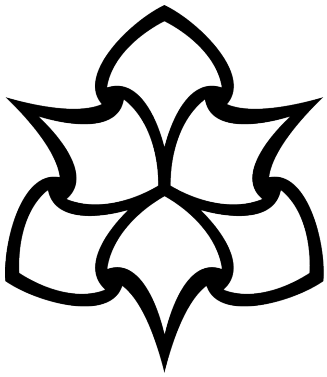

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REVIEW ARTICLE

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Understanding the socio-economic impacts of climate change on riparian communities in Bangladesh

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Abstract

Riparian communities in developing countries such as Bangladesh, whose livelihoods depend especially on fisheries and other subsistence activities, are under considerable pressure due to climate change. Therefore, there is a need to better understand how the dynamics of riparian communities are influenced by climate change and how its impacts can be assessed. Using Bangladesh as an example, this paper describes the various climate stressors affecting riparian communities and their socio-economic impacts, and it outlines some measures needed to increase their resilience to a changing climate. The results show that riparian communities are not only quite vulnerable to the impacts of climate change but also have a rather low level of resilience. This challenge can, at least in part, be attributed to their fragile living conditions, which intensify the socio-economic impacts of extreme events. One lesson from the paper is that handling climate-induced risks in riparian communities requires implementing strategic measures to improve local climate and livelihood resilience, such as effective public health infrastructure and a resilient built environment. Win-win scenarios comprise strategies that offer multiple benefits including better water storage, flood control, and improved riparian habitats.

KEYWORDS
adaptation, Bangladesh, climate change, communities, riparian communities

1 | INTRODUCTION

With more than 230 rivers, tributaries, canals, and waterways, deltaic riverine Bangladesh is considered to be the most vulnerable to climate change due to its disaster-prone geographical location, socio-environmental conditions, population escalation, high poverty, and low economic and technological potential (Shakhawat et al., 2020). The nation experiences a multitude of natural disasters every year, causing major losses of property and lives (e.g., Dastagir, 2015). Because of this recurring situation, Bangladesh's economic potential is expected to be severely affected, resulting in a vicious circle of poverty as well as potential future migration (Alam, Alam, & Mushtaq, 2017; Rigaud, de Sherbinin, Jones, et al., 2018). Coastal and riparian (i.e., riverbank and bar, locally known as char) households of Bangladesh are the most susceptible to the impact of climate-driven hazards such as floods, including riverbank erosion (Alam, 2016; Alam, 2017; GoB., 2010), due to sediment loading from stormwater runoff. Besides such rapid onset events, coastal and riverine communities are also facing slow onset climate hazards such as saltwater intrusion or drought that may influence migration decisions (Mallick, Rogers, & Sultana, 2022; Rahman, Islam, Khan, & Touhiduzzaman, 2019). While riparian communities share products and services from their river systems, any changes in this ecosystem adversely affect the communities (Dempsey et al., 2017; Guerra, Lizárraga-Mendiola, & Návar, 2016). Finally, because of their poor socio-economic conditions, riparian communities are particularly exposed and vulnerable to flood risk and other natural hazards such as cyclones (Alam, Alam, Mushtaq, Sarker, & Hossain, 2020; Naz, Doneys, & Saqib, 2018).

Compared to other countries prone to riverine floods, Bangladesh accounts for one of the largest populations and the highest percentage of the country's GDP (Gross Domestic Product) exposed to floods (Luo, Maddocks, Iceland, Ward, & Winsemius, 2015). It is also projected that the country could experience one of the highest increases in displacement risk from floods by the end of the century (Kam et al., 2021). Given the gravity of these challenges, this paper describes various climate stressors affecting the country's riparian communities and their socio-economic impacts. It also outlines some strategies to increase their resilience to a changing climate. The novelty of the work resides on the fact that it explores the connections between socio-economic aspects and the dynamics of riparian communities under changing climate conditions, with a focus on Bangladesh.

