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Rich water, poor people: Potential for transboundary flood management between Nepal and India

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ABSTRACT

There has been an increase in the frequency and intensity of floods in the region straddling Nepal and northern Bihar. Stricken by acute poverty despite being rich in water resources, frequent floods, and shared vulnerabilities across borders, is a grave concern for the communities in the region. This hazard adversely impacts the lives and livelihoods of millions of people especially the poor and marginalised who draw their livelihood from the immediate environment. Hence, there is potential for bringing about positive impacts on the wellbeing of the dependent communities through sustainable actions at a transboundary scale. This paper focusses on the flood-related, transboundary challenges in the Koshi and Gandak river basins. It stresses that the floods have strong upstream-downstream linkages therefore, their management demands joint action at various levels of governance. Transboundary cooperation is essential for developing a relationship of trust and a common understanding to work towards managing floods, especially in downstream areas of Nepal and India. Potential actions for transboundary flood management between Nepal and India are recommended in this paper to enhance the resilience of communities and river basins.

1. Introduction

The Hindu Kush Himalayan countries India and Nepal, being close neighbours, have a unique relationship characterised by cultural similarities, people-to-people contacts, and open borders. They also share the risk of natural disasters such as floods. This is not surprising as more than 6000 rivers flow from Nepal through to India, with a total length of about 45,000 km (Shrestha and Aryal, 2011; Khanal et al., 2007). Several of them originate in the high- or mid-Himalayan region (Fig. 1).

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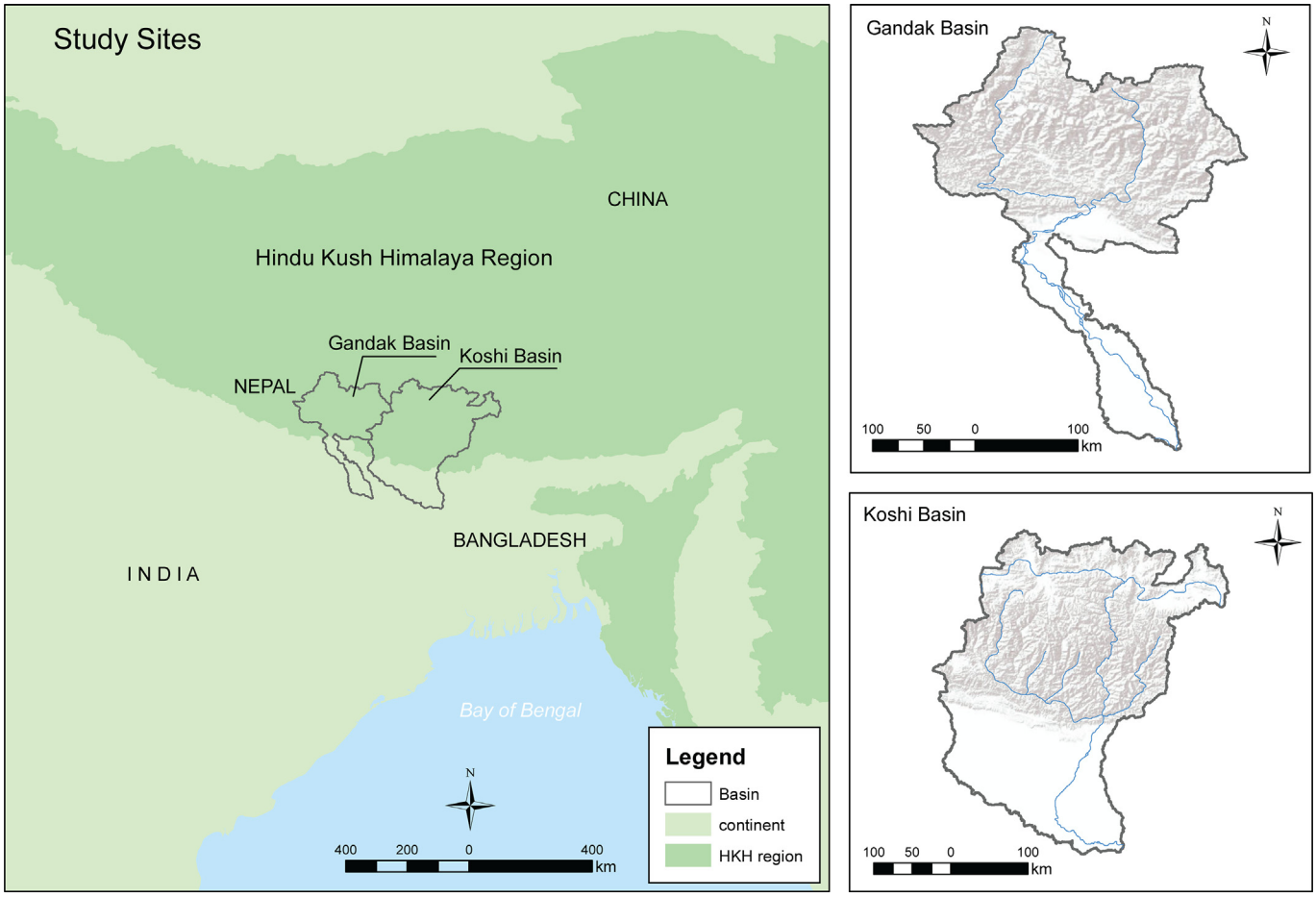

Fig. 1. Major transboundary Rivers between Nepal and India (Sources: Esri; USGS; NOAA).

There has been an increasing trend in the frequency and intensity of floods in the region (Shrestha et al., 2008; Alfthan et al., 2018). The region has received more intense seasonal precipitation coupled with glacier retreat due to global warming (Alfthan et al., 2018) and also increased floods in the region. Over the 60 years 1954–2014, Nepal faced 41 flood events, which killed nearly 6500 people and affected more than 3500,000 (Surya et al., 2015). Floods in Bihar have claimed 9500 lives between 1979 and 2017. Serious flooding in 2013 affected more than 5.9 million people in 3768 villages spread over 20 districts of Bihar. The 2017 floods affected 19 districts of North Bihar, causing the death of 514 people (BDMP, 2019).

