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Mainstreaming disaster risk reduction (DRR) into development: effectiveness of DRR investment in Khyber Pakhtunkhwa, Pakistan

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As a low-income country, Pakistan is particularly vulnerable to various natural and human-induced disasters, which have significant consequences for both the environment and human life. A substantial share of the provincial budget is allocated to disaster response and recovery efforts. Prioritizing investment in disaster risk reduction (DRR) is essential to protect lives and assets. Although there is a complex relationship between investments made before and after disasters and their effectiveness in DRR, this dynamic remains insufficiently understood in Pakistan's Khyber Pakhtunkhwa (KP) province. The current study was designed to analyze the developmental budgeting for DRR in the financial years 2000–2022 in KP province. The Sen's Slope Estimator and modified Mann-Kendall tests were used to determine the significance trend, while the correlation coefficient test was used to find the correlation between investment in DRR and disaster-induced damages such as deaths, injuries and houses damaged. The study findings reveal that the occurrence of disasters influences post-disaster spending in the KP province, with a significant negative correlation between expenditure and disaster-related damages, implying that increased DRR investment has significantly reduced the consequences of disasters. To minimize vulnerability to future disasters, the province should integrate risk-sensitive planning across all sectoral departments at local, district, and provincial levels, guided by a risk-informed development approach. This proactive strategy would embed disaster resilience within developmental activities, ensuring that each sector aligns with principles of risk reduction and sustainable growth.

KEYWORDS

disaster risk reduction, disaster risk financing, disaster risk governance, Khyber Pakhtunkhwa (KP), Pakistan

1 Introduction

Financing disaster risk reduction (DRR) is essential to addressing the growing threats of disaster risk and vulnerabilities (Ishiwatari, 2022). With disasters becoming more frequent and severe, the need for DRR financing has significantly grown (Tin et al., 2024; Wen et al., 2023). The importance of sustainable DRR financing is critical for building resilience in developing regions with limited resources to manage climate change and disaster-related risks (Alam and Ray-Bennett, 2021; Hussain et al., 2023). For example, disasters trend in South Asia, particularly in Pakistan, India, and Bangladesh, reflects a complex pattern during 2000–2022. The frequency and intensity of climate-related disasters, such as floods (Lan et al., 2022; Ullah and Zhang, 2020), cyclones (Alam, 2024), and heatwaves (Behera, 2024; Ullah et al., 2023b) have shown a noticeable increase. Although the deaths from disasters have generally decreased over time, especially in the last decade, injuries, infrastructural damages, and economic losses due to disasters have increased (EMDAT, 2023). A decrease in disaster-related deaths may be attributed to a better early warning system (EWS) (Deng et al., 2024) and evacuation planning. In contrast, an increase in injuries, infrastructural damages, and economic losses may be due to increased disaster frequency, higher exposure, and less investment in long-term DRR.

Disaster management is not a new subject (Quarantelli, 2000); however, the concept and approaches to disaster management evolved, and today it is a multidimensional and multi-stakeholder process (Panneer et al., 2021). All stakeholders contribute actively to disaster management efforts. Effective disaster risk governance, as a complex and multi-sectoral field, demands adopting multi-stakeholder engagement (Heltberg, 2008; Pal and Shaw, 2018), with local governance as a key stakeholder (Alam and Ray-Bennett, 2021). In developing countries especially, community-based disaster risk management (CBDRM), strong local governance, and institutionally-led strategies play vital roles in reducing disaster risk and enhancing resilience across communities. For example, in Bangladesh, developmental initiatives that enhance institutional response and empower communities' engagement through EWS and the construction of cyclone shelters have reduced facilities from cyclones in recent decades despite their increased frequency (Alam et al., 2024). Strengthening multiple sectors with the engagement of various stakeholders guarantees resilience against disasters (Izumi and Shaw, 2014; Kapucu, 2020; Olu et al., 2016). The adoption of a multi-stakeholder approach has been extensively debated across national and international forums, with numerous studies identifying optimal strategies for effective legislation, institutionalization, and implementation of DRR measures. These discussions focus on developing collaborative frameworks that bring together multiple stakeholder such as government agencies, private sectors, NGOs, and local communities to enhance disaster preparedness and resilience. Various research emphasizes that engaging multiple stakeholders in DRR not only strengthens legislative frameworks but also supports the integration of indigenous knowledge and resources into broader, institutionally supported initiatives, ensuring a more holistic and sustainable approach to disaster management (Ahmed, 2013; Rahman, 2015; Benson et al., 2007b; Burghila et al., 2015; Cannon et al., 2003; Heltberg, 2008; Mojtahedi and Oo, 2017; Pelling and Holloway, 2006; Shah et al., 2019; van der Veen and Gebrehiwot, 2011; Yodmani, 2001). On the international platform, various initiatives, like the Yokohama Strategy and Plan of Action for A Safer World (YSPA), the Hyogo Framework for Action (HFA) 2005–2015, the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030, and various reports of the Intergovernmental Panel for Climate Change (IPCC) have been taken to guide institutional resilience and disaster risk governance. The implementation of these initiatives has significantly reduced disaster mortality but the cost of disasters has not yet been reduced (Figure 1).

The term "mainstreaming DRR into development" gained recognition in the late 20th century and accelerated over the first decade of the 21st century. It integrates natural hazard risks into strategic planning, sectoral policies, and investment decisions to build resilience and reduce vulnerability (Benson et al., 2007a). Mainstreaming DRR into development means looking at how disasters could affect the outcomes of policies, programs, and projects and how these effects could be avoided through careful planning in a pre-disaster environment. Some of the major components of mainstreaming DRR to development include familiarization with the terminologies and concepts (Tiepolo and Braccio, 2020); collecting and using information about prevalent disasters (Benson et al., 2007b); environmental assessments (Amaratunga et al., 2017); economic analysis and budget support (Ishiwatari and Sasaki, 2020; Mikio and Daisuke, 2021); clearly defined roles and responsibilities of the organizations (Shah et al., 2019); logical and result-based DRR frameworks (Tiepolo and Braccio, 2020); sustainable livelihood approaches (Gyawali et al., 2020); social impact assessment (Aleksandrova, 2020); building codes (Chmutina and Bosher, 2015; Iglesias et al., 2009); scientific approach to risk management (Wilderspin et al., 2008), and evaluation of DRR initiatives (Khan et al., 2022). The institutionalization of risk management in policymaking is a tool for mainstreaming DRR into development.