As such, this paper is unique in the sense that it explores the subject matter of climate change impacts on riparian communities in Bangladesh, with a focus on the socio-economic elements. It builds, for instance, on the work performed by Brammer (2016) which analysed the relations between floods, cyclones and climate change and how they impact riparian communities in Bangladesh, and a work undertaken by Islam and Nursey-Bray (2017) which investigated the role of formal institutions. The paper also followed up on a study performed by Alam, Alam, Mushtaq, and Clarke (2017) which analysed the vulnerability to climatic change in riparian char and river-bank households in Bangladesh, and a further work by Alam, Alam, Mushtaq, and Leal Filho (2018) where an assessment of how climate change and associated hazards impact the resilience of riparian rural communities in Bangladesh was undertaken. In addition, this paper provides useful background information on socio-economic aspects, which complement the understanding of hydrological ones such as those looked at in a study undertaken by Rahman, Thompson, and Flower (2020). A further element of innovation of this study is related to the fact that it also touches upon human influences on habitats, hence furthering a work undertaken by Islam et al. (2021) which looked at climate change and anthropogenic interferences for morphological changes in the Padma River in Bangladesh.

2 | BACKGROUND

Every year, about one-third to half of Bangladesh is affected by climatic events that have killed hundreds of people, injured thousands, damaged buildings, infrastructure, vast hectares of crops and agricultural land, and livelihoods (World Food Program, 2020). For example, during the pre-monsoon months of April and May, the north-eastern and western hilly regions experience flash floods that usually occur after heavy rainfall, which extensively damages crops and property (Chowdhury et al., 2021; Hossain et al., 2019; Hossain et al., 2019). Moreover, the sixth Assessment Report from the IPCC suggests that, as global warming continues, the frequency of extreme events in continents such as Asia is likely to increase (IPCC, 2021).

Resource-poor households are vulnerable to the effects of regular flooding and waterlogging because of their proximity to the river (Alam et al., 2018). Studies suggest that people in riparian areas of Bangladesh are suffering from floods on an increasing basis, and with the progressing climate change, flooding frequency is expected to increase (Agrawala, Ota, Ahmed, Smith, & Aalst, 2003; IPCC, 2001; Mclean & Moore, 2005). Approximately 34% of the land area remains underwater every year for about 5 to 7 months (Islam, 2004; MoEF, 2005). The most recent flooding events from 2020 may indicate a changing pattern towards more severe and frequent river flooding events along the Brahmaputra River and low-lying areas of Northern Bangladesh, due to heavy monsoon rain and water from upstream sources. At an earlier start of the monsoon season, longer duration and higher water levels have been observed in certain parts of the country (UNCT Bangladesh, 2021).

In terms of economic losses, riverbank erosion - a common and serious issue – is considered the most damaging impact (Alam, Alam,

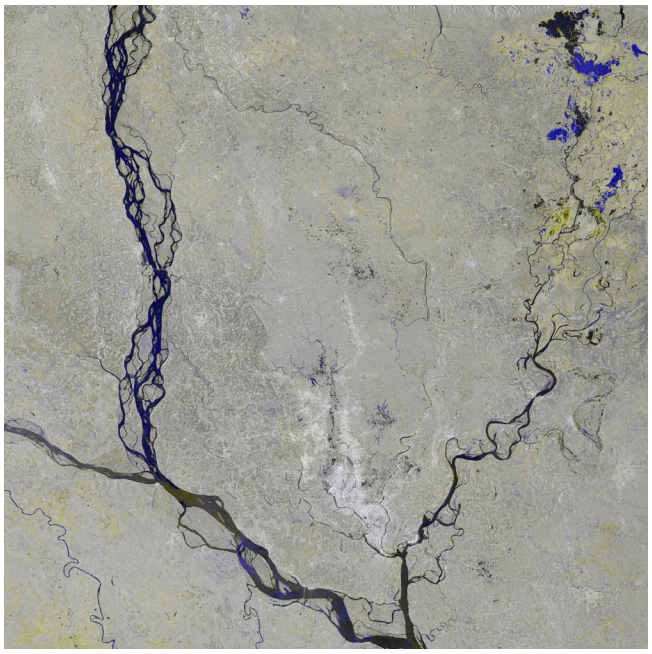

FIGURE 1 Overview of Bangladesh in a pre-floods period, May 4, 2022. *Source*: Contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO [Color figure can be viewed at wileyonlinelibrary.com]

