plan. The Agency was charged with developing scientific studies for the optimum use of water resources in the country and with carrying out surveys and investigations of ways to transfer water from surplus to deficit basins. It was also charged with identifying possible reservoir sites and conducting feasibility studies of the canal links needed to transfer water within and between two groups of river basins, the Himalayan and peninsular groups. However, no concrete steps were taken in this direction due to ambiguity in the ecological fall out (19,20).

It was the NDA government that prioritised it after winning an overwhelming victory last year on a platform of development and growth. The National River Linking Project (NRLP) formally known as the National Perspective Plan, envisages the transfer of water from water ‘surplus’ basins where there is flooding to water ‘deficit’ basins where there is drought/scarcity, through inter-basin water transfer projects as in the figure below(21):



Source: National Interlinking of Rivers Authority/ National Water Development Agency (NWDA)

It aims to connect 37 rivers through a massive network of storage dams and 14,900 km of canals to transfer surplus water from flood-prone northern/eastern basins to water-scarce southern/western regions. Besides controlling floods, supporters claim the project could irrigate 35 million additional hectares of agriculture and generate over 34,000 megawatts of electricity. It is also being promoted as a means of clean energy generation through the plan of building hydropower and solar power units alongside water storage structures to supply extra electricity to local grids and facilitate supplying safe tap water to millions of rural households in alignment with national welfare targets (22,23)

But critics argue the interlinking project is neither economically feasible nor environmentally sustainable, and neighbouring states have expressed alarm about cross-border implications. It would need rehabilitation of people on an unprecedented scale disturbing the socio- cultural anchorages of the people. Some point out to the geopolitical tensions with neighbouring countries on account of it as the Himalayan component is critically dependent on these countries as dams need to be constructed in their regions which might hinder the water supply to these countries. Bangladesh is primarily the one citing a problem as it is a downstream country. Bangladesh is thinking of taking the matter of the interlinking project up to the UN.

Ever since it was proposed, river interlinking in India has been fraught with disagreements among many stakeholders. Much of the criticism arising from river interlinking has been rooted in its terrestrial effects. Environmentalists and activists have argued that river interlinking could change groundwater levels, introduce alien invasive species and reduce sediment deposits downstream, among other ecological concerns. In the case of the Ken-Betwa interlinking project – the first of 30 such projects to reach the implementation stage – 10 percent of the Panna Tiger Reserve stands to be submerged. Around 6,809 hectares of forest land will be diverted for the project, according to government documents. Now, new research from the Indian Institute of Technology, Bombay, considers what the possible impacts of moving vast amounts of water could be on atmospheric feedback loops that regulate evapotranspiration and precipitation. “This research introduces a new dimension to the challenges of river and points out it can lead to a deficit in rainfall by up to 12 percent in already water stressed regions, when the monsoon is withdrawing in September (24,25,26). Environmentalists are concerned with the ecological impact of the project as Indian National Water Development Agency are planning to create hundreds of reservoirs and more than 600 canals with most pointing out that so called water surplus constitutes the water flowing into the sea, which is an important link in the water cycle and is not waste. With this link severed, the ecological balance of land and seas, freshwater and sea water or ocean water is threatened. Financial analysts point out to its huge cost that could come at the cost of other crucial development projects without a clear end result. Some claim that local decentralized alternatives such as restoring traditional village tanks, check dams, and watershed management would achieve higher water security for a fraction of the cost(27,28,29). The recent indefinite hunger strike against Madhya Pradesh's Ken-Betwa Link Project and other regional irrigation schemes by protesters largely comprising tribal women, has brought back the debate to centre stage.

II. BENEFITS OF RIVER INTERLINKING

1. Water security:

Water security is fundamental for the wellbeing of India’s people and for the country’s development. Water-dependent sectors contribute roughly half of economic value added and employ nearly 70 percent of India’s workforce. Water is, therefore, not just a resource but a core economic asset - a creator, enabler, and protector of jobs that is central to the economy, food security, and the environment. India has 18 percent of the world’s people but only 4 percent of its water resources. Rainfall is highly seasonal; nearly 70 percent occurs in just three months. With rising population, per capita water availability has fallen by half since 1970. Some 600 million people face water stress, while the frequency of both floods and droughts is increasing with climate change. Growing urbanization, rising industrial demand, and climate change are intensifying competition for scarce water resources. By 2050, an additional are expected to live in India’s cities, placing enormous pressure on already overstretched municipal water systems (30). Per capita annual water availability reduced from 1816 cubic metre in 2001 to 1544 cubic metre in 2011. There is high variation in per capita water availability ranging from 263 cubic metre (CM) in the Sabarmati basin to 2013, 6 CM in Ganga-Brahmaputra-Meghna system. With the country already experiencing water stress, there is need to augment both water supply in water-rich regions lacking infrastructure and manage water demand in water-scarce regions(31). India's per capita water availability has plunged from around 5,000 cubic metres in 1950 to nearly 1,500 cubic metres today. Any figure below 1,700 cubic metres is internationally considered water stressed. India has already crossed that threshold and is steadily moving towards the 1,000-cubic-metre mark that translates to water scarcity (32).

The National River Linking Project (NRLP), initiated by the National Water Development Agency (NWDA), aims to redistribute water resources across the country. This river interlinking involves connecting surplus river basins with deficit ones through a network of canals, reservoirs, and pipelines. This approach ensures that excess water from flood-prone regions is transferred to water-deficient areas, thereby mitigating both floods and droughts. In the first phase the Ken-Betwa link supply vital water to dry farming areas like Bundelkhand (33,34). With an estimated cost of 44,605 crore, the project is set to provide irrigation for 1 million hectares of farmland across 2,000 villages, ensuring water security for farmers in Madhya Pradesh and Uttar Pradesh. It will also supply drinking water to 6.5 million people across 22 districts, significantly improving the region's water accessibility (35). This ambitious initiative envisions connecting 30 major rivers categorized into Himalayan and Peninsular River links, through a network of approximately 15,000 kilometres of canals. The plan includes 30 links and 3,000 storage structures to transfer water from surplus to deficit regions (36). Canals help refill empty underground water tables by allowing water to slowly leak or seep through their unlined beds into the soil. This process is a form of USGS Artificial Groundwater Recharge where surface water moves down into dry underground aquifers. This is critical as the Indian summer monsoon (ISM), which serves as the primary source of GW recharge in India, is increasingly unreliable due to irregular climatic patterns leading to excessive exploitation during dry periods even in monsoon time. Regular monsoon shifts and unpredictable extreme precipitation events due to climate change disturb the crop calendar and force farmers to fulfil the crop water requirements by drilling more wells for GW extraction. In water-scarce regions, the interplay of unregulated GW pumping practices, farmer-centric policies, and significant climate variability has resulted in over-exploitation and a critical decline in GW availability and sustainability. Thus, this could help resolve the issue to some extent and make India move from water scarcity to greater water security (37,38,39,40,41,42).