Flooding causes economic and livelihood losses, especially in developing countries, where low-income earners undergo great stress during and after flooding events. Losses due to floods diminish the asset base of households, communities, and societies through the destruction of the standing crop, dwellings, infrastructure, machinery and other livelihood assets, and buildings, in addition to the tragic loss of life (Alfthan et al., 2018). Both Nepal and India are prone to environmental disasters and have witnessed a decline in their gross domestic product (GDP) due to concurrent disasters, in which floods have played a major role (Alfthan et al., 2018). Despite the rich natural resources and water, people living in these river basins are poorer as compared to those in the rest of the country, primarily due to the repeated, annual floods and related devastation (Mishra, 2008a). The resulting financial burden is often backbreaking for the communities here.

This paper focusses on the issue of floods that are transboundary and affects two countries – the plains of Nepal (Terai) and the state of Bihar in Eastern India. The paper documents the challenges faced by people in these two regions and outlines actions that may help in saving lives and livelihood of millions of people affected by floods every year. The paper is based on dialogue and literature (the novelty of the paper) and divided into five sections. Section one provides the introduction. Section two focuses on the transboundary challenges for flood management in the Koshi Basin and Gandak Basin, examining different aspects including upstream and downstream linkages, flood typologies and the myths that have been perpetuated. Section three explores the different facets of the transboundary collaboration for flood management including a brief look at the treaties between India and Nepal, transboundary early warning systems and the global frameworks. Section four puts forth ways for enhancing transboundary river basin management and benefits that could be derived from co-management of the river systems across political boundaries. Finally, Section five provides the conclusions of the study.

2. Transboundary challenges in the Koshi and Gandak basins

The Koshi and Gandak rivers are extremely important for millions of people, who depend on them for irrigation, domestic use, fishing, tourism, transportation, and hydropower. The Koshi River (known as Kosi in India), one of the tributaries of the Ganga, originates in the Upper Himalaya in Tibet and flows through the hills and plains of eastern Nepal into northern Bihar (Fig. 1). Of the nearly 88,000 km^2 area of the basin, 32.4% lies in China, 45% in Nepal and 22.6% in India (Wahid et al., 2017). The basin's densely populated areas are in the plains of Nepal and Bihar, with nearly 40 million people dependent on its resources (Neupane et al., 2015).

The tendency of the Koshi to carry high loads of silt from its upper catchment areas in Nepal to the lower plains of Bihar results in the flow of its water being obstructed, leading to perpetual changes in the course of the river (Sinha et al., 2019). This meandering nature of the Koshi causes a lot of havoc in the lower catchment. Known as the 'river of sorrow,' the Koshi has a long history of causing devastating floods in Bihar. The Koshi Barrage, along the Nepal–India border, was constructed after the Koshi

Agreement was signed between the governments of Nepal and India on 25 April 1954, to control floods and expand irrigated lands.

The Gandak River, known as Narayani in South Nepal and Gandak in India, is also one of the major tributaries of the Ganga (Dandekhya et al., 2017). The Gandaki originates in the Mustang district of Nepal near the Tibetan border at an elevation of 6268 m (CWPRS, 2012). The Gandak Agreement signed in 1959 between the governments of India and Nepal necessitates a shared usage of Gandak river water through the construction of a barrage for flood control and irrigation purposes (Dixit and Shukla, 2017).

Expectedly, this context generates several flood-related, transboundary challenges for India and Nepal. Upstream downstream linkages need to be understood for developing appropriate flood risk management. Both the Koshi and the Gandak are transboundary river basins, in which the biophysical and socio-economic conditions upstream affect conditions downstream.

2.1. Upstream downstream Linkages in the river basins

Upstream downstream linkages in a river basin require an integrated approach for the improved basin (Flügel et al., 2018) and flood risk management (Nepal et al., 2014a). For example, human activities such as land use and land cover changes (including infrastructure development) and climatic changes in upstream areas can affect hydrological conditions and erosion and sedimentation in the downstream areas of the basin (Nepal et al., 2014a; Sinha et al., 2018). These conditions, including sediment dynamics, can be some of the determining factors for when and where flooding may occur as they directly contribute to channel stability (Sinha, 2008b).

However, the lack of data and the limited understanding of upstream-downstream linkages make it a challenge to integrate such upstream-downstream linkages in flood management (Nepal et al., 2014a). A recent study by Sinha et al. (Sinha et al., 2019) indicated at a high level of Spatio-temporal variability within the Koshi basin and a high level of aggradation downstream (about 3.9–5.3 cm^3/year of sedimentation). Such a high-level sediment yield can have high serious implications for thresholds of flood avulsion and embankment breaches. Breaching of embankments has occurred frequently in the Koshi basin as the riverbed is 4–5 m above the surrounding floodplain in many places. This underlines the need for improved transboundary collaboration between Nepal and India through joint, collaborative basin-level research that informs basin and flood risk management.

2.2. Good floods, bad floods

2.2.1. Defining a 'flood'

There is no single, all-encompassing definition of a flood. It depends on numerous factors such as their severity, the time of year they occur, and context, that is, whether they are urban or rural. The *Oxford English Reference Dictionary* defines a flood as "an overflowing or influx of water beyond its normal confines, especially over land". Flooding is said to occur when the volume of water in a water body exceeds its total carrying capacity or when the flow exceeds the capacity of a river channel (MoHA and DPNet, 2009). According to Western Fuller, floods are when the daily chores of the people are disrupted by rains and the spilling of streams (Mishra, 2008a).

Floods are a recurrent problem in the Terai, the lowland region in southern Nepal and northern India that lies north of the Indo-Gangetic Plain. They are regarded as a natural phenomenon. Floods are closely intertwined with the lives of farmers in the plains of the two river basins, indicated by the local words used for several different water levels, such as *majarana, baarh, boah, humma, saah* and *pralay* (Mishra, 2008a).

2.2.2. Varied flood typologies

Floods are multifaceted and cannot be captured by a common definition. In India, agencies at the national and state levels, such as the National Disaster Management Authority (NDMA) and the Flood Management Improvement Support Centre (FMISC), Bihar, have identified different types of floods, based on factors such as causes, intensity, duration, and frequency. The FMISC recognizes two types of classification: one based on intensity, duration, and frequency, and the second based on the level of inundation. In the case of the former, the FMISC classifies floods into four classes, (i) Class I: Flash floods – floods arising from rainfall in Nepal, where the lead time is short (8 h) and recession fast; (ii) Class II: River floods – having a longer lead time of 24 h, but also a longer recession of one week or more; (iii) Class III: Drainage congestion in the river confluence – the lead time is greater than 24 h, and the waters remain behind for the full monsoon season, not allowing for any Kharif cultivation; and (iv)Class IV: Permanent waterlogging – the area remains underwater throughout the year, and shrinkage in the area flooded occurs only in February (FMISC, 2013).