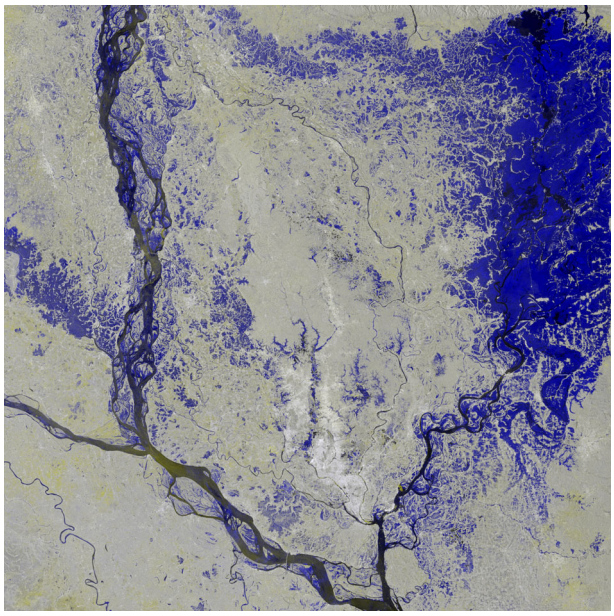

FIGURE 2 Overview of flooded areas in Bangladesh, June 21, 2022. Contains modified Copernicus Sentinel data (2022), processed by ESA, CC BY-SA 3.0 IGO [Color figure can be viewed at wileyonlinelibrary.com]

Shahbaz, & Clarke, 2017; Makenro, 2000; Penning-Rowsell, Sultana, & Thompson, 2013). 20 out of the 64 districts of the country are considered vulnerable to riverbank erosion (Alam, 2016; CEGIS, 2012). Riverbank erosion (Figure 1) remains the key problem for floodplain residents in the region, despite government attempts to minimise it, primarily through erosion protection systems along the bank (Alam, 2016; GoB., 2010). Approximately 8,700 ha of the homestead and agricultural land are lost annually due to the erosion of the riverbank, displacing approximately 200,000 citizens (Alam, 2016, 2017; CEGIS., 2012; GoB., 2010). Empirical findings show that riverbank erosion has a devastating effect on the lives and livelihoods of riparian communities in Bangladesh (Alam, 2016; Alam, 2017; Alam, Alam, & Mushtaq, 2017; Hutton & Haque, 2003; Lein, 2010; Penning-Rowsell et al., 2013). Char dwellers lose large quantities of productive land every year because of persistent riverbank erosion (Alam, Alam, Shahbaz, & Clarke, 2017).

As a consequence, migration from north-western rural Bangladesh has been driven by these slow-onset natural dangers (Kabir, Serrao-Neumann, Davey, & Hoaason, 2018; Rahman, Rahman, Khan, & Renzaho, 2018). The riparian rural households, the most risk-prone, are unable to cope with the effects of climate change and associated environmental risks due to a lack of adaptation options and poor socio-economic conditions (Alam et al., 2018). Social inequality and food insecurity induced people to migrate and seek employment elsewhere (Alam, 2016; Alam et al., 2020; Penning-Rowsell et al., 2013); those families who lost their entire assets due to environmental hazards became permanent migrants (Ahmed, 2009; Gardner, 2009; Kartiki, 2011). Akter (2009) revealed that an average of 25%, 3%, and 2% of people in Bangladesh were displaced a decade ago because of floods, riverbank erosion, droughts, and cyclones, respectively. With more than 4.4 million disaster-related, mostly pre-emptive evacuations, Bangladesh was among the countries recording the largest number of displacements (IDMC, 2021). Supporting public information and disaster preparedness since 2014, the Bangladesh Water Development Board's Flood Forecasting and Warning Centre provides open access flood inundation maps and forecasts depicting vulnerable areas for example, according to rivers, divisions, or districts. Variations in the volumes of rivers before and during flooding are seen in Figures 1 and 2.

Even though land losses shape the main cause of rural–urban migration, this movement to cities is also a recognised response strategy to cope with climate change impacts (Alam, 2016). Attributed to climate change, riparian communities are also expected to experience increases in mean annual temperatures, resulting in a likely reduction in crop productivity (Alam, 2016; Niang et al., 2014). However, critical information on the degree of their livelihood vulnerability remains scarce.

This communication departs from similar previous studies. It underscores the need to understand better how the dynamics of riparian communities are influenced by climate change and assess its impacts, using Bangladesh as an example. The paper is a welcome addition to the literature since it describes the extent to which climate change related hazards impact riparian communities in Bangladesh and describes some measures that may be deployed to reduce their vulnerability and increase their resilience.