2. Flood Control:

India is highly vulnerable to floods. Out of the total geographical area of 329 million hectares (mha), more than 40 mha is flood prone. Floods are a recurrent phenomenon, which cause huge loss of lives and damage to livelihood systems, property, infrastructure and public utilities. It is a cause for concern that flood related damages is showing an increasing trend owing to climate change (43).

According to recent analyses of government data compiled by sources like Factly on Flood Impact, the average annual economic impact due to floods in India has surged to over Rs. 25,000 crores per year in recent decades, affecting roughly 7.4 million hectares of land and claiming an average of about 1,600 to 1,671 lives annually (44).

Climate change has led to extreme precipitation events which pose enormous pressure on millions of people living in the Indian sub-continental region. Under the warming climate, the frequency of floods and associated damage has also substantially increased. Moreover, the projected increase in air temperature and the monsoon season (June–September) precipitation extremes is likely to lead to more frequent floods. The rather significant increase in extreme precipitation events over central India has been reported, has been attributed to warming of sea surface temperature (SST) over the equatorial Indian Ocean. Moreover, a few recent studies show a gradual decline in monsoon circulation and precipitation amount over India while a considerable increase in the intensity and frequency of extreme precipitation reported a threefold increase in the number of widespread extreme precipitation events over central India for 1950–2012. For instance, extreme precipitation (940 mm in 18 h) event in Mumbai (July 2005) was a disaster that led to flooding affecting 20 million people and causing around 1200 deaths . Similarly, Mumbai experienced flooding in September

2017 due to extreme precipitation (330 mm in 24 h), which largely affected road transportation. Furthermore, Chennai received 483 mm precipitation in 48 h in November 2015, which had a devastating impact with economic loss of over $3 billion. Other than localized flooding, the river basin scale flooding due to extreme precipitation and other factors associated with catchment characteristics can pose serious challenges. For instance, extreme precipitation resulted in a large flooding in Uttarakhand in June 2013 claiming more than 6000 lives and an estimated loss of $3.8 billion. More recently, extreme precipitation in August 2018 in Kerala caused a widespread flooding and death of more than 440 people; A preliminary estimate of economic loss due to Kerala flood exceeds over $3 billion. Both flooding and extreme precipitation events are likely to increase under the warmer climate in India (posing more risk of economic loss and damage to infrastructure. showed that 1.5 °C increase in global mean temperature from the pre-industrial level will lead to an increase in human losses from flooding by 70–80% with a higher risk in South Asia (45.46.47.48.49,50,51).

The river Interlinking of Rivers Program prevents floods by capturing excess monsoon water in large upstream storage dams and diverting those high flows through a network of canals into separate, water-deficient river basins, reducing peak downstream flood volumes. These large dams and reservoirs hold back sudden surges of heavy rain instead of letting them overwhelm river channels. By diverting excess water from flood-heavy basins through the connecting canals to dry regions. This prevents flooding and destruction of life and property. By capturing high-volume peak flows during heavy rains and excess water in newly built artificial lakes and dams, it breaks the force of water nd prevents flooding rather than letting it run off destructively. China uses massive engineering works like the South-to-North Water Diversion Project and large reservoirs to move water from water-rich southern basins like the Yangtze to the dry north. While primarily built to fight northern drought, these systems help manage floods by storing and shifting excess water away from overflowing channels during heavy rains. The project has contributed to socioeconomic growth in recipient regions and reduced flood risks in the Yangtze River Basin (52,53,54,55,56). India can emulate that feat.

3. Hydropower generation:

India is the world's second largest populous nation, fifth largest economy with seventh largest geographical area but experiences high energy poverty. With the lowest per capita energy consumption among world's top ten economies, India ranks at 137 out of 218 nations. Severe power shortage is one of the greatest obstacles to India's development. Over 40 percent of the country's people, mostly living in the rural areas, do not have access to electricity and one-third of Indian businesses cite expensive and unreliable power as one of their main business constraints. India's energy shortfall of 10 percent (rising to 13.5 percent at peak demand) also works to keep the poor entrenched in poverty. Power shortages and disruptions prevent farmers from improving their agricultural incomes and stifles economic growth by increasing the costs of doing business in India, reducing productivity, and hampering the development of industry and commerce which are the major creators of employment in the country (57,58).

Hydropower has the potential to alleviate India's energy asymmetry as well as realize its sustainable growth aspiration of a low-carbon regime. Projection models reveal that the demand-supply gap in electricity in India was around 20.5% in 2021–22 which is likely to reduce to 17.4% by 2026–27 and to 14% by 2036–37 . Generating electricity from as many sources as India possibly can, is key to the nation's energy policy. Hydropower is an important part of this mix as it gives the electrical grid steady, round-the-clock energy unlike other renewable sources like wind and solar. It can help India overcome its high coal dependency and pursue its clean energy goals (59,60). Share of hydro-power in the hydro-thermal in India mix is only19% today against an ideal share of 40%. It is only 10- 12% of India's total installed capacity consisting of thermal, hydro, nuclear and other renewable powers (like solar, tidal and wind power) (61,62). In the international climate conference, Indian Govt. has committed zero carbon emission by 2047 and to reach 40% of cumulative electric power installed capacity from non-fossil fuel sources (solar, wind, hydro, nuclear) by 2030. Besides raising solar and nuclear energy, hydro-power development is a must to achieve the goal. Apart from clean and renewable energy, the greatest advantage of hydropower is its flexibility, long life and very little maintenance cost (63,64).

The interlinking of rivers in India aims to generate approximately 34,000 MW of clean electricity by building new dams, reservoirs, and canals across major northern and southern basins, as detailed on the National Water Development Agency portal. This infrastructure transforms unmanaged seasonal water flow into a steady, reliable source of renewable energy (65).

4. Economic benefits:

India's economy needs to grow rapidly to support its roughly 1.47 billion people. It still needs to lift millions out of poverty, create tens of millions of new jobs for its massive youth population, raise individual incomes toward developed-nation levels, and fund vital public infrastructure, health, and education systems.

This is where the economic benefits of the river interlinking project will help revitalise the economy. Agriculture remains a core pillar of India's economic stability. While agriculture's share in India's economy has progressively declined to less than 15% due to the high growth rates of the industrial and services sectors, the sector's importance in India's economic and social fabric goes well beyond this indicator. First, nearly three-quarters of India's families depend on rural incomes. Second, the majority of India's poor (some 770 million people or about 70 percent) are found in rural areas. And third, India's food security depends on producing cereal crops, as well as increasing its production of fruits, vegetables and milk to meet the demands of a growing population with rising incomes. To do so, a productive, competitive, diversified and sustainable agricultural sector will need to emerge at an accelerated pace (67).