It is evident that natural disasters and a nation's socioeconomic condition are strongly correlated (Fothergill and Peek, 2004; Griffith-Jones and Tanner, 2016; Ramachandran et al., 2010; Schumacher and Strobl, 2011). A country's socioeconomic status is closely linked to its vulnerability to natural disasters; poor nations often face greater impacts due to limited resources for disaster preparedness and recovery (Raviola et al., 2020). The 2010 Haitian earthquake (Cho, 2014) and the 2011 Japanese earthquake (Silbert and Useche, 2012) serve as examples of this. Similarly, in the first half of the twenty-first century and the final decade of the 20th century, almost 90% of deaths worldwide and 98% of those impacted by disasters occurred in developing nations (WorldBank, 2022). In this sense, it becomes crucial to integrate disaster risk reduction (DRR) into development in order to change the way that disasters are managed in poor nations. Due to the significant harm that disasters are causing to infrastructure and human life, the government and key stakeholders, including the general public, are also growing increasingly interested in mainstreaming disaster risk reduction (DRR) into development (Ibrahim et al., 2024; Pelling and Holloway, 2006).

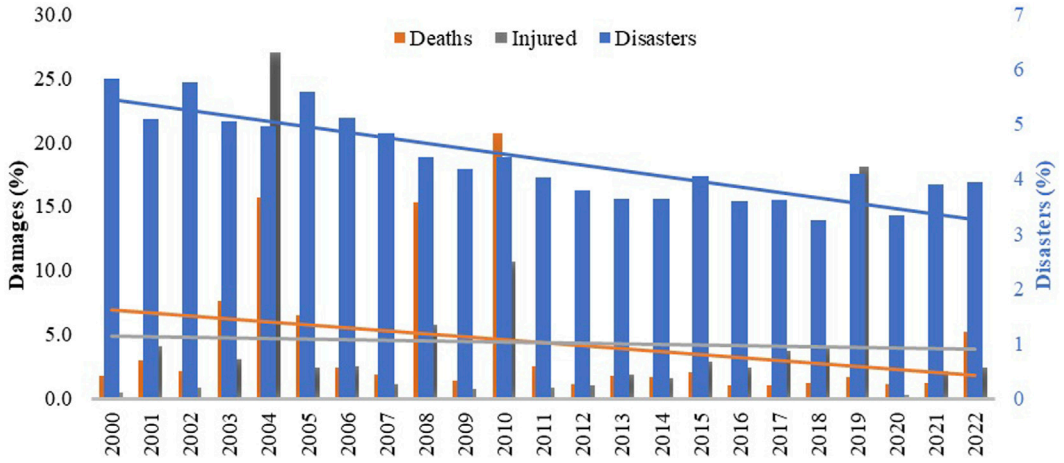

FIGURE 1
Number of disasters and subsequent damages globally from 2000 to 2022 (Source: EM-DAT, 2022).

Disasters have become a common phenomenon in Pakistan, causing severe damages to the decades of developmental progress (Rahman, 2015; Nawab and Nyborg, 2017; Shah et al., 2017; Shah et al., 2018a; Ullah et al., 2023; Zaré et al., 2009). Among these, the 2005 earthquake (Hashmi et al., 2012; Maqsood and Schwarz, 2008), floods 2010 (Nanditha et al., 2023), floods 2022 (Ahmad et al., 2018), the 2015 earthquake (Abbas et al., 2023; Ismail and Khattak, 2015), the 2015 heatwaves (Ali et al., 2023; S; Ullah et al., 2023; Ullah et al., 2019a; Ullah et al., 2019b) and accelerated urban flooding (Halvorson and Hamilton, 2010; Tayyab et al., 2021) are the most recent mega-disasters that caused widespread destruction across the country. A paradigm shift in disaster management is seen in Pakistan's decision to give up the old response-centric approach and concentrate on DRR due to the rising frequency of these disasters (Ismail-Zadeh et al., 2017). According to Math et al. (2015) and Shah et al. (2018b), a paradigm shift is a fundamental change in fundamental concepts and experimental practices, and in the context of disaster management, this change is the transition from a response-centric approach to a preparedness, prevention, and mitigation-based approach (Math et al., 2015; Shah et al., 2018a). Pakistan relied on reactive and relief efforts prior to the 2005 earthquake (Quesada-Román, 2022; Shah et al., 2019) and there were no proper mechanisms for preparedness and resilience building (Rahman, 2015).

Pakistan is modifying its policies to integrate DRR into development in accordance with international disaster risk management plans. The efficiency of DRR investment and the degree to which it has been mainstreamed into development planning and practices in Pakistan, particularly in the disaster-prone province of Khyber Pakhtunkhwa (KP), are unclear due to the fact that there is insufficient data to calculate the financial impact of DRR investment (Ishiwatari and Sasaki, 2020; Mikio and Daisuke, 2021) and differentiated risk (GoK, 2023) This study aims to fill this gap by;

i. Asnalyzing the mainstreaming of DRR into development planning and budgeting.
ii. Gauging the budgetary shift from post-disaster reactive to pre-disaster proactive approach.
iii. Evaluating effectiveness of DRR investment in terms of securing lives, property, and infrastructure in KP province.

This study provides comprehensive details about the mainstreaming of DRR into development and the effectiveness of DRR investment in securing lives, property, and infrastructure, evaluating KP's developmental budgeting and budgetary shifts to inform future disaster management strategies. This study is the first of its kind, as no such study has been conducted in Pakistan, particularly KP to comprehensively evaluate DRR budgeting and its effectiveness. By offering a novel perspective on DRR funding, this study provides valuable insights to improve pre-disaster interventions across Pakistan.

2 Materials and methods

2.1 Study area

The study area (KP province) extends from 31° 9′N to 36°54′N latitudes and 69°14′E to 74°7′E longitudes and is one of the four regular administrative provinces of Pakistan. The province is bordered by Afghanistan in the northwest, while within the country, it shares borders with Baluchistan in the south, Azad Kashmir and Gilgit-Baltistan (GB) in the northeast, and Punjab in the east. KP has a complex topography, consisting of both planes and mountains. The climate in the south to north is semi-arid having various fault lines in its catchment. The diverse topography, climates, and geological physique expose the area to various hazards. In terms of economic share, KP ranks as the third-largest provincial contributor to the national GDP (Government of Khyber Pakhtunkhwa, 2022). The total GDP (nominal) of KP during the financial year 2021–2022 was $38 billion (Ullah et al., 2018). However, this potential is recurrently challenged by the province's high vulnerability to disasters (Griffith-Jones and Tanner, 2016; Rahman et al., 2023; Shah et al., 2019; S; Ullah

et al., 2023). The study area has a rich history of floods (Hussain et al., 2021; Shah et al., 2020), earthquakes (Halvorson and Hamilton, 2010), land sliding (Ullah et al., 2024; Rahman and Shaw, 2015), Glacial Lake Outburst Floods (GLOFs) (Government of Khyber Pakhtunkhwa, 2022), drought (Rahman et al., 2023; Khan et al., 2020), desertification, famine, forest fires, heat and cold waves, and waterborne diseases. Alone, the flood in 2022, resulted in 306 deaths, 369 injured, and 91463 houses fully/partially damaged (Government of Khyber Pakhtunkhwa, 2022). In a nutshell, the province is exposed to several disasters which, if not properly addressed, will result in more damages than in the past due to climate change-induced threats.