3 | METHODS

The methodological approach utilized in the present study comprised a literature review of recent scientific evidence, which allowed categorizing key socio-economic and physical impacts of climate change in riparian areas and identifying measures that may improve the resilience of affected local communities. The insights of the authors who are experts in the field also fed into the analysis. The study utilized Google Scholar, Ref Works, Science Direct, Scopus, and Web of Science databases as comprehensive scientific databases with a wide coverage of academic research to search and retrieve relevant literature. The search used terms such as climate change, Riparian communities, flood control, storm surges, socio-economic impacts, resilience, adaptation and mitigation, agriculture and livelihoods, green infrastructure, habitat protection. Academic literature such as articles, book chapters, and conference proceedings were collected. Grey literature such as website and newspaper contents and official government sources were accessed to reflect recent riverbank erosion and affected by flooding in the case of Bangladesh. The inclusion criteria are that the document is (a) relevant to the study objective (b) published within the last 10 years, and (c) the full text is available. The exclusion criteria refers to the geographical focus, Examples from other regions/countries other than Bangladesh were excluded.

The literature (52) meeting the above criteria were downloaded and analysed, using a thematic content analysis approach that involved a three-step iterative process (Abubakar & Aina, 2019). First, the gathered documents were organized based on two categories: (a) physical, social and economic impacts of climate change; and (b) measures that can improve the resilience of the riparian communities, although some documents fall into both categories. Second, themes related to each or both categories were developed from each document to corroborate each emerging theme or discover a new one until all the documents were exhausted. Finally, the discovered themes from each document were synthesized, harmonized, and summarized in the next section.

4 | RESULTS AND DISCUSSION: THE PHYSICAL AND SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE IN RIPARIAN AREAS

Local communities directly benefit from the advantages of living close to rivers. These entail the provision of food (fishery and agriculture) for both, subsistence and income generation, leisure, and affordable housing (Panezai et al., 2022; Rabbani, Cotton, & Friend, 2022). On the other hand, they are also generally more prone to the impacts of frequent floods, waterlogging, and saltwater intrusion, which also increases their vulnerability (Haque & Reza, 2017; Mondal, Murayama, & Nishikizawa, 2020). About 8,700 ha of homestead and farming land are lost to riverbank erosion every year, which causes the displacement of approximately 200,000 people and contributes to increasing their food insecurity and worsening poverty (Alam, 2016). The problems and related uncertainties are among the reasons why people migrate, both temporarily and permanently. Some of the key impacts of climate change on riparian areas are summarised in Table 1. These indicators are important since they provide an overview of the physical (e.g., climatic and hydrologicals components), social (e.g., aspects related to livelihoods) and economic (e.g., aspects related to poverty and limited opportunities for income generation) contexts of the studied area. This is necessary since these elements are usually considered on an isolated manner.

As can be seen in Table 1, the socio-economic impacts vary both in nature, and scope, but their implications are wide-ranging and, in consequence, weaken the resilience of riparian communities. There are also occasions when a cascading effect takes place (e.g., low access to finances leading to migration), which may deepen inequalities and exacerbate poverty among the members of these communities. Such cascading impacts which can constrain adaptation efforts resemble the consequence of interdependencies between systems and sub-systems of coupled natural and socio-economic systems (Lawrence, Blackett, & Cradock-Henry, 2020). An understanding of these elements and the trade-offs among them is an important element in pursuing climate change resilience (Leal Filho, 2021). Masud et al. (2017) and Alam (2016) have listed a wide range of elements that exemplify the vulnerability of riverine communities to climate change. These are summarized in Figure 3.

Climate change significantly threatens the ecosystem and livelihoods (Hossain, Ludwig, & Leemans, 2018). From 2009–2014, the estimated economic losses associated with climate change were USD833.73, 137.46, and USD133.92 m from crops, livestock, and fisheries, respectively (Biswas et al., 2019). By 2030, climate change impacts could reduce agricultural land efficiency and decrease crop yield by 13.0% for wheat and 5.0% for rice (Bandara & Cai, 2014). By 2050, land productivity decline is expected to result in a decrease in 8% in rice and 32% in wheat production, in a country where the agriculture sector employs about 40% of the country's workforce and provides raw materials to industries (World Bank, 2013).