In the second type of classification recognised by the FMISC, Bihar, which is based on the flood's intensity, that is, the extent of the area inundated. Here, floods are categorised into four categories – (Shrestha and Aryal, 2011) 'Not affected' (less than 10% of the area inundated), (Khanal et al., 2007) 'Low flood' (11%–30% of the area inundated), (Shrestha et al., 2008) 'Medium flood' (31%–60% area inundated); and (Alfthan et al., 2018) 'High flood' (over 60% area inundated) (FMISC, 2013). Despite these elaborate classifications, floods and their impacts are still perceived as a general phenomenon. Further typologies of floods can be drawn, say, by location. In the floodplains, for instance, crisscrossed by embankments, the nature of floods differs within and outside these structures, and have differing impacts.

In addition to these, six flood typologies have been developed by Megh Payne Abhiyan (MPA), based on their action research in 22 panchayats across five flood-prone districts in northern Bihar since 2006. Their typologies are (Shrestha and Aryal, 2011) Waterlogged regions, (Khanal et al., 2007) General flood-affected regions riverside of the embankments, (Shrestha et al., 2008) General flood-affected regions outside embankments, (Alfthan et al., 2018) Flooding between two embankments of different river systems, (Surya et al., 2015) Flash flood-affected regions riverside of the embankments; and (BDMP, 2019) Flash floods along the Nepal–Bihar (India) border (Pyne et al., 2018).

While these typologies are not absolute and require further exploration, typologies help in developing an understanding of the linkages between aquifers (local, regional, or transboundary) and floods concerning the flood-prone and flood-affected areas. In other words, even in a seemingly uniform geographical setting such as the alluvial Gangetic floodplains, there is a diversity in flood typologies. The typologies exist because of the inherent diversity of the region and anthropogenic modifications to the landscape such as embankments, roads, and railway networks, all of which influence the way human beings and floods interact. Often, floods and their impacts have been seen as general phenomena, whereas the identification of typologies will help in understanding floods and their related impacts from an entirely new perspective (Pyne et al., 2018) and also could inform appropriate management strategies.

2.2.3. Not all floods are bad

Floods are not only damaging, but they also bring benefits in many ways: by recharging groundwater, making the soil more fertile, and increasing nutrients in some soil types. Floodwaters provide the much-needed water resources in dry regions. Freshwater floods, in particular, play a key role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biodiversity. Floodwaters can spread nutrients to lakes and rivers, which can lead to increased biomass and improved fisheries for years ahead (Tockner and Stanford, 2002). It is important to note here that there is a need for a comparative socio-economic benefit analysis of the impacts of floods on dependent ecosystem services such as regulating, habitat, and cultural services.

Agrarian communities accept floods as a normal part of the seasonal cycle. They invite rain by performing rituals (*puja)* and the arrival of the monsoon is celebrated with songs and dances. Areas near the floodplains used to be the first choice for people to reside as the land there is usually

flat and fertile. "The three most ancient civilizations on Earth all developed on fertile floodplains. The floodplains between the Tigris and Euphrates rivers, in what are today Syria and Iraq, are known as Mesopotamia, 'the land between the rivers.' The floodplains of the Indus River, in what is today Afghanistan, India, and Pakistan, gave rise to the Indus River Civilization. Ancient Egyptian culture developed around the fertile flood plains of the Nile" (Geographic, 2019). Also, rivers provide easy travel and access to commerce, an incentive for more people to live on the plains near water bodies.

2.3. Reasons for floods and their changing patterns

The region is identified as the hotspot for flooding disasters (Elalem and Pal, 2015). In both Nepal and India, flooding is associated with the southwest monsoon season, which normally starts in June and lasts until the end of September every year. In Nepal, almost 80% of the total annual rainfall occurs in this season. In addition to continuous precipitation, cloudbursts, glacial melt, landslides, and glacial lake outbursts can also cause floods in the Koshi and Gandak basins.

The impacts of floods tend to get magnified by encroachments on the floodplains, poor infrastructure and inadequate drainage management (Dixit, 2003). Modern science and technology have not been fully effective in addressing the problem through timely prediction and information-sharing (Mishra, 2008b). What is more worrying is that structural interventions (through on-ground infrastructure) to mitigate/reduce floods can, paradoxically, exacerbate their impacts (Dixit, 2003; Sinha, 2008a). On the other hand, traditional knowledge regarding dealing with floods has been forgotten (Mishra, 2008b). Traditional and local knowledge can provide critical guidance to planners and policymakers (Sinha, 2008a; Dekens, 2007).

Besides, changes in the patterns of extreme precipitation events have been observed in the Koshi and Gandak river basins over the last few decades (Zhan et al., 2017; Shrestha et al., 2016). Flooding patterns are expected to change due to the impact of climate change on the hydrological regime (Alfthan et al., 2018). Studies have shown that the intensity of rainfall events is expected to increase in the Koshi and Gandak basins (Rajbhandari et al., 2018).

2.4. Myths around floods

Two major myths are surrounding the causes of floods and the approach needed to manage them. The transboundary nature of floods originating in upstream Nepal and impact both Nepal and India creates opportunities for different narratives to be perpetuated about their causes. One narrative in India is that Nepal releases floodwater to cause flooding downstream. Whereas the perception in Nepal is that the dams, embankments, and high roads constructed by India are contributing to the flooding in Nepal, a perception bolstered by media reports (Adhikari, 2019). This narrative exists in parallel with the transboundary cooperation taking place for flood management in the Koshi Basin through the Nepal–India Joint Committee on Inundation and Flood Management (Shrestha et al., 2010). A second myth is that powerful rivers such as the Koshi and the Gandak can be controlled by engineering methods such as dams and embankments. However, it is important to note that the dynamic nature of these rivers requires an integrated river basin approach (Dixit, 2003; Sinha, 2008a; Iyer, 2008).