2.2 Data collection and analysis

Quantitative data analysis is carried out in three stages. During the first stage, quantitative data on expenditure in developmental schemes in 34 different governmental sectors, from the financial year 2000–2022, are obtained from the Planning & Development (P&D) Department, Government of KP. The data were in raw form and included all the expenditures of developmental schemes either relevant or irrelevant. Customized cleansing, based on the inclusion-exclusion criteria (Khan et al., 2022), was performed to prepare data for analysis on multiple dimensions. All projects directly or indirectly related to disaster management were included for further analysis. During the second stage, a database of the disasters and subsequent damages was maintained in order to draw the disaster damage profile of KP province. Lastly, robust statistical analysis was carried out to know the effectiveness of investment in DRM within developmental expenditure.

2.3 Target sectors

Currently, 35 different regular governmental departmetns are operating in the study area. The record of financial expenditure in the developmental head for the period 2000–2022 is obtained from each department. Prominent sectors along with their relevance with DRR are listed below in Table 1.

2.4 Statistical analysis

The data analysis involved the application of statistical techniques, including the Sen's Slope Estimator (SSE), the modified Mann-Kendall (MK) test, linear regression, and correlation analysis on the developmental funding in disaster management, disasters profile, and disaster-related damages in KP province. Further details about the selected statistical tests can be found in recent studies (Abbas et al., 2023; Ullah et al., 2018; Ullah et al., 2019a; Ullah et al., 2023).

3 Results

With a focus on integrating DRR into development planning and budgeting, this study aims to comprehend KP province's shift from a response-based reactive to a risk-informed planning and development proactive approach. The study evaluated the budgetary shifts from a reactive to proactive approach for disaster management and assessed provincial government developmental budgeting in Disaster Management (DM). The efficiency of DM funding is assessed by analysing the expenditures in disaster management through annual developmental programs, disaster occurrences, and ensuing damages. A generalised framework is developed to evaluate several facets of fiscal DRR governance and ascertain the degree of the paradigm shift from reactive to proactive DM.

3.1 Nature of developmental projects and expenditure in pre- and post-disaster phases in KP province (2000–2022)

The government made substantial investments in disaster management between 2001 and 2022. Figure 2 represents the year-wise statistics of pre- and post-disaster expenditures across all sectors of the KP province during the study period. It is worth noting that the Pakistani currency (PKR) is depreciated against the US Dollar and between 2000–2022 the conversion rate has shown fluctuation from 1$ = 55.7 to 1$ = 155. The results show that the highest number of projects in the pre-disaster phase was initiated in the year 2018 (238 projects with an investment of 19709.84 million PKR), while the lowest number of projects and investments was made in the year 2001 (21 projects with an investment of 914.284 million PKR). Similarly, the highest investment of 51018.96 million PKR was made in the year 2021, having the government share of 25440.12 million PKR and donors' share of 25578.84 million PKR. The results indicate that the frequency of projects gained vertical pace with time during the study period.

Between 2000–2022, the KP government has implemented a number of pre-disaster intervention programs. For instance, in agriculture, implementing sustainable farming methods, managing watercourses, and enhancing food security all contribute to the United Nations Sustainable Development Goals (SDGs) (UN, 2023) of ensuring access to clean water and sanitation (SDG 6) (Alam, 2024; Koppen, 2024), eliminating hunger (SDG 2) (Otekunrin, 2023), and creating sustainable communities (SDG 11) (Ionescu et al., 2024). Initiatives in other sectors, including health, education, and urban development, have been carefully designed to correspond with specific SDGs. Health initiatives target wellbeing and health (SDG 3), while educational programs focus on ensuring quality education (SDG 4). However, these initiatives extend beyond immediate concerns, integrating into the broader framework of sustainable development. By aligning their objectives with the SDGs, these programs aim to enhance sustainable growth while reducing disaster risks. Their ultimate aim is to strengthen the province's development path and improve societal wellbeing by promoting community resilience. Notably, pre-disaster interventions tend to be less influenced by disaster occurrences compared to those implemented in the post-disaster phase.

In terms of post-disaster investment, the highest number of projects was initiated in the year 2010 due to major floods (302 projects with spending of 44821 million PKR), while the

TABLE 1 Prominent governmental sectors in KP province and their relevance to DRR.

S. No	Department	Relevance with DRM
1	Agriculture	The net-zero target of SDGs emphasizes the importance of DRM in achieving sustainable and resilient food production
2	Auqaf	The religious affairs sector plays its role in DRM through community engagement, humanitarian aid, and providing psychological, peaceful coexistence and interfaith harmony
3	Board of Revenue	A key actor in DRM that plays a crucial role in revenue collection, land assessment, and land records
4	Building	This sector plays a vital role in shaping the infrastructure and urban landscape of KP, contributing to the overall wellbeing and development of the region
5	Drinking Water & Sanitation	The WASH sector is critical to DRM. The sector is covered under SDG 6: Clean Water and has paramount importance for health and hygiene
6	Education	A strong education system strengthens disaster preparedness and response (SDG 4: Quality Education). Additionally, schools can serve as evacuation centers and community hubs in emergencies, making them crucial for disaster response
7	Energy & Power	Investing in resilient energy systems (SDG 7: Affordable and Clean Energy) ensures critical services remain operational during disasters. Additionally, promoting renewable energy sources can contribute to a more sustainable, disaster-resistant power sector and climate action (SDG 13)
8	Environment	A healthy environment plays a vital role in disaster risk reduction (SDG 15 and 16: Life on Land and Below Water). Protecting and restoring these ecosystems (SDG 13: Climate Action) can decrease communities' vulnerability to disasters. Additionally, environmentally conscious disaster response and reconstruction efforts minimize negative environmental impacts and promote long-term sustainability
9	Establishment & Administration	The Establishment and Administration (E&A) Department plays a crucial role in ensuring efficient governance including DRM and ensuring consistency by coordinating policies across all departments within its jurisdiction
10	Excise & Taxation	The Excise and Taxation (E&T) department has a key role in the socio-economic uplifting of the province. It primarily focuses on revenue collection. Disasters disrupt economic activity. Revenue collected by the department contributes to the provincial government's budget and this budget could be used to fund disaster response and reconstruction efforts
11	Finance	The finance department is a key actor in DRM. It supervises and controls provincial finances, preparation of budgets, formulation, and interpretation of financial rules, management of public funds, management of public debt, banking, coordination of national and provincial finance commissions, and administration of local fund audits and treasuries
12	Food	The Food department is vital for DRM. By assessing food security vulnerabilities and stockpiling essentials beforehand, they ensure food access during emergencies. They also manage emergency food distribution and market stabilization during disasters, fostering long-term food security and building resilience (SDGs 2 Zero Hunger)
13	Forestry	The Forestry Department contributes to DRM by promoting healthy ecosystems (SDG 15: Life on Land). Healthy forests act as natural buffers against floods, landslides, and storms, reducing disaster risks for communities (SDG 11: Sustainable Cities). The efforts of the forestry sector significantly contribute to SDG 13 (Climate Action)
14	Health	A robust health system strengthens disaster preparedness and response (SDG 3: Good Health and Wellbeing). Integrating disaster preparedness training into healthcare and incorporating emergency stockpiles ensures communities can address medical needs during disasters. This fosters faster recovery and minimizes disease outbreaks