The Indian agricultural system faces deep structural flaws notably fragmented small landholdings, severe groundwater depletion, heavy reliance on unpredictable monsoons, and inadequate cold-chain storage and rural infrastructure. These issues lead to low productivity, high debt, and distressed farmers (68).

Agriculture is India's largest user of water. However, increasing competition for water between industry, domestic use and agriculture has highlighted the need to plan and manage water on a river basin and multi-sectoral basis. As urban and other demands multiply, less water is likely to be available for irrigation. Climate change has made the monsoons even more unpredictable and since most crop cycles across the country rely heavily on monsoon rains, the yields are vulnerable to climate shifts. Ways to radically enhance the productivity of irrigation ("more crop per drop") need to be found (67).

The river Interlinking project has the potential to bring up to 35 million hectares of new farmland under reliable irrigation and reduce the heavy dependence on erratic monsoons, allowing multiple crop cycles per year. This increased yield will not only add to India's food security but would revitalise agriculture and stop the increasing migration from the rural areas that is putting unprecedented pressure of India's urban infra structure and resources. Increased yields and cover from the vagaries of Indian monsoons will protects farming communities from sudden crop failures, directly boosting rural livelihoods (69,70,71).

The first phase of India's pioneering Ken-Betwa Link Project (KBLP) involves building the Daudhan Dam complex, low- and high-level tunnels, a 221-kilometer link canal, and hydro-power houses to transfer surplus water from the Ken River to the dry Betwa basin. This objective is to move extra water from the Ken River in Madhya Pradesh to the water-short Betwa basin in Uttar Pradesh, which will be a boon for the dry Bundelkhand region which has very little water for agriculture and drinking water supplies. Ken river has surplus water of about 1,074 cubic meters, which is proposed to be transferred to Betwa river through a 218-km long main canal. This scheme aims to alleviate drought-like conditions in Bundelkhand by ensuring year-round irrigation. It ensures enhanced agriculture for about 10.62 lakh hectares (ha) of farmland, thus improving crop yields and farming income. The scheme will also provide additional drinking water supply to about 62 lakh people in MP and UP, thus improving public health. The project also proposed to generate about 103 megawatts of hydropower and 27 megawatts of solar power, thus boosting renewable energy capacity in rural areas, and ensuring Bundelkhand's overall development. The Ken-Betwa project will generate employment both, at the time of construction and after it. The indirect employment generation in the agricultural sector is estimated to be over 225 lakh man days in the command area of the project. The project, with over 5.765 lakh ha of command area, will create eco-friendly conditions for increasing cattle population. It is projected that riparian vegetation on the project area will provide shelter and cover for aquatic life and the water bodies in the form of a reservoir at Daudhan village will become a habitat for agri-fauna in the long run (72,73,74).

By boosting the energy sector as discussed earlier, it can save crucial investment on importing coals and the loss that comes from its environmental fall out. The same resources can be invested back in the economy. The network will give India a good network of inland waterways which can serve as functional transport routes, lowering overall fuel use and freight shipping costs. Despite technological advances of air, rail, and road transport to move bulk goods and large numbers of people, inland waterways continue to play an important role in improving domestic connectivity and lowering logistics costs. The World Bank estimates that in India, for example, it costs 1 cent per kilometer to carry a ton of freight by waterway, compared to 2 cents by rail and 3 cents by road. Often, the cost of shipping by an inland waterway in India can be even less—as little as one-seventh of the ground shipping cost. Affordability is not the only advantage of inland waterway transport. Although ground transport wins at speed, waterways move up to four times as much cargo per one liter of fuel, making trade cost-effective. In addition, less energy consumption, low noise, and reduced carbon footprint turn waterway transport into a greener and more reliable way of moving freight. This will give a boost a new market for inland waterway logistics, improve regional integration, promote economic growth in the region, and enhance logistics competitiveness—unlocking opportunities for private investment in the new sector(75).

The industrial sector in India is the second highest user of water after agriculture. As competition for water increases across different sectors, the temporal variability in available supply leads to increasing pressure to develop surface storage, or to use groundwater resources unsustainably. Consequently, while it is interesting to explore (the magnitude and extent of) water stress at a national or continental scale, ultimately one can benefit from analyses that directly highlight the water stress faced locally by the industrial and agricultural sectors given endogenous supplies (i.e, at the district scale). Keeping this in mind, the water stress index conducted by the Columbia Water Center presented the following figure that highlights the magnitude of the water problem (76,77). This project could help change this water situation.

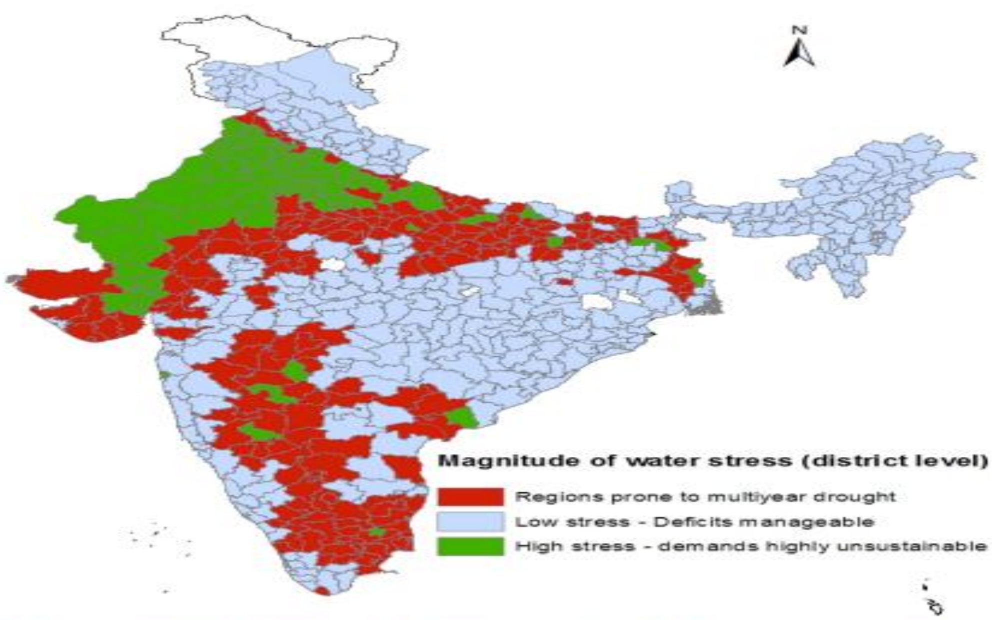


Figure 4: Spatial distribution of the magnitude of water stress at the district level in India (Devineni, Perveen and Lall, 2011)