2.5. Adverse impacts

In the 20th century, the Koshi river recorded a peak discharge in the range of 24,000–26,000 m^3/s in three years (1924, 1954, and 1968). The flood of 1968 was the largest in terms of geographical area, while the one in 1954 was the worst in terms of the devastation caused (Kale, 2008 (Kale, 2008)). If one were to consider more recent times, the Koshi flood of 18 August 2008 remains the most disastrous in the recent history of both Nepal and India. It caused devastating inundation in Sunsari district in Nepal and Bihar. About 65,000 Nepalese were affected by this flood. Four of the eight village development committees (VDCs) remained underwater for an extended period, and the East-West Highway was rendered impassable (MoHA and DPNet, 2009). In Bihar, the floods forced nearly 3 million people from their homes. According to the Government of Bihar, 2,36,632 houses were fully or partially destroyed, and over 2,43,200 ha (6,08,000 acres) of crop area damaged, impacting close to half a million farmers (GFDRR, 2010). The flood severely hit five districts in Bihar. Nearly 3700 km^2 of the affected areas were inundated, affecting 412 panchayats and 993 villages. Approximately 493 lives were lost, and 3500 people were reported missing after the disaster (Alli and Bhatt, 2013).

Agriculture which forms the backbone of both countries is also affected by frequent floods. Both the Kharif/summer and the rabi/winter crop that follows are regularly adversely impacted due to waterlogging. The huge accumulation of floodwater in low-lying areas impacts lives, livelihoods, and critical assets such as livestock, houses, and household belongings, increasing people's vulnerability and poverty (Alfthan et al., 2018). 60% of Bihar's GDP is from agriculture with nearly 80% of the population engaged in this sector and the annual flooding has a substantial adverse impact on this sector, affecting both the livelihoods and food security of dependent communities (Najmuddin et al., 2018).

Floodwaters typically inundate farmland with a thick layer of silt deposition, making the land unworkable, and preventing crops from being planted or harvested. This can lead to shortages of food both for human beings and animals (Awate, 2016). These create a wide range of problems, experienced at the individual, family, community, and societal levels. At every level, emergencies erode normally protective support systems, increase the risks of diverse problems, and tend to amplify the pre-existing social injustice and inequality. For example, natural disasters such as floods typically have a disproportionate impact on poor people, who may be living in relatively dangerous places (IASC, 2007). Similarly, emergencies caused by flood disasters also increase the risk of child abuse and trafficking and violence against women. Vulnerable groups, especially children, women, and in particular pregnant women and lactating mothers, face the brunt of the effects of poorly maintained and overcrowded temporary shelters in the displacement setting (IFRC, 2015). The pressure to manage day-to-day expenses, the education of children, rituals, and health in the face of these recurrent disasters, increasing poverty, and few available adaptive mechanisms sometimes leads to migration from the area, widely observed in these river basins. Flood and migration have a direct relation; the higher the flood, the higher is the outmigration rate (Belasen and Polachek, 2013).

There are secondary impacts as well. The floods damage or contaminate drinking water sources. They may also cause the loss of sewage disposal facilities. The lack of clean water, combined with human sewage in the floodwaters, heightens the risk of waterborne diseases such as diarrhoea, cholera, and typhoid. This adversely affects children, women, and other vulnerable groups the most (Moors et al., 2013). Adding to the already complex situation, the damage to the roads and transport infrastructure makes it difficult for the authorities and NGOs to distribute relief material and provide emergency health services.

3. Facets of transboundary collaboration for flood management

About 76% of the population of North Bihar lives under the threat of recurring floods, which affect around 73% of Bihar's total area (De et al., 2005). Most of the rivers flowing through Bihar originate in Nepal and China, and when heavy rains occur, the water flows into the major drainage systems of the Narayani, Bagmati, Gandak, and Koshi rivers, eventually inundating the plains of Bihar (Mishra, 1997). This situation, therefore, warrants an understanding of the systems of flood risk management in Bihar, in the context of increasing anthropogenic stressors, climate change, and adaptation.

The issues of transboundary floods and inundation in the region were identified several decades ago (Regmee, 2013). However, floods have increasingly been adversely impacting the socio-economics of marginalised communities in recent years. The issue of flood forecasting, including preparation and implementation of the Flood Forecasting Master Plan, was

raised at the 8th (2014), 9th (2015), 10th (2016), and 11th (2017) sittings of the India–Nepal Joint Committee on Inundation and Flood Management (JCIFM). However, this was not discussed during the 12th sitting of the JCIFM that took place in June 2018 and is a potential matter of concern.

Beyond floods management, India and Nepal can benefit immensely from transboundary cooperation on water resources potentially resolving the paradox of water as plenty and scarce in the region (Rasul et al., 2019). Thus the Cooperation over the management of water resources, included water-related disasters, has the potential to reduce the loss of lives and livelihoods in both countries. Better management of water resources can increase income levels of communities as well as improve their food security. Cooperation over water resources could also help in hydropower development resulting in a win-win situation for both countries. An increase in irrigation capacity will benefit millions engaged in agriculture). Improved agriculture will also improve the health situation and nutrition levels of communities here. As better resource management will increase livelihood opportunities, distress migration of poor people can be reduced. Increase in regional trade in the region in a cooperative atmosphere could boost trade and commerce between the two countries.

3.1. Bilateral treaties, data-sharing, and enhanced communication

The 1954 Koshi Treaty between Nepal and India was signed to primarily attenuate the routine, devastating floods in the river basin, primarily in Bihar and to some extent improve irrigation facilities (World Bank and Assessment, 2014). The 1959 Gandak Treaty, on the other hand, was primarily for irrigation and hydropower. These bilateral treaties have facilitated cooperation in constructing embankments and other related infrastructure in Nepal and India to control flooding both in Bihar, and that section of Nepal that borders with India (Shrestha et al., 2008).

Embankments have been constructed on the Koshi River to protect local communities from the adverse impacts of floods. The length of the embankments along the Koshi River in Nepal is 68 km and in India 3644 km. Through the JCIFM, India has invested billions of rupees in the construction of embankments and taken other structural measures on either side of the border to mitigate flooding problems. Notwithstanding this, floods have increasingly been adversely impacting the socio-economic condition of marginalised communities in recent years.