(Continued on following page)

TABLE 1 (*Continued*) Prominent governmental sectors in KP province and their relevance to DRR.

S. No	Department	Relevance with DRM
15	Home & Tribal Affairs	Khyber Pakhtunkhwa's Home & Tribal Affairs Department is a key player in DRM. They coordinate emergency response, maintain order during disasters, and support community preparedness, promoting safety and quicker recovery (SDG 16: Peace, Justice, and Strong Institutions)
16	Housing	Khyber Pakhtunkhwa's Housing Department plays a key role in DRM by assisting with post-disaster housing reconstruction. This includes financial aid, temporary housing solutions, and promoting safe building practices for future resilience
17	Industries, Commerce & Technical Education (IC&TE)	IC&TE department SDG 9: Industry, Innovation and Infrastructure and SDG 8: Decent Work and Economic Growth. While IC&TE's role in direct disaster response might be limited, their focus on skills development and supporting businesses can contribute to long-term disaster resilience and economic recovery
18	Information	The Information Department plays a crucial role in DRM through effective communication relating public awareness and preparedness by disseminating information on disaster risks, preparedness measures, early warning, evacuation plans through various channels, and post-disaster communication, empowering communities to take action before disasters strike
19	Labor	The Labor Department of Khyber Pakhtunkhwa can contribute to DRM relating to SDG 8 (Decent Work and Economic Growth). The department promotes and enforces workplace safety regulations, particularly for industries potentially at risk during disasters
20	Law & Justice	The Law and Justice Department contributes to DRM by focusing on maintaining order and upholding the rule of law during emergencies (SDG 16: Peace, Justice, and Strong Institutions)
21	Local Government	Local Government Departments are critical for DRM. They assess risks, educate communities, and prepare plans beforehand. During disasters, they coordinate emergency response and provide relief. Post-disaster, they lead recovery efforts like reconstruction and economic revitalization
22	District Governance	
23	Mines & Minerals	The safety of mine workers and sustainable excavation of mines and minerals fall under the direct purview of disaster management
24	Multi-Sector Development	KP's multi-sector development strengthens disaster risk management (DRM). Projects like the ADB's urban growth strategy consider disaster resilience. Collaboration (USAID partnership) and multi-sectoral approaches (nutrition strategy) improve DRM. Overall, MSD builds long-term resilience in KP.
25	Population Welfare	The Population Welfare Department promotes family planning (SDG 2) and maternal/child health (SDG 3), and they contribute to a more disaster-resilient population
26	Social Welfare	Social Welfare is a key player in DRM (SDG 1, 10). Their 2022 policy provides a framework for aiding vulnerable populations during disasters. The SWD likely distributes relief supplies and offers financial support (SDG 1). Their focus on women, children, and people with disabilities ensures no one is left behind. They also help with livelihood restoration (SDG 8) for long-term recovery
27	Roads	Roads & Communication Dept. is vital for DRM. They maintain roads and bridges for disaster resilience, clear debris after disasters to restore access for relief efforts, and rebuild infrastructure for faster recovery
28	Relief & Rehabilitation	Provincial Relief, Rehab. and Settlement Authority (PaRRSA) is central to DRM. They lead the charge in preparing for, responding to, and recovering from disasters across the province. This includes policy-making, coordinating relief efforts, and overseeing long-term recovery
29	Science & Technology	Regulate e-Governance for better communication during disasters. The department has a significant role in response to climate change (paperless governance, e-governance, e-health, and hospital management)

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TABLE 1 (*Continued*) Prominent governmental sectors in KP province and their relevance to DRR.

S. No	Department	Relevance with DRM
30	Special Initiatives	Special initiatives taken by the provincial govt. indirectly supports DRM through initiatives like women's empowerment, which can improve disaster preparedness and recovery. Their focus on vulnerable populations (e.g., COVID-19 response) strengthens disaster resilience. Additionally, community engagement efforts can promote proactive DRM strategies
31	Sports, Tourism, Culture/Archaeology/Youth Affairs	Cultural heritage, as the United Nations Educational, Scientific and Cultural Organization (UNESCO) highlights, is a nation's legacy that promotes understanding, communication, and identity among civilizations. DRR and the preservation of cultural heritage are linked in the UNESCO framework as a cross-cutting theme for risk-informed and sustainable development
32	Transport	One of the crucial aspects of DRM is seamless transport management to ensure the timely provision of relief
33	Urban Development	DRR initiatives and SGDs 11 (Sustainable Cities and Communities) are in line with projects like urban development plans and flood protection structures. In keeping with SDG 11, addressing pollution, waste management, and bolstering local governance enhance resilient urbanization and disaster risk reduction
34	Water	The water sector is so diverse that covers DRM through watershed management, construction of dams, managing drought, improving water infrastructure, climate resilience, etc. These directly contribute to DRM by mitigating floods, building small dams, and managing drought. They align with SDG 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), and 13 (Climate Action) by improving water management, infrastructure, and climate resilience. Additionally, they support SDG 2 (Zero Hunger) by ensuring efficient water use for agriculture and food security