Indian industries are increasingly exposed to climate risks such as extreme heat, flooding, water stress, and supply-chain disruptions. While some leading firms have begun implementing targeted adaptation measures, climate resilience across the broader industrial ecosystem remains uneven. MSMEs, which form the backbone of India's industrial value chains, face significant constraints in accessing climate data, finance, and technical expertise required to respond effectively to these risks. Water shortages in India threaten economic growth and severely hit manufacturing. For the Micro, Small, and Medium Enterprises (MSME) sector which lacks capital scarcity causes production delays, higher operating costs from buying tanker water and regulatory shutdowns over zero-liquid-discharge rules (78,79). Climate-sensitive critical infrastructure systems, such as power, water supply, and transportation networks, are essential to uninterrupted industrial operations. However, the high climate sensitivity of these systems increases overall vulnerability and their impacts on businesses. Climate risks affect all layers of the industrial supply chain, ranging from physical assets to raw material availability, logistics and transportation, labour productivity, and finished goods(80,81,82). The increased water reliability and security across India holds the potential to guarantees steady raw water supply for growing urban centres and heavy manufacturing plants which has a direct impact on industrial output and its ability to create jobs.

5. Strategic geopolitical and national security advantages

The National River Interlinking Project (NRLP) offers strategic geopolitical and national security advantages alongside its primary economic goals. Creating deep, perennial canal networks along border regions acts as a natural physical barrier on the lines of the famous Dutch Water Defence Lines. This Defence lines system represents a defence system extending over 200 km along the edge of the administrative and economic heartland of Holland. It is comprised of the New Dutch Waterline and the Defence Line of Amsterdam. Built between 1815 and 1940, the system consists of a network of 96 forts, dikes, sluices, pumping stations, canals and inundation polders, working in concert to protect Holland (83).

India shares several transboundary rivers with its neighbours, making water an important aspect of foreign policy and regional cooperation. While shared rivers promote irrigation, hydropower, and flood management, they also create challenges related to water sharing, dam construction, and upstream-downstream disputes. As water scarcity, climate change, and regional tensions increase, water diplomacy has become important for maintaining good relations with neighbours and ensuring India's water security (84).

Water has been a source of conflict throughout history, causing fights at the local, regional, and international levels. The Brahmaputra water dispute between India and China is a prime example. In the world of Himalayan hydro-politics, China and India are both important players. India, as a lower-middle riparian, is more vulnerable to water insecurity because it is more dependent on the Tibetan plateau's headwaters to keep rivers like the Indus, Sutlej, and Brahmaputra flowing. China, with its advantageous hydrological position, holds greater power to determine broader political relationships with its riparian neighbours. The lack of proper institutionalisation exacerbates existing challenges in the basin, which runs across a disputed border between two nuclear-armed countries (85,86).

China's engagement in Pakistan's hydropower sector commenced in 2006 with the initiation of the first Pakistan-China Energy Forum in Islamabad. The forum focused on discussions about energy security and explored various energy sources, including hydro, thermal, and nuclear power. The agreement encompassed the implementation of projects in the energy sector, encompassing hydropower, nuclear power, renewable energy sources. As China rises, its axis with Pakistan will have a greater reach in the Himalayan region. It makes India's water vulnerable to two hostile regional neighbours: Pakistan and China. Moreover, the Increasing nexus between China and Pakistan, in the future, can hamper the hydro-diplomacy between India and China (87,88,89,90).

This project help India build its water resilience to avoid pressure from the Chinese side and eases the pressure on upstream Hydro-Diplomacy, while giving it strategic advantage with water diplomacy with neighbours, Bangladesh and Pakistan. Nearly 65% of Pakistanis live in the Indus Basin region, compared with 14% for India. It is therefore not surprising that Pakistan has warned that any attempt to cut off the water supply, as India has threatened, would be considered an act of war. Bangladesh and India share a complete of 54 rivers between them. Since 1972, water relation between the two countries has been works-in-progress with both parties attempting to realize equitable water sharing. Bangladesh and India signed the 'statute of the Joint Rivers Commission' on 17 March 1972 which governs all rivers common to both nations. Bangladesh also feels insecure about India's River Linking Project and Tipaimukh Dam Project, giving India a huge leverage (91,92,93).

III. THREATS ASSOCIATED WITH THE PROJECT

1. Environmental risk:

India's National River Linking Project (NRLP) proposes to build nearly 3,000 storage dams and reservoirs connected by a massive canal network spanning about 14,900 kilometres across 30 distinct river links (94).

Environmentalists have criticised the project on the grounds that the ambitious project to transfer water from the surplus basin to the deficit basin could time, involves modifying the behaviour or courses of rivers is essentially geomorphic engineering, and the effort to sideline it because planners prioritize rigid civil engineering targets like moving water volume from "surplus" to "deficit" basins over the dynamic, natural behaviour of river channels, sediment loads, and valley landforms could have catastrophic ecological consequences. Since something like this has never attempted in India , there would be no previous studies available to guide the teams. They argue that a river is an open system, as it constantly exchanges materials and energy with its environment. The study of a river needs to be taken as a system rather than a single water course. The river, unlike a canal, augments its flow all along its path, by additions from the tributaries and from rain in the lower catchment. The geomorphology is thoroughly stochastic, within a rough deterministic envelope. In one sense, the catchment is the envelope. Rivers are bounded by these domains and shaped by their domains. Breaking the envelope would unleash forces of uncontrolled change and invite unintended consequences (95,96).

Constructing dams and diverting river water traps large amounts of silt and sand in upstream reservoirs, which significantly reduces the amount of sediment that reaches river mouths and coastal deltas. Depriving coasts and deltas of fresh sediment starves the land, causing beaches and deltas to shrink or sink beneath rising sea levels. The Akosombo Dam on the Volta River in Ghana has reduced the sediment to the coast, resulting in coastal erosion is a living example of what could go wrong. Sediment deposition creates habitats for aquatic life. While too much sediment can be detrimental, too little sediment can also diminish ecosystem quality . Some aquatic habitats are even grain-size specific (97,98,99,100,101).

Large sediment loads are the most common issue seen in dams. Too much sediment can cause poor water quality, algal blooms, and deposition build-up. For aquatic life, excessive suspended sediment can disrupt natural aquatic migrations, as well damage gills and other organs .Turbidity can cause water temperatures to rise (sediment absorbs more solar heat than water does) . Rising water temperatures will cause dissolved oxygen levels to drop, as warm water cannot hold as much oxygen as cold water . Besides, suspended sediment can block sunlight from reaching submerged plants, decreasing photosynthesis rates and lowering dissolved oxygen levels still further destroying more habitats than it creates. Deposition can also alter a waterway's banks and direction as an unusually high sediment load settles out . Sediment deposition shapes Earth's surface by forming Alluvial Systems like deltas and fans. However, too much buildup chokes channels with sand and silt, raising levees and cutting off water flow to vital wetlands and floodplains .Nutrients stay locked in the lake instead of feeding the whole river valley (102,103,104,105,106). The effects downstream are also negative. Since the sediments settle to the bottom of the dam, the relatively clean water rushes out and erodes riverbanks and beds. Dams block natural sand and nutrient flow down rivers. This starves coastal beaches of sand and deprives downstream wetlands of vital water and rich silt, leading to severe shoreline erosion, shrinking habitats, and a higher risk of saltwater mixing into freshwater areas. In the same way, the Aswan High Dam (Egypt) has significantly reduced sediment flow to the Nile Delta, leading to coastal erosion, soil salinization, and decreased agricultural productivity (107).