There are divergent views expressed by experts on the protection embankments provide. On the one hand, embankments are said to provide short-term and localised benefits in protecting agricultural lands, lives, and property that faces the chronic risk of flooding (World Bank and Assessment, 2014). Conversely, it has also been argued that embankments can accentuate the risks of flooding. The breaching in August 2008 of the eastern embankment of the Koshi River at Kusaha (around 12 km upstream of the Nepal–India border) and the subsequent impacts downstream highlighted these risks (Dixit, 2009; Devkota et al., 2018). The embankments are said to have caused a narrowing of the river, and a change in the river morphology, with increased sedimentation and aggradation, thereby increasing the risk of flooding and waterlogging (Devkota et al., 2018; Devkota et al., 2012). While some experts agree that it is important to move away from embankment-centric flood management (Mishra, 2008a; Dixit, 2009), several such infrastructure programmes are ongoing and planned by the Government of India.

Regarding information and data-sharing, the JCIFM conducts site visits almost every year and provides information about floods for water management projects at border sites. Effective cooperation can be achieved by sharing knowledge and fostering practises that address the transboundary scale of disasters. The Joint Committee on Water Resources between India and Nepal also set up the bilateral Committee on Flood Forecasting in October 2000 with the task of drawing up the Comprehensive Flood Forecasting Master Plan (CFFMP) for India and Nepal (MoEWRI, Minutes of First Meeting of the Nepal–India Joint Committee on Water Resources, 2000). In total, 23 meteorological and 19 hydrometric stations have been set up in Nepal and 18 hydrometric stations in India to facilitate an efficient flood forecasting and warning system for the India–Nepal border region. The information collected is communicated to provincial/basin offices of the Central Water Commission (CWC), located in Patna and Gorakhpur. This is routine communication as per the agreement, not necessarily for a flood. It provides information about a flood if the communication takes place at the time of a flood event in the river (Khatiwada et al., 2016).

However, the data communication process is lengthy and follows formal bilateral governmental procedures. The data is communicated from Kathmandu to the CWC office in New Delhi, then to the CWC's state office in Patna. It is then forwarded to the concerned district and finally reaches the local level. Consequently, there is a delay in action for community preparedness and response. Shrestha et al. (Shrestha et al., 2008) underlined the challenges in the communication processes as being complex, slow, and ineffective, as seen during the Koshi floods of 2008.

The predictive accuracy of early warning systems for floods in India and Nepal is improving as datasets expand and new modelling techniques are introduced. However, even as the trend continues in a positive direction, the accuracy—particularly for warnings with longer lead times—about unpredictable rivers remains a concern. There could thus be simpler data-sharing mechanisms between the two countries at the subnational level so that real-time data exchange is possible at the community level. Having joint bilateral committees at the subnational level (through bilateral treaties between the two countries) may enable faster data exchange.

3.2. Transboundary flood early warning systems

Flood policy frameworks in India and Nepal provide a glass-half-full or half-empty understanding, depending on an individual's viewpoint. The capacity of governments to meet well-intentioned policies is low on both sides of the border. Local officials have several responsibilities, of which disaster management (under which floods are categorised) is just one. Budgetary allocations continue to prioritise response over preparation, despite the known cost savings associated with the latter and regardless of policy frameworks. In both countries, there are claims that the extent of disaster response is politically determined, and the implementation and interpretation of the policy is generally more important than the policy itself. Finally, the policies generally discuss higher-level approaches, such as the need to develop early warning systems, and do not set out specific points on how this should be done.

One of the key challenges in developing cross-border flood warning systems is the fact that hydrological data regarding transboundary rivers is classified information in India. Furthermore, the environment for civil society actors varies significantly between the two countries. While local officials in Bihar may welcome assistance in disaster management, this is not necessarily reflected across different levels of government. While the various water-related national plans do talk of the need for regional cooperation, this is limited to cooperation in responding to disasters.

Efforts at forging formal government-level cooperation in sharing flood and early warning information have been going on for decades. Even as these efforts continue to evolve, community-level cooperation between border villages is emerging as an effective mechanism of collaboration (Molden et al., 2017). Regional cooperation and collaboration regarding flood risk reduction at the community level are effective. A good example of this is along the Ratu River, where low-cost, community-based flood early warning systems (CBFEWS) established in the Terai in Nepal and across the border in Bihar were effectively used during the August 2017 floods. They were instrumental in saving people's lives and protecting livelihoods (Shrestha, 2017). Communities saved substantial property as well because of these early warning systems (Molden et al., 2017). These CBFEWS mechanisms on the border between Nepal and India need to be upscaled to cover all vulnerable areas in the region.

Mobile phones in both India and Nepal provide a new means of last-mile connectivity in warning vulnerable communities, beyond traditional mediums of disaster communication, such as newspapers, television, and the radio. This was demonstrated during the floods of 2017. Targeted short message services (SMS) text messages were the primary means of disseminating early warnings to communities. However, this does raise a series of

challenges regarding the sustainability of the required critical infrastructure—notably power supply and mobile phone coverage—which can be vulnerable during a disaster. There is clear scope for greater shared learning between the groups and agencies working in the early warning space.

3.3. Implementation of international disaster risk reduction frameworks

Both India and Nepal have signed the (non-binding) Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR), which calls for strengthened regional cooperation towards disaster risk reduction (DRR). To "substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030" is one of the seven global targets of the SFDRR (UNISDR, 2015). The Asian Ministerial Conference on Disaster Risk Reduction in New Delhi in November 2016 also recognised multi-hazard early warning systems (EWS) for DRR as an area in which investment, collaboration, and global partnerships are needed (AMCDRR, 2016). Both countries have also agreed to the Asia Regional Plan for Implementation of the Sendai Framework which calls for "a common understanding and approach to tackling regional and trans-boundary issues" including "science-based trans-boundary risk assessments in the region, fostering data, information and knowledge exchange in the region" and promoting regional cooperation among "other non-intergovernmental and informal networks". It also calls for strengthened roles for regional organizations. The implementation of these global frameworks and agreements on regional early warning systems (though non-binding) is an important move towards strengthened transboundary cooperation on early flood warnings between Nepal and India.

3.4. Local participation in water management

It is often claimed that a flood catastrophe impacts all in its path indiscriminately. However, assessments of flood disasters in Bihar have shown that the vulnerability of the people depends on multiple factors such as age, gender, economic status, social strata, population density, race/ethnicity, the caste system and social discrimination, and culture (Dixit, 2003; Pandey et al., 2010). Since floods impact different sections of society differently (Nepal et al., 2014a), it is important to implement solutions that appropriate to these local differentiated contexts. The different sets of flood typologies further demonstrate, how one-size-fits-all flood management approach may not be effective. There is the need for a shift in water policies that would promote the participation of local communities in water resource management including flood management.