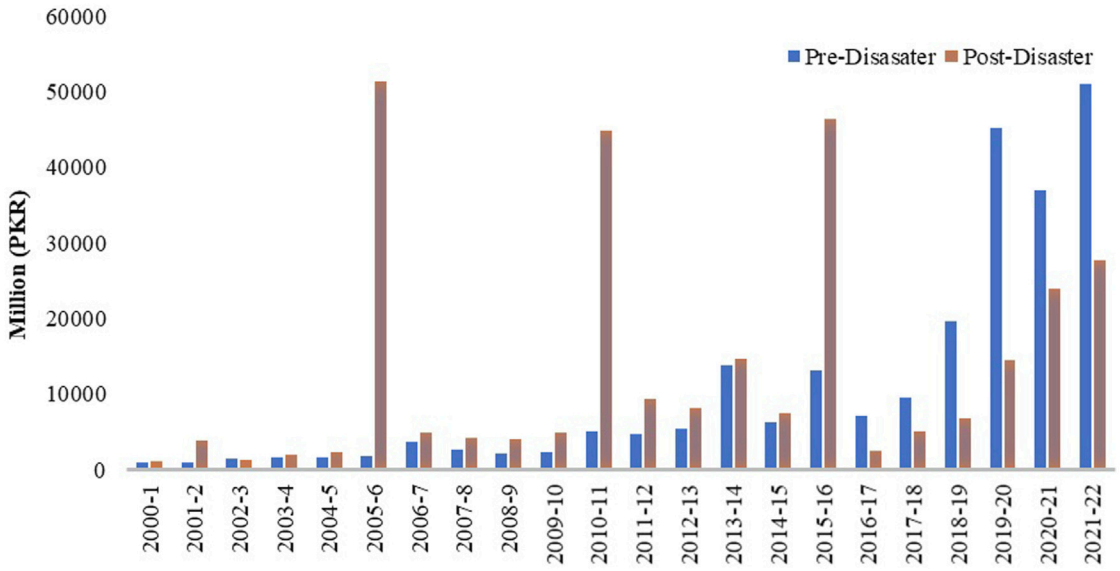

FIGURE 2
Expenditure incurred in disaster management from 2000 to 2022.

lowest number of projects and spending made in the year 2000 (14 projects with investment of 1047.028 million PKR). The frequency of projects gained a vertical pace over time during the study period but the years 2005 and 2010 had a sharp jump in the number of projects, due to earthquakes in 2005 and floods in 2010. The highest spending of 51429.23 million PKR was made in the year 2005, having the government sharing 48863.94 million PKR and donors sharing 2565.286 million PKR. These projects also include compensation initiatives for disaster-affected communities in the province.

There are year-to-year fluctuations in post-disaster spending by both the government and donors. Investments in risk-informed interventions are more likely to be successful during both the pre- and post-disaster phases. Additionally, post-disaster initiatives that focus on improving health services, strengthening infrastructure, and ensuring economic stability in vulnerable areas align with the broader objectives of the SDGs. In conclusion, post-disaster initiatives play a critical role in rebuilding communities, resuming essential services, and building resilience against future hardships. They are essential in supporting rehabilitation initiatives and laying the groundwork for long-term, sustainable growth. It is worth mentioning that spending in the post-disaster phase is influenced by disasters.

The provincial government's post-disaster initiatives span various sectors, including infrastructure, agriculture, environment, health, governance, education, communication, etc. These programs aim to reduce the suffering of the affected population and to ensure a more secure future. Key initiatives focus on the rehabilitation of infrastructure, restoration of essential services, and reconstruction of hospitals and schools, as well as the repair of water supply systems and the promotion of economic development. Additionally, a holistic recovery approach is emphasized, which incorporates aspects of security, environmental management, forestry, and relief compensation for those impacted by disasters. This comprehensive strategy aims to facilitate recovery across multiple sectors.

3.2 Disasters and damages in KP province (2000–2022)

KP province experiences both natural and human-induced disasters because of its complex topographic features, diverse climate conditions, and distinct geographic location (Government of Khyber Pakhtunkhwa, 2022; Ibrahim et al., 2024; Shah et al., 2019; 2021; Shah et al., 2018b). Figure 3 illustrates the annual occurrences of disasters, along with associated fatalities, injuries, and damage to housing in the study area between 2000–2022. During the study period, a total of 113 disasters of varying types and intensities were recorded in the region, leading to 35,250 deaths, 48,553 injuries, and damage to 1,040,895 houses, both partially and fully. The data reveals that the highest number of disasters (10) occurred in 2000, while the most significant fatalities were reported in 2005 (29,425) during the catastrophic earthquakes. The second-highest death toll (1,221) occurred in 2010 due to historic floods. Despite considerable spending in the post-disaster phase, the study highlights that the frequency and intensity of disasters, along with their resulting damages, have been increasing over time. This trend is largely attributed to the province's highly fragile infrastructure, which is unable to withstand the impacts of such disasters (Khan et al., 2022). Moreover, threats imposed by climate change are not taken into account while developing new infrastructure (Bankoff et al., 2004; Shah et al., 2018a). The already weak infrastructure coupled with no consideration of DRR in development has alarmingly exposed the region to disasters and damages.

3.3 Nature of disasters occurred in KP province (2000–2022)

Table 2 shows the nature of disasters that occurred in KP Province during 2000–2022. Avalanches, earthquakes, epidemics, floods/flash floods, GLOFS, landslides, rains, heavy snowfall, and windstorms are the recurrent natural disasters in the province during the span of the study period. The frequency of floods is recorded the highest (21 times), followed by heavy snowfall (16 times), heavy storms (15 times), landslide (14 times), heavy rains (12 times), earthquake (10 times), avalanche (9 times), epidemic (6 times), flash flood (5 times), GLOFs (3 times), cyclone and drought (1 time each). The frequency of avalanches during the study period is 9 and reported in 2001, 2003, 2008, 2009,