Dams impact aquatic ecosystems as they impact water quality due to reduction in oxygen content and gas release (methane, sulphuretted hydrogen) caused by the anaerobic decomposition of inundated vegetation. Slow water flow in dams stops natural mixing. This causes thermal stratification, where warm water stays on top and cold water stays at the bottom. Because the cold bottom layer is cut off from the surface, it loses oxygen over time, creating a harsh environment for fish and other aquatic life (108,109).

Reduced discharge into the sea would affect the commercial fisheries. Dams and diversions have reduced the discharge of several rivers into the Caspian, Black and Azov Seas by 50 to 70 percent causing a reduction of commercial fisheries by over 90 percent. It also affected the biodiversity significantly . The shrinking of the Caspian Sea, the largest inland body of water on Earth, is an example of the effect of the heavy engineering activity on the Volga River. Dams, reservoirs, use for irrigation, industrial consumption and navigation systems have fundamentally altered the hydrology of the basin. Studies initially blamed climate change for the shrinking. However, later studies revealed that the main reason is not declining rainfall. In fact, rain over the Volga Basin, which supplies roughly 80 per cent of the Caspian's inflow, has slightly increased. They found that while climate change certainly plays a role with increase in evaporation across the Caspian as regional temperatures rise. But evaporation alone explains only about 40 per cent of the observed water loss since the mid-1990s. The remaining decline points overwhelmingly toward human activity. Water that once flowed naturally into the Caspian is increasingly intercepted upstream. The Volga—Don canal system, which links the Caspian basin to the Black Sea through Russia's internal waterways. diverts water away from the Caspian system. The cumulative effect is now visible from space. Since the mid-1990s, the Caspian Sea has lost roughly 24,000km² of surface area. Water levels have fallen by about two metres. This matters because the northern Caspian is not empty water. It is a critical ecological zone supporting fisheries, wetlands, migratory birds and spawning grounds for sturgeon, the ancient fish species that produce most of the world's caviar (110,111).

Biodiversity - the variety of species and their habitats - plays an important role in ecosystem function and in the many services ecosystems provide. These include nutrient and water cycling, soil formation and retention, resistance against invasive species, plant pollination, climate regulation, and pest and pollution control. Escalating biodiversity loss has widespread implications for both human and environmental security. 16,928 plant and animal species are known to be threatened with extinction. This may be a gross underestimate because less than 3% of the world's 1.9 million described species have been assessed for the IUCN Red List of Threatened Species (112). Dams impact terrestrial biodiversity in three basic ways a) Habitat loss b) Habitat fragmentation c) Cumulative impacts. The construction of a storage dam and subsequent inundation of the reservoir area effectively leads to irrevocable loss of habitat. Large-scale impoundments may eliminate unique wildlife habitats and affect populations of all species. Along with the ecosystems, the biodiversity in them is most often wiped out or in some cases may displace few species. Habitat loss and fragmentation lead to the formation of isolated, small, scattered populations. These small populations are increasingly vulnerable to inbreeding depression, high infant mortality and susceptible to environmental stochasticity, and consequently, in the end, possible extinction. Changes in forest composition and quality, and the resultant habitat type leads to decline in primary food species for wildlife. There are secondary impacts associated with dams, which also get rarely quantified and reported. For example, the disturbance caused by the pre dam construction 15 activities, including the noise and vehicular movement, building of roads, extraction of stone and soil, construction of buildings, etc. negatively impact on biodiversity at and around the project site. Similarly, construction of irrigation infrastructure may have many secondary impacts. Land use changes provoked by dams not only have direct negative impact in terms of habitat loss, elimination of flora and fauna and, in many cases, land degradation, but also feedback effects on the reservoir through alterations in hydrologic function. The loss of vegetative cover leads to increases in sedimentation, storm flow, and annual water yield; decreases in water quality; and variable changes in the seasonal timing of water yield. . When dams are built, along with the ecosystems, the silent services the ecosystems provide are irrevocably lost. While the benefits of dams' flow to a small segment of the society, it is the society at large that bears the losses of these ecosystem services – raising the issue of equity and benefit sharing. None of the Environmental Impact assessment studies in India have addressed the issue of "ecosystem services" and none of the studies tried to value (in economic terms) the ecosystem services loss due to dam

building. The economic value of ecosystem services loss / or the costs of alternates provision is not taken into account while computing the benefit cost analysis of dams. This is a major gap in conceptual and methodological aspect of current EIA process which could lead to a wrongful miscalculation of the exact environmental cost of this project (113, 114,115,116).
This water management plan of mammoth proportions will alter the river valley ecology, land use and economy across India irrevocably. However, as the impact assessments and mitigation strategies are conducted for a single project at a time, most often, the interlinkages and the cumulative impacts at macro landscape level are missed out. The mitigations planned at a project level are ultimately ineffectual at a macro level. Secondary impact identification and mitigation is most often outside the preview and scope of the current EIA reports (117,118).
Reservoirs often submerge productive agricultural land. This will have an associated social and economic cost but will also adversely affect agricultural biodiversity. Endemic species of cultivable plants, domestic fauna and gene pools might be irrevocably lost, before their full potential is realized. A host of birds, insects, mammals and reptiles that are dependent on agricultural ecosystems also are negatively impacted in the process. In many cases, traditional crop varieties and methods of cultivation might disappear because of the submergence of agricultural lands. The EIA reports in India have so far ignored this component of biodiversity and concentrated more on the "wild" biodiversity – that too in a narrow sense of larger and charismatic wildlife forms. Agricultural management during the last century has caused widescale changes in land cover, watercourses, and aquifers, contributing to ecosystem degradation and undermining the processes that support ecosystems and the provision of a wide range of ecosystem services. Many agroecosystems have been managed as though they were disconnected from the wider landscape, with scant regard for maintaining the ecological components and processes that underpinned their sustainability. Irrigation, drainage, extensive clearing of vegetation, and addition of agrochemicals (fertilizers and pesticides) have often altered the quantity and quality of water in the agricultural landscape. The resultant modification of water flows and water quality have had major ecological, economic, and social consequences, including effects on human health [well established]. All too often the consequences of modifying agroeco-systems have not been fully considered nor adequately monitored. This is clearly evident in this case (119,120,121,122,123).
The National River Linking Project (NRLP) envisages the transfer of water from water 'surplus' basins where there is flooding to water 'deficit' basins where there is drought/scarcity, through inter-basin water transfer projects. Digging further into the term 'surplus' as per the Government, states that it is the extra water available in a river after it meets the humans' requirement of irrigation, domestic consumption and industries thereby underestimating the need of the water for the river itself. The term 'deficit' has also been viewed in terms of humans only and not from the river's perspective, which includes many other factors (124). Detaching human need from the larger ecosystem is detrimental in the long run as we are obviously dependent on the planet and its non-human inhabitants for our survival (125,126). Some environmentalists have questioned the concept of "surplus water," maintaining that there is no "'surplus' water, because every drop performs some ecological service all the time." Others have pointed out that a river assessed to have "excess" water today may not have that "surplus" tomorrow. This is important particularly in the context of climate change impacting glacier masses and water volumes in the Himalayan rivers, argues Ashvani Gosain, professor at the Indian Institute of Technology, Delhi, pointing out that if these perennial rivers "don't retain the character of donor basins," the ILR plan would collapse (127).