Acharya and Prakash (Acharya and Prakash, 2018) have documented the local knowledge about floods in the floodplains of the Gandak river basin in India. They report that local people have developed a highly evolved local knowledge system, which triangulates between their understanding and official flood forecasting systems. They have also highlighted how women have a fine-tuned understanding of various indicators of flood forecasting, which partially overlaps with, but are also distinct from indicators perceived by men. Local knowledge about disaster preparedness has been documented previously in the Eastern Terai to draw attention to include such traditional knowledge in disaster management plans and activities (Dekens, 2007).

Flood-prone villages of Nepal and India had very selective and flood-adaptive crop systems traditionally. Different varieties of paddy were used, depending on the inundation depths of the floodwater. Singra and Dumma Kheraha varieties were suitable for inundation up to 3–4 ft. Palia up to 5 ft, and Parwa Pankh and Harin Kher varieties needed 2–2.5 ft of water. The Nanhia variety needed only 1.5–2 ft of water. While the Kalam Kathi and Bakaul paddy varieties grew in waterlogged land, crops such as barley, horse gram, khesari, and flax were commonly grown during the monsoon season. Green gram and maize were grown before the rains.

Polices have been well framed for integrated water resource development in both countries. However, their implementation is not grounded to ensure that the objectives are met in a timely fashion. For example, the National Water Mission of India encounters varied challenges in the context of the country's rising population, changing expectations due to economic growth, and climate change-related impacts. The devolution of authority and decision-making from the federal to the state level in Nepal has led to an increase in local participation in water management. The greater flexibility of programming through state funding has, in recent years, led to more involvement at the local level through watershed councils. As a result, local actors are getting increasingly involved in water management and decision-making and is something which could be further enhanced in the Indian context.

4. Enhancing transboundary flood risk management

Flood risk management in the Koshi and Gandak basin has many challenges that stem from the biophysical conditions of the river systems such as annual monsoon, upstream-downstream linkages and high sediment carrying capacity. This is further complicated by the political and social dimensions, which include the transboundary impacts and the myths surrounding the flood management in these basins. The differentiated impact of the floods calls for associated adaptive measures informed by local practices. In these sections, we recommend three areas which could reduce the flood risks in the future through collaborative actions between India and Nepal.

4.1. Hydro-diplomacy beyond flood management

The benefits of transboundary cooperation are often determined by the political, geographic, economic, and cultural aspects of the river basin (Biswas, 2011). The benefits would be the better management of ecosystems, increased energy production, economic benefits, and increased cooperation among countries (Pandey et al., 2020).

The co-operation between India and Nepal especially concerning open borders and water-sharing described in the paper is critical given the current state of hydro-diplomacy between the two countries (Dahiya, 2012). As a report from IDSA mentions, 'Anti-Indianism' is a major factor and crutch for politicians in Nepal because India is such a huge part of the average Nepali person's life. Media and policymakers often point fingers at India for interfering in internal politics of Nepal and this practice has not reduced over time (Karki and Hari, 2020). This attitude of lawmakers in Nepal also casts a shadow on the sharing of water resources between the two countries as well. In Nepal, water is considered the most important resource and the perception of India 'exploiting' its resources is a pain point for the people of Nepal. This can be most aptly seen with hydro-electricity co-operation, which has become a major factor in the distrust between the two countries. A more recent example of this is the May 8th, 2020 announcement by India of the opening of the new road (80-km road in the Himalayas) at the border between China and India. Nepal government protested the announcement of the road immediately, claiming encroachment of their territory, to the surprise of Indian authorities (Xavier, 2020). It is cited by experts as an example of the miscommunication, lack of coordination, and mistrust that exists in the relationship between the two countries. In this context, the fraught ties between the countries can be overcome, considering the historical and current mistrust between governments on both sides (Shakya, 2020).

Both India and Nepal have multiple agreements/treaties for the water sector, some examples include the Sarada Agreement (1920), Kosi Agreement (1954), Gandak Agreement (1959) and Mahakali Treaty (1996). While the Nepal government is often blamed by its people in devising policies which are India-centric; India is often seen criticizing the Nepal government's political intervention in the water sector. Many experts see the water cooperation between India and Nepal as the consequence of hydro-hegemony rather than mutuality. Moving forward, both countries need to work towards trust-building to benefit mutually from the rich resources of its shared rivers. Below we present some way forward towards achieving this, with an emphasis that rethinking of the economic,

diplomatic and strategic ties between the two countries is paramount, considering that water is a resource of national importance for both Nepal and India.

In the Mahakali Basin, the Indo Nepal Joint Action Forum (INJAF) is working on transboundary issues such as water management. Through community-led dialogues, it has identified important areas of transboundary water cooperation, including irrigation, transboundary early warning systems, drinking water, sand mining management, and mahseer conservation (INJAF, 2018).

Currently, the transboundary collaboration in the Koshi and Gandak has a limited focus, one of harnessing benefits from flood protection and irrigation. However, the focus needs to shift towards maintaining the flow of ecosystem services in upstream areas, such that the benefits may be shared by people both upstream and downstream. Incentives for ecosystem services has been indicated previously by Nepal et al. (Nepal et al., 2014a) and Patterson et al. (Patterson et al., 2017). The improved management of ecosystems can help reduce erosion in the upstream regions, which will benefit upstream and downstream communities. Putting barren land, often prone to erosion, to productive uses may stimulate economic growth. The longevity and functionality of infrastructures such as hydropower plants, roads, and bridges in Nepal could also benefit from the reduced sediment load, and not just the bed stability across the border. Sediment management requires the identification of erosion hotspots in upstream regions, an appropriate land use management strategy to reduce erosion, regular monitoring of the sediment load, and integrated assessment at a transboundary scale. These measures necessitate cooperation at the transboundary scale as well (Sinha et al., 2018).

Recent studies have indicated the benefits of transboundary collaboration for integrated water resource management (Pandey et al., 2020). The nexus between water-energy-food can be more efficiently exploited through this collaboration (Rasul and Sharma, 2016). For example: in the Koshi Basin, using electricity production from hydropower to increase agricultural production while reducing flood damage control at the transboundary basin scale is estimated at over 2.4 billion USD annually with an investment cost of 0.7 billion USD. Increasing water reservoir capacity to support flood regulation and regional electricity trade would be some of the precursors for such benefits.