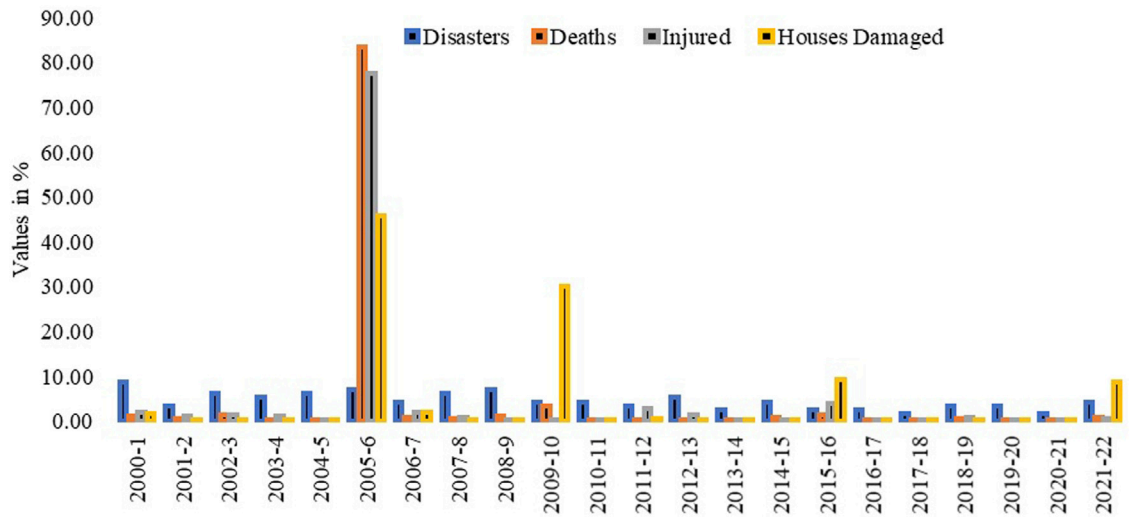

FIGURE 3
Year-wise disasters and subsequent damages in KP province during 2001–2022.

TABLE 2 Historical disasters in KP province during 2001–2022.

Year	Disaster	Year	Disaster	Year	Disaster	Year	Disaster
2001	Windstorm	2005	Storm	2009	Earthquake	2015	Cyclone
2001	Drought	2005	Heavy Rains	2009	Heavy Rains	2015	Flash flood
2001	Flood	2005	Landslide	2009	Storm	2015	Earthquake
2001	Avalanche	2005	Landslide	2009	Flood	2016	Avalanche
2001	Heavy Rains	2005	Earthquake	2009	Avalanche	2016	Flash flood
2001	Landslide	2006	Snowfall	2010	Heavy Rains	2016	FLOFs
2001	Landslide	2006	Flood	2010	Avalanche	2016	Earthquake
2001	Epidemic	2006	Heavy Rains	2010	Lightning	2016	Rains and floods
2001	Snowfall	2006	Hailstorm	2010	Floods 2010	2017	Avalanche
2001	Earthquake	2006	Flash flood	2010	Snowfall	2017	Floods
2002	Heavy Rains	2006	Landslide	2011	Snowfall	2017	Heavy Rains
2002	Snowfall	2006	Epidemic	2011	Landslide	2018	Earthquake
2002	Storm	2006	Earthquake	2011	Heavy Rains	2018	Flood
2002	Flood	2007	Snowfall	2011	Flood	2019	Flood
2003	Snowfall	2007	Landslide	2011	Epidemic	2019	Earthquake
2003	Epidemic	2007	Earthquake	2012	Snowfall	2019	Landslide
2003	Heavy Rains	2007	Storm	2012	Storm/rain	2019	Storm
2003	Flood	2007	Flood	2012	Landslide	2020	Flood
2003	Windstorm	2008	Snowfall	2012	Flood	2020	Landslide
2003	Avalanche	2008	Heavy Rains	2013	Snowfall	2020	Avalanche
2003	Landslide	2008	Hailstorm	2013	Flood	2020	Storm
2004	Snowfall	2008	Flood	2013	Rains/storm	2021	Flood
2004	Flood	2008	Earthquake	2013	Flash flood	2021	Avalanche
2004	Flash flood	2008	Landslide	2013	Landslide	2022	Flood
2004	Heavy Rains	2008	Avalanche	2013	Epidemic	2022	Flood
2004	Epidemic	2009	Snowfall	2014	Snowfall	2022	GLOF
2004	Landslide	2009	Snowfall	2014	Storm	2022	GLOF
2005	Snowfall	2009	Snowfall	2014	Flood	2022	Heavy Rain
2005	Flood						

2010, 2016, 2017, 2020, and 2021. Drought and cyclones are reported only 1 time in 2001 and 2015, respectively. The frequency of earthquakes is 10 and reported in the years 2001, 2005–2009, 2015, 2016, 2018, and 2019 among, which the 2005 earthquake was extremely catastrophic in terms of loss of lives and infrastructure. The frequency of epidemics is 6 and reported in the years 2001, 2003, 2004, 2006, 2011, and 2013. Similarly, flash floods are reported 4 times in the years 2004, 2006, 2013, 2015, and 2016. Flood frequency is 21 and reported throughout the study period except 2015. GLOFs are reported 3 times in the years 2016 and 2022. The frequency of reported landslide events is 14 and occurred in 2001, 2003–2008, 2011–2013, 2019, and 2020. Similarly, the study area was hit by lightning, heavy rainfall, and storms with a frequency of 15 in the years 2001–2006, 2008–2011, 2017, and 2022. The 2016 heavy rainfall also caused flash flooding. Heavy snowfall in northern areas of KP is reported 16 times from 2001 to 2014. While, heavy storms are reported 12 times in the years 2001–2003, 2005–2009, 2012, 2014, 2019, and 2020.

3.4 Expenditure in DRR and disaster impacts in KP province (2000–2022)

Table 3 presents comprehensive details of year-wise funding in DM, disasters that occurred and their frequency, and damages in terms of deaths, injuries, and houses damaged between 2000 and 2022 in the KP province. It also includes data on pre- and post-

10.3389/fenvs.2024.1474344

TABLE 3 Year-wise detail of investment in the pre-disaster phase and subsequent damages.

Year	Post-Dis. Spending	Pre-Dis. Investment	Projects	Disasters	Houses damaged	Injured	Deaths	Year	Post-Dis. Spending	Total investment	Projects	Disasters	Houses damaged	Injured	Deaths
2000–1	1047	966	49	10	16912	938	416	2011–12	9393	4764	141	4	5220	1341	150
2001–2	3766	914	44	4	452	621	211	2012–13	8153	5360	121	6	2163	760	103
2002–3	1273	1478	77	7	1220	776	511	2013–14	14699	13837	147	3	74	92	68
2003–4	1972	1609	138	6	2648	587	124	2014–15	7473	6307	132	3	4591	130	305
2004–5	2228	1618	131	7	339	225	130	2015–16	46483	13091	211	5	97995	1989	519
2005–6	51429	1796	206	8	476773	37676	29425	2016–17	2463	7167	96	3	1007	162	138
2006–7	4876	3610	135	5	20668	966	374	2017–18	4990	9462	143	2	928	134	121
2007–8	4247	2583	118	7	437	503	229	2018–19	6775	19710	294	4	508	437	197
2008–9	4078	2186	141	8	2005	236	378	2019–20	14433	45165	252	4	990	132	160
2009–10	4927	2351	126	5	312608	126	1221	2020–21	23919	36992	269	2	124	133	93
2010–11	44821	5085	413	5	1770	220	71	2021–22	27721	51019	290	5	91463	369	306

disaster funding by the donors and the government (combined), the number of developmental schemes initiated in DM, the number of disasters recorded, and subsequent damages resulting from these disasters.