The project envisages the building of many dams, canals and tunnels with some of them having high lifts upto 120 m. This will lead to a huge social and environmental cost. The recent example is the proposed Ken-Betwa link, which has been approved by the Government. The project puts in danger over 4,100 hectares of forest land and threatens to submerge approximately 98 km² of the Panna Tiger Reserve in Madhya Pradesh. This endangers local wildlife populations, including tigers and gharials. This will cause huge vegetation loss as hundreds of thousands of trees face felling, which can lead to habitat fragmentation and loss of endemic flora and fauna. Thus, if a single project of interlinking could accrue such an environmental cost, then one can only imagine how it will impact the country's biodiversity if all the 30 links are implemented. Certain scientists have also expressed their concern that the physical and chemical properties of sediment load may significantly change due the diversion of river. River formation and the shape of the delta formed at the river basin my also get altered which is not something that can be ignored (128,129,130,131).

2. Impact on microclimate:

While dams impact localized weather, large-scale river interlinking and inter-basin water transfers have macro-scale effects on connected river basins. Research reveals that moving water from "surplus" basins alters land-atmosphere exchange. Because land evaporation contributes to roughly 25%of monsoon rainfall, changing soil moisture in both donor and recipient basins can disrupt monsoon dynamics on a national scale. Thus, the existence of a reservoir and the resultant changes in temperature and humidity can negatively impact the biodiversity of a region, which otherwise might be naturally adapted to a warmer and dryer climate. This aspect has also not been looked at in any of the dams studied. The inter-basin water transfer's effects on land water management influence the spatial distribution of rainfall in distant basins. As a result of high evapotranspiration during periods of high soil moisture (SM), the intra-basin land-atmosphere connection results in surface cooling. Soil moisture contributes to the moisture content of the air in this way. The moisture supplied by evapotranspiration may result in recycled precipitation in the same basin or may be carried by the wind to distant regions, which may change the region's precipitation patterns. The thermal contrast between the ocean and land or between various land regions is altered by evaporative cooling, which also alters wind patterns, which in turn alters moisture transport and rainfall. This could change the entire ecological ecosystem which no one is really anticipating accurately (132).

Research published in Nature Communications highlights that increased irrigation from the transferred water reduces mean rainfall in September by up to 12% in already water stressed regions of India. They observed more drying in La Niña years compared to El Niño years. Reduced September precipitation can dry rivers post-monsoon, augmenting water stress across the country and rendering interlinking dysfunctional (133).

When Soviet authorities began building the Krasnoyarsk Dam in 1956, the Yenisei River had an ice-free period of only 112 days a year. The thick and long-lasting ice impeded dam building and navigation. However, as the dam rose, it produced an environmental anomaly; for more than 200 kilometers downstream, the Yenisei became ice-free year-round. This led to a change of microclimate in the Yenisei basin. This article adds nuance to our conceptualization of melting glaciers and icecaps, and thawing permafrost, as harbingers of imminent global climate change. Today, the effects of the dam-related climate change endure and exacerbate the air pollution in the Krasnoyarsk region. But a technological solution to curtail it has not been found (133). The negative effects that the Krasnoyarsk Dam had on the surrounding natural environment, as well as on the population of the Krasnoyarsk urban agglomeration, were not limited to changes in the microclimate. The dam disrupted the movement of sediment and deprived the Yenisei of what Soviet hydrologists called its “self-cleaning” ability. It also disrupted the migration of fish to their usual spawning and feeding grounds. In a bitter commemorative account, those who remained after the inhabitants of the Daursk District had been resettled tell of a thirty-six-foot layer of rotting fish at the upstream base of the dam (134,135).

A study conducted by the European Water Association on the evaporation rate from artificial and municipal lakes and reservoirs in Istanbul concluded that the amount of evaporation per year was equal to the city’s water needs for about 26 days. This evaporation also affects the microclimates of the surrounding areas, disrupting natural temperature fluctuations, ecosystems, and habitats. For example, increased evaporation in the region of a large dam changes the moisture concentration of the air, leading to increased heavy rainfall . This deprives the surrounding areas of their traditional rainfall patterns, placing stress on ecosystems and municipalities that depend on those patterns. It also leads to an increased rate of storm surges, which can create more frequent and intense flooding than the dam was designed to handle.

3. Increased vulnerability to climate change:

Dams increase climate change vulnerability by emitting potent greenhouse gases like methane from decaying vegetation and destroying natural carbon sinks. Although dams are often framed as a climate-friendly alternative to fossil fuels, their impact could be negative. Most reservoirs, especially those in tropical regions, emit significant amounts of greenhouse gases due to anaerobic bacteria that break down vegetation at the base of the reservoir, giving off carbon dioxide and methane. In 2020, dams were responsible for more than 5% of global methane emissions (138).

Additionally, the changes to rivers' chemical and sediment composition, and flow lead to dramatic variations in floodplains and wetlands, which can cause the destruction of surrounding forests. Deforestation contributes significantly to climate change because the trees no longer store additional carbon dioxide, while their previously absorbed carbon is released into the atmosphere. Meanwhile, the drying out of wetlands destroys another valuable carbon sink (139).

Dams are detrimental to carbon sinks in the ocean as well. Studies of the Amazon and Congo Rivers underscore how their nutrient- and sediment-rich water drives biological processes deep within the Atlantic Ocean, contributing to algal growth [xxi]. When those sediments and nutrients disappear in the feeing rivers, the conditions that support carbon dioxide-storing algae break down, destroying a crucial carbon sink along with it. Blocking the sediments traveling downstream can also have devastating effects when river deltas are deprived of the silt they need to defend against damage from the ocean. Without the shoring up of river deltas and wetlands, inland ecosystems and human communities become even more vulnerable against the storm surges and sea level rises caused by climate change (140).