A one-meter sea-level rise can inundate about 17% of biodiversity and agricultural land, forest, and aquatic resources, thereby affecting the livelihoods of at least 35 million people, especially those in coastal districts (Hasan et al., 2020). For example, a 32 cm rise in sea level could lead to a 25–28% decline in rice production. Similarly, sea-level rise, low flow river condition, and landslide contribute significantly to saltwater intrusion in the river and underground water. According to the UK Department for Environment Food and Rural Affairs (2007), high salinity affects about 6.0 million people in 2005, which is anticipated to rise to 13.6 million and 14,8 million people by 2050 and 2080, respectively. In coastal and offshore areas, varying degrees of soil salinity affect about 1.2 million hectares (42%) out of 2.85 million hectares of agricultural land (World Bank, 2013). In addition, floods and salinity intrusion causes habitat change, impoverish local farmers, destroy livelihoods, force people to migrate, change or diversify their occupation (Kabir et al., 2018). Mitigating these socio-economic impacts of climate change requires strategic measures to

TABLE 1 Some of the key socio-economic impacts of climate change in riparian areas

Dimension	Indicators	Main effects	Sources
Physical	Storms and cyclones	Instability of riverbanks and worsening of riverbank erosion	Alam et al. (2020)
	Floods	Recurrent flood damages of riparian households several times per year	Alam, Alam, and Mushtaq (2017)
	Storm surges	Saltwater intrusion renders the soil not suitable for cultivation, also damaging high-yielding crops	Sarker, Wu, Alam, and Shouse (2020a)
Social	Education	Due to frequent flooding, educational institutions cannot work smoothly, affecting the whole school system in riparian areas	Islam, Sallu, Hubacek, and Paavola (2014)
	Government Supports/extension services	Government support and services are often interrupted in connection with extreme events	Sarker, Wu, Alam, and Shouse (2020b),Alam et al. (2018)
	Social cohesion	Social networks are weak due to people living in remote places and to poor communication	Sarker et al. (2020b), Bhuiyan, Islam, and Azam (2017), Islam (2018)
Economic	Household income	Riparian households face hardships each year due to a lack of income-generating activities and unemployment	Alam et al. (2018), Sarker et al. (2020b)
	Crop failures	Due to flooding and riverbank erosion, riparian households are facing crop failures every season	Karim and Thiel (2017), Sarker et al. (2020a)
	Low access to finances	Riparian households have very low access to financing for investments	Alam (2017)
	Limited access to health facilities	Riparian households have very limited access to health facilities	Alam et al. (2018), Alam (2017)
	Migration	Due to the frequent riverbank erosion, riparian households are forced to migrate to the mainland or nearby cities	Alam et al. (2020), Islam (2018)

Source: Compiled by Authors.

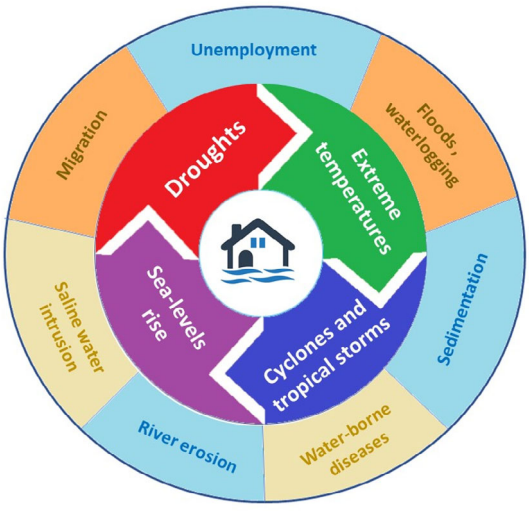

FIGURE 3 Some examples of vulnerabilities in riverine communities in Bangladesh. *Source*: Authors [Color figure can be viewed at wileyonlinelibrary.com]

increase the resilience of riparian communication. Some of the strategic measures which may support increasing the resilience of local communities to a changing climate include:

a. changed production practices to accommodate phenomena such as saltwater intrusion which may have a detrimental impact on some types of crops (see, for example, Hossain et al., 2018);
b. a diversification of economic activities such as fishing, tourism, or production of handicrafts and paid employment, to assist local communities in securing a regular income (see, for example, Chowdhury et al., 2021);
c. increased physical coastal and riverine protection (see, for example, Sultana & Luetz, 2022);
d. adjustable biodiversity restoration efforts to help to upkeep the ecosystems and the services they offer (see, for example, Chausson, Turner, Seddon, et al., 2020); and
e. improved access to health facilities and health services such as doctors and nurses - including immunisation and treatment of vector-borne diseases - in hazard-prone areas and riverbank communities, to foster the resilience of these vulnerable groups (see, for example, Alam et al., 2018).

Many other measures could be added, also those related to technological solutions, but their deployment is often limited to the high costs associated with some of them.