The results show that investment in risk mitigation and preparedness was relatively low during the early part of the study period, there has been a significant increase in investing in DRR over time. This is a good sign and reflects an evolving recognition of the importance of a proactive approach in DM. This recognition of a proactive approach in DM is particularly notable in recent years, indicating improved preparedness, mitigation, and resilience-building activities such as sustainable agriculture and environment, improved health and hygiene, and strengthening governance and infrastructural programs. In contrast, post-disaster expenditure incurred on emergency response, relief, rehabilitation, and recovery efforts. The results highlighted that the gap between pre- and post-disaster funding has reduced in recent years of the study period. This is also a good sign and signaling towards a more integrated and balanced approach to DM.

Despite the increasing frequency of disasters, a reduction in disaster-related deaths and injuries may be attributed to these expenditures. For example, while the region experienced frequent flooding events during the study period, the integrated approach to DM and increased investment in DRR have contributed to a reduction in the damages.

3.5 Total finance incurred in pre-disaster phase and subsequent damages

The correlation between pre-disaster investments and subsequent disaster-related damages has been analyzed to determine if a relationship exists between the two variables. As indicated in Table 4, there is a strong positive correlation (coefficient value of 0.80, $p < 0.05$) between the number of pre-disaster projects and expenditures during the pre-disaster phase. This suggests that as the number of initiatives increases, so does the associated financial investment.

Conversely, a significant negative correlation (−0.57, $p < 0.05$) was observed between the frequency of disasters and pre-disaster expenditures, indicating an inverse relationship between frequency of disasters and pre-disaster investment.

Additionally, the data reveal a negative correlation (−0.43) between disaster-related deaths and pre-disaster expenditures, implying that as investments in DRR increase, the number of fatalities tends to decrease. Similarly, there is a statistically significant negative correlation (−0.56, $p < 0.05$) between the number of injuries caused by disasters and DRR investments, further supporting the notion that greater financial commitment to DRR correlates with reduced disaster-related casualties. The correlation between the number of houses damaged due to disasters and expenditure in the pre-disaster phase is negative (−0.26), meaning that the investment in DRR has reduced the number of houses damaged due to disasters and *vice versa*. The overall relationship between investing in DRR and lower damages suggests that the higher the investment in DRR, the lower the frequency of disaster (Pelling and Holloway, 2006; WorldBank, 2022). However, an alternative explanation for this also exists

TABLE 4 Correlation between investment in pre-disaster interventions and disaster damages.

		Total Finance Incurred in Pre-Disaster Phase	Number of Projects in the Pre-Disaster Phase	Number of Disasters	Deaths	Injured
Number of Projects in the Pre-Disaster Phase	Correlation Coefficient	0.80**				
	Sig. (2-tailed)	0.00				
Number of Disasters	Correlation Coefficient	−0.57**	−0.45*			
	Sig. (2-tailed)	0.00	0.04			
Deaths	Correlation Coefficient	−0.43*	−0.30	0.55**		
	Sig. (2-tailed)	0.05	0.18	0.01		
Injured	Correlation Coefficient	−0.56**	−0.38	0.41	0.45*	
	Sig. (2-tailed)	0.01	0.08	0.06	0.04	
Houses Damaged	Correlation Coefficient	−0.26	−0.03	0.41	0.67**	0.47*
	Sig. (2-tailed)	0.24	0.89	0.06	0.00	0.03

10.3389/fenvs.2024.1474344

that the regions more prone to disasters naturally receive higher DRR investment.

3.6 Total finance incurred in the post-disaster phase and subsequent damages

The results of the correlation between post-disaster expenditure and its impact on disaster-related damages indicate a strong and significant positive correlation (correlation coefficient = 0.83, $p < 0.05$) (Table 5). This statistically significant relationship suggests that an increase in spending leads to an increase in post-disaster projects. However, the correlation between the frequency of disasters and post-disaster phase expenditure is found to be negative (−0.21), indicating that there is no comprehensive evidence to hint that spending post-disaster influences the future frequency of such disasters. The correlation between the casualities due to disasters and post-disaster expenditure is negative (−0.37 and −0.32, respectively), indicating that spending in the disaster-response has reduced the number of disaster-related deaths and injuries in the province. Interestingly, a slightly negative and non-significant correlation of −0.04 exists between the number of houses damaged and the post-disaster expenditure, suggesting a weak connection between spending in the post-disaster phase and decreased property damage in the following incidents.

3.7 Overall funding in DRR and subsequent damages

To determine the correlation between DRR funding and subsequent damages, the results of the underlying relationship are shown in Table 6. We found a robust positive and significant correlation (0.84, $p < 0.05$) between the total number of projects carried out and the total funding allocated for DRR. This indicates that the number of implemented projects increased with a rise in DRR funding in the KP province. However, a different picture emerged when looking at the frequency of disasters and total funding in DRR; here, the correlation is negative (−0.41). We observed similar results when examining the correlations between total funding in DM and casualties due to disasters. The correlations stand negative with correlation coefficients of −0.41 and −0.45, respectively. Furthermore, this inverse relationship highlights that investment in DRR has reduced the number of deaths and casualties in the KP province. Finally, the correlation between number of houses damaged and the total DRR funding is negative (−0.14), indicating that higher investment in DRR has reduced the impacts of disasters on houses in the study area.

3.8 Budgetary shift in disaster financing and its effectiveness

The province of KP is prone to geological and hydrometeorological hazards. The frequency and magnitude of disasters are different during the selected study period. However, there is a strong relationship between the budgetary investment and the subsequent damages, such as the number of disasters, deaths, casualties, and house damages. While year-wise data may present a less accurate picture, the analysis of decadal and overall study periods (2000–2022) offers a more reliable and realistic understanding of disaster trends, their impacts, and associated budgetary allocations. This broader perspective allows for clearer identification of patterns and the effectiveness of investments in DRR over time. To have more robust, clear, and accurate estimates, the SSE test is used to estimate trend slope/magnitude, while the MK test is used to determine trend significance. These tests are applied to decadal data of total expenditure, number of disasters, number of deaths and injured and houses damaged. Results indicate that investment in DRR (528242.36 million PKR) has resulted in the reduction of decadal disasters by 2.50, deaths by 63.33, injuries by 226.67, and house damages by 605, while an increase of 13595 million PK has been observed in pre-disaster-investment (Figure 4).