Furthermore, shifting weather patterns and extreme storms compromise structural integrity, escalating the risk of catastrophic, uninsurable flooding for downstream communities. According to the American Society of Civil Engineers, by 2030, seven out of 10 dams will be more than 50 years old . And already, over 2,000 state-regulated "high hazard" dams are in need of repair. These dams could result in a high loss of life if they fail. Thus it is not only the initial investment on dams but also their maintenance which must be factored in the cost. Due to the high cost of maintenance and safety, many of the world's dams get more dangerous as they age. The Mosul Dam in Iraq and the Kariba Dam in Zambia rank among the world's most dangerous . Should the Mosul Dam fail, it could result in the deaths of 500,000 people and deprive millions more of power and water. The 60-year-old Kariba Dam, meanwhile, jeopardizes the lives of 3.5 million people who live downstream of it. The dam's collapse would leave 40 percent of South Africa without power and result in untold damages to surrounding wildlife and could even lead to the destruction of another nearby dam, the Cahora Bassa . In 2024, during an extreme rainfall event in Minnesota, the century-old Rapidan Dam finally burst, causing massive damage to local infrastructure and raising fears about future dam failures from climate-related flooding (141,142,143, 144,145).

Climate change makes rainfall more severe primarily because warmer air holds more moisture, with atmospheric capacity increasing by about 7% for every 1°C of warming. This extra moisture fuels larger, more intense storms, often dropping weeks or months of rain in just a few hours. These torrential rains increase the water levels in the reservoir rapidly. To prevent the dam from overtopping or suffering structural damage, operators are often forced to release large volumes of water through spillways. These sudden, massive discharges can flood downstream floodplains, often at rates much higher and more dangerous than a natural river's flow. Several major flash floods in India have been linked to dams, often triggered by glacial lake outbursts, cloudbursts, or structural failures. Notable examples include the Teesta III Dam breach in (Sikkim, 2023), Rishiganga Hydroelectric Project (Uttarakhand, 2021) and Panyor Lower Hydroelectric Project / Ranganadi Dam (Arunachal Pradesh, 2026) are examples of how dams only increased the flooding damage (146,147).

4. Social and Ethical concerns:

Dams and river interlinking projects include construction of large reservoirs and extensive canal networks requires acquiring vast tracts of land, resulting in the displacement of thousands of families. Many of these populations, especially indigenous communities, are detached from their ancestral homes, land, and traditional means of income. Their compensation and rehabilitation measures are frequently delayed or insufficient, leaving displaced communities with a compromised standard of living and a loss of identity spreading fear and anarchy.

In India alone, it is estimated that dams and reservoirs have displaced some 21 million to 42 million people till 2000. Indigenous and Adivasi communities bear the heaviest burden, disproportionately representing up to 40% of all displaced persons despite making up only 8% of the national population (148,149).

The Ken-Betwa Link Project, which is the first phase of the project will directly and indirectly impact over 50,000 people, with thousands of families facing displacement and village submergence across Madhya Pradesh and Uttar Pradesh Approximately 24 villages are scheduled for displacement. Of these, 16 villages are being evicted for the Critical Tiger Reserve (under the Wildlife Protection Act), and eight villages will be completely submerged by the reservoir. Across the broader Bundelkhand region, socio-economic and water resource shifts could affect up to 2 million people. A significant number of those displaced belong to indigenous tribal communities (such as the Gond and Kol tribes) who rely on farming and forest produce (150,151,152). There is growing detachment from such projects in these marginalised communities as they feel that they have to bear the major share of the ecological burden of the projects to benefit wealthier, water-scarce urban or agricultural zones. Dams frequently submerge historically and culturally significant sites, including ancient temples, burial grounds, and pilgrimage routes, causing irreparable cultural trauma (153,154).

5. Increased seismic vulnerability:

Scientists have attributed over 100 earthquakes around the world to dams and reservoirs, a phenomenon known as Reservoir-Induced Seismicity (155). This happens when extra water seeps into the micro-cracks and fissures under the reservoir and surrounding areas and lubricates faults already under tectonic strain. The 7.9 Wenchuan Earthquake in China in 2008 killed 90,000 people and has been linked to the construction of the Zipingpu Dam (156). India has earthquake-prone regions in India lie along the active tectonic boundaries and fault lines in the north and northeast. The highest risk zones (Seismic Zone V), include the entire Himalayan belt, the Northeastern states, the Andaman and Nicobar Islands, and the Rann of Kutch. This makes dam construction very risky. The most notable and heavily studied example in India is the Koyna Dam in Maharashtra. The impoundment of the Koyna reservoir is widely recognized by geologists as the cause of the devastating 6.3 magnitude earthquake in December 1967. This disaster, which resulted in over 180 deaths and widespread destruction, remains a benchmark case study globally for reservoir-induced earthquakes. Located in a highly active tectonic zone, the Tehri reservoir has always been looked at sceptically for the increase in seismic events (157).

6. Fuelling inter state water conflicts:

Water is legally a state subject under India's Constitution, leading states to resist centralization and pursue territorial visions of water resource development . River interlinking exacerbates interstate conflicts by altering natural basin flows, leading to disputes over water rights. When "surplus" water is diverted to "deficit" regions, upstream states fear losing vital irrigation supplies, while downstream states worry about reduced water volumes. These projects can also disrupt local climate patterns and soil moisture. The question of who decides what surplus is could be contentious. The fundamental disagreement lies in how states calculate and define "surplus" or "deficit" water. Upstream states often argue they need their water for future agricultural expansion, sparking fears that inter-basin transfers will deplete their reserves and hurt local farmers. This dynamic triggers fierce opposition, similar to historical disputes like the Cauvery River conflict between Karnataka and Tamil Nadu (158,159). The first phase of the project has also spread fears that its vast scale and massive ecological footprint carry precedent-setting effects for states like Odisha and Chhattisgarh in terms of changing rainfall patterns breeding scepticism against water exports.

7. Implementation and Governance challenges:

Costs for the ILRP are projected to exceed ₹5.5 lakh crore. Without rigorous oversight, inflated budgets, cronyism in contract allocation, and stalled construction pipelines lead to massive taxpayer burdens rather than infrastructure value. India's highway and rural road networks have been criticised for being heavily compromised by systemic corruption, crony capitalism, and politically motivated contract allotment. This nexus characterized by inflated tenders, substandard materials, and manipulated toll structures—] forces citizens to pay the ultimate price through inflated tolls, dangerous infrastructure, and squandered public funds. The damage caused by breached or poor roads is far lesser than the one that could accrue from faulty canals and dams. As per media reports, in the last four years, 170 bridges have collapsed leading to more than 200 deaths. The cost of corruption is not just loss of public money but also the loss of lives. Every year thousands of crores are spent on desilting of drains and yet our cities are flooded after just a few hours of rain. The BMC spent Rs 7,000 crore over 10 years on desilting of drains and rivers, and storm water drain projects and despite that Mumbai gets flooded in every monsoon. The central government could struggle to find contractors and legal help that are acceptable to all stakeholders. Post construction governance could pose its own share of challenges.