There is evidence that these strategies work. Mambet Doue et al. (2020), for example, documented the fact that several communities,

both riparian and coastal, have successfully adopted strategies to cope with a changing climate, which have helped to safeguard their livelihood and to increase their resilience.

In the agricultural sector, some specific resilience-boosting measures include changing cropping schedules, crop rotation, cultivating short-duration and stress-tolerant varieties, and livestock rearing (Ahmed, Guha, Shew, & Alam, 2021; Alam et al., 2018). Other measures include promoting solar home systems, solar irrigation pumps, and energy-efficient equipment for garments industries, and cleaner brick kilns (Chowdhury et al., 2021). In many cases, these measures have been implemented with aid from international donors, but they are as not widely spread as they should be.

One further measure which may assist in increasing the resilience of riverine communities is related to internal migration. Bearing in mind that men living in riverine communities in Bangladesh seasonally migrate to urban areas for work in the informal sector, measures such as microloans, which may contribute to the financial capital and resilience of households (Alam et al., 2020; Sultana, Thompson, & Wesselink, 2020) should be considered. To prevent social conflicts, appropriate policies that can help streamline the influx of workers from riverine to urban areas are needed. For example, special web portals or offices that enable workers' registration, search for jobs, wage protection, work safety, etc., may assist in systematising the movements of seasonal workers.

Finally, measures against erosion and related loss of land can promote economic opportunities and resource diversification for the poor, to eventually break the vicious cycle of poverty and continued low livelihood status (Alam, 2017). This cycle, defined by Alam (2016) and Leal Filho et al. (2021) as a "poverty trap".

5 | CONCLUSIONS

This paper has provided an overview of the various climate stressors affecting riparian communities in Bangladesh and their socio-economic impacts. The results show that riparian communities are not only quite vulnerable to the impacts of climate change but also have a rather low level of resilience.

It is acknowledged that resilient communities recover their basic components and functions after experiencing climate change impacts and risks (Abubakar & Aina, 2019) since they tend to implement the lessons learned and address some of their vulnerability. Significant pointers to local climate resilience include the capability to deploy long-term planning initiatives, governance processes, and efficient systems to persevere during hazards and successfully recover afterward (Alam et al., 2018; Hasan et al., 2020).

As this paper has shown, climate-induced risks common to riparian communities such as floods and other extreme hydrological events may lead to an influx of water-borne diseases, for which health and medical facilities need to respond. Also, cyclones, sea-level rise, extreme temperatures, drought, erratic rainfall patterns, and salinity intrusion affect homes, schools, infrastructure, agriculture, biodiversity, and livelihoods (Chowdhury et al., 2021) in a way that endanger socio-economic development. Apart from assistance to address materials losses, support for psychosocial impacts- such as loss of family members-, can assist victims in recovering from such extreme climate events.

This paper has two limitations. Firstly, it is based on a review of the available peer-reviewed literature in English and did not include grey literature in the local languages. Secondly, constraints associated with the COVID-19 pandemic prevented the collection of first-hand data from local inhabitants. Despite these constraints, the paper provides a contribution to the literature in the sense that it provides additional insights into the vulnerability of riparian contributions in Bangladesh, providing a basis for the design of appropriate means to address them, a matter which this paper now attempts to address. It also fills a gap on publications which examine the various components associated with climate change in riparian settings, and a gap on research on socio-economic aspects of climate change as it relates to the resilience of these communities.

An additional insight from the study is related to the fact that it sheds some light on the fact that, despite their degree of vulnerability, riparian communities can deploy some strategies which may increase their resilience such as, for instance, the diversification of income-generating activities.

The fostering of an improved understanding of how different socio-economic components interact is necessary in order to address the various challenges experienced by riparian communities associated with the management of nature-based solutions and ecosystem services. As to the future, win-win scenarios for degraded riparian zones comprise adjustable restoration measures: channel and floodplain reconfiguration, improved water management, and afforestation (Perry, Reynolds, Beechie, Collins, & Shafrth, 2015). Also, effective restoration efforts are needed, which consider site-specific contexts, and use spatial data to guide their implementation (Stutter, Baggaley, Ó hUallacháin, & Wang, 2021). Together, these strategies may support efforts to understand and manage current and projected sources of degradation and offer multiple benefits such as better water storage, flood control, and improved riparian habitats, whose conservation is vital to the millions of people who directly or indirectly depend on them for their livelihoods.

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DATA AVAILABILITY STATEMENT

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