The integrated solutions to harness the underdeveloped water resources could generate multiple benefits both upstream and downstream (Rasul et al., 2019) in the region including enhanced regional connectivity from Nepal to the Indian Ocean. This can help in generating trade, employment, and reduce dependence on other means of transport. Its modalities can be worked out, and the political will generated through the rigorous influencing of policymakers on both sides of the border.

A revised treaty between the two countries which talks about people, river water, and its uses can provide benefits in terms of reduced flood damage and increased employment, through an increase in critical communication. In this context, regional cooperation between the two countries as a part of hydro-diplomacy could help in building confidence, and create an external environment that could facilitate national governments implementing policy actions on time. Further, joint monitoring visits and transboundary dialogue at all levels could help in creating the environment in which cooperation could be facilitated. Platforms for dialogues such as the Koshi Disaster Risk Reduction Knowledge hub could engage researcher and civil societies towards building the much-needed trust-building at the transboundary level through a bottom-up approach.

It is important to note that policy frameworks would be needed to be put in place to ensure that community-community information and knowledge sharing occurs to enable the bottom-up approach to flood management is achievable. Besides, the existing local bureaucratic machinery needs to be able to overcome national interest to ensure the working of the recommendations as mentioned above.

It is important to note that the Koshi river and the basin are divided between China, Nepal, and India. Of the total area covered by the river basin, around one-third lies in China. This is of particular relevance to India as both countries try to gain power in the region – aiming to become the next superpower in the region and make a global stand. The two countries have had a history of hostilities and waters in the Himalayas is one of the most contentious issues. The recent territorial disputes stress the hostilities between these two water neighbours (see https://www.bbc.com/news/world-asia-53062484) and calls for a more refined approach to dealing with potential water issues in the future. Chinese dam construction upstream on rivers such as Koshi can have disastrous results environmentally, especially in downstream reaches in Nepal and India. Many experts use the 'Sino-Indian' water dispute as a test of whether India and China can peacefully settle conflicts along the border (Holslag, 2011). Hence, although it is vital to bring the Chinese government and communities into the cooperative framework for flood management in downstream communities (Feng et al., 2019), it is also important to dwell upon the fact how the aggressive dam building on the Chinese side, affect flood management for both Nepal and India. This is important as upstream-downstream linkages can be more successful if along with Nepal and India, China is also involved in a bottom-up approach of flood management (Nepal et al., 2014b). This is easier said than done, and also requires the collaborative intervention from the Government of Nepal. Given the increasing skirmishes along the borders between China and India, the path to a joint dialogue and approach for water/flood management in the basin seems an uphill task.

4.2. Transboundary flood management and early warning systems

While the existing embankments have been built by India to protect villages, these measures are temporary and limited to short periods only. Moreover, they influence river courses and landform patterns, which potentially could result in the additional complexity of geomorphological and environmental hazards (Shrestha et al., 2008). These also point to the need to revisit the efforts of JCIFM more scientifically to achieve its long-term goals. Joint hydrological research at the basin level will be helpful in risk assessment and planning for the mitigation of hazards.

As the region is prone to floods, developing systems towards the mitigation of flood hazards and flood protection need to be the priority. Early warning systems will provide critical time for hazard mitigation; losses can be thus minimised. India and Nepal could design effective institutional mechanisms for the purpose. With the understanding that a majority of the floods in this region are transboundary, it is important to work on the transboundary Flood Early Warning System (FEWS) and Evacuation Plan (EP). Currently, the Department of Hydrology and Meteorology, Nepal (DHM) is implementing FEWS through a network comprising about 70 hydrological stations with telemetry across the country to provide real-time hydrological information. Besides, the DHM provides warning messages to the National Emergency Operation Center, which subsequently disseminates the warning information to all concerned entities. Likewise, services such as mass SMSs to local FM stations, DRR bodies, and communities are also provided for effective and timely preparedness. Besides, the preparation and implementation of a systematic EP linked with the FEWS could be one of the measures of transboundary cooperation soon (Xavier, 2020).

Community-to-community early warning systems are positive for their beneficiaries but run counter to government strategies, particularly in India, which are more focused on technology (such as mobile and SMS mechanisms) to provide warnings. Combining the government's top-down approach with the non-governmental organizations' (NGOs) bottom-up approach could be the way forward. Community-to-community systems self-evidently have greater community buy-in and investment than top-down models but are more labour intensive. There is clear scope to integrate lessons drawn from community-based projects—in particular about building effective, last-mile connectivity and response—into official national warning systems, targeting those most at risk. Furthermore, if contact details can be maintained, the concept of people upstream warning communities downstream of an impending flood, reinforcing official warnings, is a positive measure.

The authors would like to note here that it is critical to not consider the communities in India as a homogenous set of people. Overlooking caste dynamics in many parts of Bihar and the various implications of such caste

dynamics on management, access, and decision making with regards to water resources would be an error going forward. The literature discusses the pitfalls of looking at a resource community as a 'homogenous' and 'harmonious' community, especially in the context of common-pool resources. Caste-based coalition in some areas lead to people from lower caste being excluded from access to resources and benefits thereof. In addition, caste dynamics affect access to basic resources like water, sanitation, electricity, etc. Bihar is a state especially prone to such caste dynamics and therefore, viewing the communities as a homogenous set of people has implications for flood management decisions and disaster management as well.

It is important to note that multiple challenges arise from climate change at various scales and stages of community. Hence, it is important to enhance adaptive capacity and transform livelihoods through sustainable and locally applicable actions (Cramer et al., 2016). Nonetheless, financial support, local political and religious complexities could be a hindrance and need addressing from the very beginning. In this context, it is the need of the hour to understand caste dynamics and how this will have any impact on the community-to-community system of flood management. Jha and Gundimeda (Jha and Gundimeda, 2019) analyses the vulnerability of flood affected people in Bihar understanding their exposure, sensitivity, and adaptive capacities. The authors find that there is a strong social pattern to vulnerability which is related with caste and social deprivations of people. Caste is an important factors in Terai of Nepal and flood zones in Bihar (Acharya and Prakash, 2019; Pritchard and Thielemans, 2014) which needs attention while planning for flood management as they have strong implications on water resources based decisions, information flow and disaster management.