8. Geo- political repercussions:

The Supreme Court's verdict directing the Government of India to implement the interlinking of rivers seems to have overlooked the regional and international implications of what the Indian Court strangely considers "the rivers of the country". Just Bangladesh shares 54 rivers with India. Any unilateral action by India on any of its international rivers will degrade its relations with its neighbours while also adversely affecting its ecology, economy and society. Pakistan views any upstream diversion or large-scale tunnelling as a direct threat. Officials argue these changes violate the spirit of the IWT and give India the ability to artificially restrict or alter water flow during times of political crisis. India's river interlink vision relies entirely on Nepal acting as an upper riparian state to store monsoon waters. Historically, Nepalese stakeholders and political factions perceive water-sharing treaties (such as the 1954 Kosi Agreement, the 1959 Gandak Agreement, and the 1996 Mahakali Treaty) as disproportionately benefiting India. They fear that the proposed storage dams would submerge large swaths of Nepali territory, displacing thousands of people. Nepal often resists these mega-projects due to fears of losing sovereignty over its natural resources and receiving unequal economic returns on hydroelectricity or water distribution. Bhutan has similar fears. China benefits from India's strained regional relations by successfully expanding its geopolitical, economic, and military footprint in South Asia. By leveraging diplomatic and economic ties, Beijing actively pursues a strategic containment of New Delhi, challenging India's traditional sphere of influence (162,163,164,165).

IV. CONCLUSION

China and India both face the twin problem of floods and droughts and that of ensuring food security for it billion plus population. While building dams has been the typical way of dealing with this problem, both the countries are exploring the more controversial project for water transfer between river basins, with China taking the lead with its South-North Water Transfer Project (SNWTP). Pegged at a mind-boggling $50 billion [1] , there is no doubt that the cost of the project will increase as it nears completion; which will not be before the year 2050. While the project is seen as a monumental example of macro-engineering, it may not be the ideal model for India. The SNWTP rode on China’s centralized governance, which can override popular opinion, massive state funding, and a dominant south-to-north geography where source and receiver are isolated within one country (166,167). In contrast, India’s hydrological realities, federal structure, and transboundary complexities make it tough for it to follow timelines and plans with complete integrity and discipline that the project demands.

China had no federal state compulsions and could acquire land with force mandating relocation of displaced communities. In India’s democratic and federal system, inter-state river disputes and localized protests make such sweeping land acquisition virtually impossible. Moreover, China’s rivers are largely internal, whereas India shares major river basins (like the Ganga, Brahmaputra, and Indus) with neighbouring countries like Bangladesh and Pakistan. Massive unilateral diversions by India would severely inflame international water-sharing disputes (168).

Environmentalists have been warning about the environmental fallout of building an extensive network of dams. Growing recognition that old and eroding dams pose too high a risk have resulted in an increasing number of dam removals inother developed countries. The United States has taken down approximately 2,000 dams since 1912, with a majority of those dams removed in the last two decades, and 57 in 2021. Removing damaged and aging dams protects the surrounding population from disaster and allows the rivers to restore their natural and biological integrity (168,169, 170).

Rather than attempting a direct replica of China’s grand-scale diversion, whose real environmental consequences will unfold only with time, many hydrologists argue India should focus on decentralized, demand-side management. This includes rainwater harvesting, aquifer recharge, and local watershed management, alongside smaller intra-state links tailored to specific regional needs . In this effort, India must draw lessons from Israel's experience rather than go the China way. Israel is a desert, and water resources are scarce, but today it produces 20% more water than it needs. Israel solved its severe water scarcity through a centralized, technology-driven approach focused on mass seawater desalination, an aggressive wastewater recycling program, and world-leading agricultural drip irrigation. Given that 80% of India's fresh water is consumed by agriculture, we can learn from their example. It is important to note that the success of Israel's water management is a combination of high-tech solutions and national cultural awareness which distinguishes Israel's water conservation program from so many others. Israel succeeded in securing its water economy because the gravity of the situation was understood by all, from Israel's leaders to its citizens. India needs to embark upon a program to build people's trust and involve them in creating a more efficient system (171,172,173).

The recent backlash against the Ken-Betwa river linking project and protests in Uttarakhand against infrastructure expansion are indicators of wider concerns about environmental governance in India. At the heart of all of these concerns is the EIA (Environmental Impact Assessment) framework, a legislative process designed to balance development and environmental sustainability (174). Without transparency the government will rush into a project which could have unprecedented consequences of the delicate ecology of a country with diverse topography. Spending millions on a project which requires an estimated outlay of ₹14 lakh crore (roughly US $168 billion), a figure that would likely swell due to inevitable delays, the project would strain the national exchequer, potentially diverting crucial funds from healthcare, education, and direct infrastructure. India also cannot ignore the reality of climate change and substantial role of a network of dams and canals that can only worsen the situation.

The climate in South Asia is highly vulnerable, and extreme weather events are becoming more frequent and severe. Infrastructure planning in the Himalayas needs to be forward looking to cope with changes in precipitation patterns, glacial retreat and greater risks of landslides. Likewise, changes in rainfall patterns and temperature variations are affecting water availability and ecosystem dynamics in India's river basins. Therefore, climate projections must be integrated into environmental decision-making. This includes identifying long-term hazards, including adaptive design solutions, and ensuring projects contribute to climate resilience (175).

Local communities are essential to environmental governance as they have greater understanding of their ecosystems. Effective participation in the EIA process is about more than just formal consultation. This means getting knowledge out to more people, breaking down language barriers and opening up space for real conversation. The lessons from Ken-Betwa and Uttarakhand are that with better public engagement, more equitable and sustainable development outcomes might be achieved. The Ken-Betwa debates, and the infrastructure expansion in Uttarakhand, underline the need to adopt a more comprehensive strategy, one that recognises the interdependence of ecosystems, communities and economies (176,177).

Finally, sustainable development will be measured not just by the infrastructure built, but by the ability to protect the natural systems on which long-term prosperity depends. More equitable and inclusive environmental governance alone can contribute to resilient and equitable development. A side decision could be to stagger the project and wait to see the impact of one phase for a minimum period of ten years to understand its ecological fall outs without embarking on an ambitious and relentless project that the country may not be prepared for. Taking all the environmental impacts of the proposed project, the apparent economic gain from it may come at a higher environmental cost.

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