4.3. Integrating local knowledge in disaster management plans

Ultimately, the floodwaters impacts at the community, household and individual levels. National-level policies and transboundary collaboration can only support to create an enabling environment to improve flood management at the local level. The case studies captured by Acharya and Prakash (Acharya and Prakash, 2018) and Dekens (Dekens, 2007) illustrate the local knowledge and capabilities in the basins. The wealth of information at the local level must be leveraged to reduce the risk and vulnerabilities based on differentiated capabilities in the local government-led disaster management plans. There are at least two major benefits in doing so: first, it can reduce external dependency and boost the confidence for flood risk management (Dekens, 2007). Second, it can also respond to the different needs at the local level much faster, which may not be prioritized by higher-level governments. For example, flood alerts generated by national agencies, to be adapted to local languages and ensuring last-mile connectivity to vulnerable groups who may not have access to the information or incentivizing different preparedness measures for communities that live inside and outside the embankments.

Dekens (Dekens, 2007) outlines four steps to incorporate local knowledge in disaster management, where the fourth step to understanding the intricate linkage between disaster risk reduction and poverty reduction. The livelihood practices such as ponds and traditional water reservoirs also help in recharging groundwater repositories and also store excess floodwater. These methods were used in the past and are slowly disappearing but should be continued. Safe drinking water is one of the important requirements for the well-being of local communities and can be fulfilled using the river water after filtration. These measures have the potential to reduce dependence on groundwater.

The already available knowledge and good practices need to wide disseminate not only between communities, including across the political borders but also inform policies. Studies can be conducted to assess such practices, their benefits and the context for wider uptake of these practices. Both researcher and civil societies at the transboundary scale could advocate for creating enabling policy environment to support such practices. Nonetheless, it is important to ensure that the local knowledge from different caste, ethnicities, rural and urban parts of the basin are included in the disaster management plans. Local knowledge in urban and rural areas might be different or lost in some cases, and the best approach to integrating local knowledge in disaster management plans do occur in such instances can be very beneficial for the basin.

5. Conclusions: towards collaborative management of water

Floods are a recurrent problem in the Koshi and Gandak river basins and are directly associated with the now ever-so-erratic monsoon season, projected to become more unpredictable in the decades to come. The impacts of floods are also magnified due to the increase in anthropogenic stressors in the two basins. The myths surrounding the causal agents of floods between Nepal and India only worsen the situation and contribute to hampering ongoing and future adaptive actions. Floods cause social and economic losses, damage the agriculture sector, and contribute to male outmigration from the region. These adverse impacts are not country-specific and affect both Nepal and India. It is important to note that floods impact different sections of society differentially and require a thorough understanding of flood-related issues.

Floods will have even more adverse impacts such as the risk to life and property in the years to come, both because floods are likely to become more frequent, and also because population increases are likely to result in more people settling in areas vulnerable to flooding. An increase in floods is likely to increase the contamination of water sources and influence the prevalence of water-related diseases, whereas the insufficient water for purposes of hygiene during dry periods is likely to increase the risk of water-washed diseases.

Nonetheless, it is also important to note that floods also bring prosperity to dependent communities by providing livelihood options such as fisheries, layering fertile sediments for better yields, and catalyzing the growth of water-tolerant cash crops. The better management of water resources can resolve the paradox of 'too much water, too little water' here. India and Nepal can together benefit from critical ecosystem resources through transboundary cooperation.

Whatever the cause of its origin, while local stakeholders struggle to address preparedness and reduction of the impacts of floods, transboundary collaboration could be the key to address some of the threats of this almost annual event. Given the historical perspective of floods, and the ongoing work in dealing with its impacts, more targeted strategies between water neighbours could provide the much-needed relief from his economically back-breaking episode.

With the large pool of climate change knowledge and solutions for the region, it is critical to generate transboundary opportunities for establishing a secure and resilient Gandak and Koshi river basins. It is important to chalk out vital scientific knowledge and solutions on risk assessment and enhancement of policies. The time is right for the water neighbours to come together, share, discuss, and devise resilient strategies not only best suited to themselves but also the overall basins. It is important to view the basins as single entities, where collaborative and cooperative actions within it will provide the tools to deal with the adverse impacts of floods and move ahead towards sustainable development throughout the region. It is also worthwhile to note that any strategy for the basins needs to consider the available local knowledge and how best they can supplement the existing and proposed actions to build resilient basins. Early warning systems too can play important roles in securing the lives and livelihoods of dependent communities and needs to be co-developed further in consultation with local authorities. These tools can strengthen trust-building between the two countries, and work towards addressing common challenges and common opportunities.

The existing water policies of both countries are well within the domain of providing multiple benefits to dependent communities if applied at the grassroots level. There is the need for a shift in water policies that would promote the participation of local communities in the governance mechanism, regarding better water resource management and control measures. The better management of water will also assist in ensuring the sustainability of any conservation plans in the basins. It is important to note that both Nepal and India are signatories of the Sendai Framework for Disaster Risk

Reduction. Transboundary flood cooperation could go a long way in strengthening disaster risk reduction for both the countries and work towards fulfilling their respective international commitments.

Given the projected changes in precipitation, it is likely that there are going to be serious costs for communities and sectors reliant on the basin. For example, projected changes in the availability of water (either it being in excess, or shortages) is likely to negatively affect farmers' livelihoods, the lives of human beings and livestock, and impact the well-being of mountain and downstream communities. Because of the above, there is an urgent need for actions to assist communities and dependent sectors to adapt. Efficient, cooperative management, and the development of shared waters and adjacent floodplains, can boost food and energy production, help reduce poverty, and control rural-to-urban migration.

Going ahead, transboundary water management through the application of sustainable solutions has the potential to generate numerous benefits: more international trade, promote climate change adaptation and resilience, increase economic growth, promote food security, and improve governance and regional integration. How transboundary waters are managed also affects sustainable development within and beyond a country's borders. Therefore, the various heavily water-dependent sectors—agriculture, industry, energy, navigation, and water supply and sanitation—need to cooperate on a supranational level to work towards creating a resilient region. Transboundary cooperation facilitation through a specific knowledge network, coordinated approach for capacity building, joint adaptation project formulation and implementation, high-level coordination mechanism, and the creation of an adaptation portal could be the way forward. It is also important to stress that both top-down and bottom-up approaches will be required to bring about substantial benefits for dependent sectors and communities, given the current regional tensions between the three water neighbours. Trust-building between neighbours at all levels of governance, and identifying similar challenges and strategies which bring about basin-scale, and not just national-level positive impacts could be the way forward.

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None.

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