4 Discussion

The study evaluated the effectiveness of mainstreaming DRR into development and the effectiveness of DRR investment in terms of securing lives, property, and infrastructure in KP province, Pakistan. The study area is exposed to both geological and hydrometeorological disasters. The results show that the most recurrent disasters in KP are floods followed by heavy snowfall, storms, landslides, heavy and unusual rains, earthquakes, avalanches, epidemics, flash floods, GLOFs, cyclones, and drought. But in terms of catastrophic impacts, floods and earthquakes are noted most damaging (Arrighi and Domeneghetti, 2024; Avcil et al., 2024; Rahman et al., 2024). This might be attributed to the malpractice of existing laws on encroachment and building codes coupled with the weak socio-economic conditions of KP (Shah et al., 2020). The local people tend to acquire land for home construction in flood-prone areas due to lower prices of land, thus making them vulnerable to floods. The weak implementation of encroachment laws has further triggered the impacts of flood hazards. Similarly, the weak implementation of building codes also weakened the infrastructure and exposed it to earthquakes (Usman et al., 2022). This signifies the importance of a decentralized approach to disaster management. In vulnerable regions, community-based initiatives, such as grassroots disaster preparedness have been more successful in reducing disaster risk (Alam, 2024).

The results further indicate that pre-disaster investing in KP is not influenced by the occurrence of disaster while post-disaster funding and projects initiated are directly correlated to the occurrence of disasters and their impacts (Molnar, 2020). For example, the devastating earthquake in 2005 and floods in 2010 caused havoc in the KP province. The highest expenditure was incurred in the year 2005, while the highest number of projects was initiated in the year 2010. The provincial government's DRR programs cover a wide range of sectors, including agriculture, governance, infrastructure, health, rehabilitation, and the revival of essential services. These areas are central to the multi-sectoral approach to DRR in the study area. The strategy is all-encompassing, involving multiple sectors and emphasizing resilience-building alongside recovery initiatives (Izumi and Shaw, 2014; Kapucu,

TABLE 5 Correlation between spending in post-disaster interventions and disaster damages.

		Total Finance Incurred in Post-Disaster Phase	Number of Projects in Post-Disaster Phase	Number of Disasters	Deaths	Injured
Number of Projects in the Post-Disaster Phase	Correlation Coefficient	0.83**				
	Sig. (2-tailed)	0.00				
Number of Disasters	Correlation Coefficient	−0.21	−0.00			
	Sig. (2-tailed)	0.36	0.99			
Deaths	Correlation Coefficient	−0.37	−0.32	0.55**		
	Sig. (2-tailed)	0.10	0.14	0.01		
Injured	Correlation Coefficient	−0.32	−0.27	0.41	0.45*	
	Sig. (2-tailed)	0.15	0.22	0.06	0.04	
Houses Damaged	Correlation Coefficient	−0.04	−0.07	0.41	0.67**	0.47*
	Sig. (2-tailed)	0.86	0.75	0.06	0.00	0.03

10.3389/fenvs.2024.1474344

TABLE 6 Correlation between total funding in disaster management and disaster damages.

		Total Funding in Disaster Management	Total Projects in Disaster Management	Number of Disasters	Deaths	Injured
Number of Projects in the Post-Disaster Phase	Correlation Coefficient	0.84**				
	Sig. (2-tailed)	0.00				
Number of Disasters	Correlation Coefficient	−0.41	−0.27			
	Sig. (2-tailed)	0.06	0.23			
Deaths	Correlation Coefficient	−0.41	−0.40	0.55**		
	Sig. (2-tailed)	0.06	0.07	0.01		
Injured	Correlation Coefficient	−0.45*	−0.37	0.41	0.45*	
	Sig. (2-tailed)	0.03	0.09	0.06	0.04	
Houses Damaged	Correlation Coefficient	−0.14	−0.12	0.41	0.67**	0.47*
	Sig. (2-tailed)	0.55	0.59	0.06	0.00	0.03

10.3389/fenvs.2024.1474344

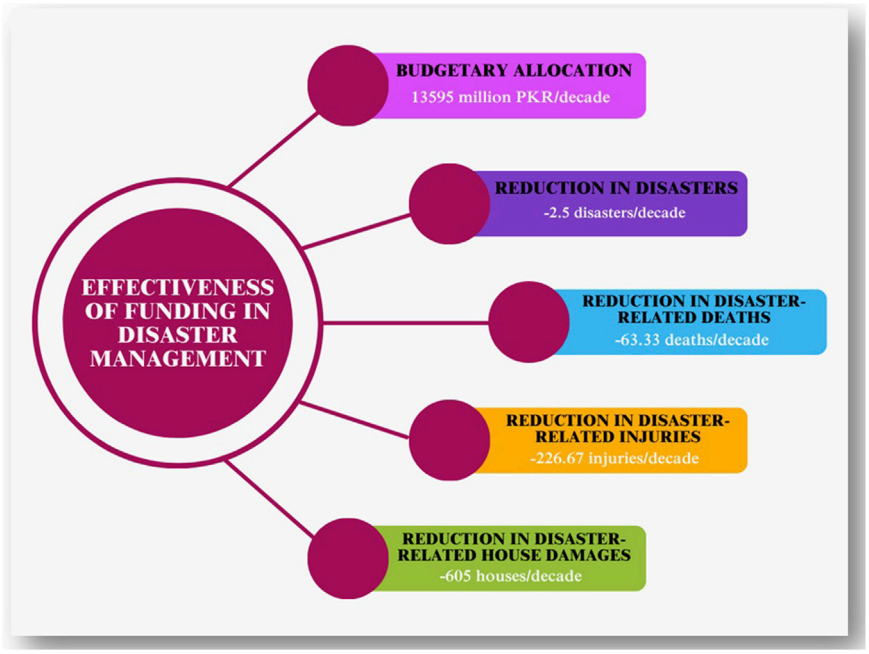

FIGURE 4
Effectiveness of DRR expenditure in the KP province.

2020; Pandey and Okazaki, 2005). Additionally, lower pre-disaster expenditures have been linked to higher damages when disasters occur (WorldBank, 2022).

During the study period, a significant association was observed between increased spending and a reduction in casualties (FAO, 2019; Ishiwatari and Sasaki, 2022; Martins et al., 2022; United Nations, 2019). Notably, a positive correlation emerged between funding levels and fewer casualties, indicating that higher financial investment is inversely related to disaster damages. This consistent trend reveals that as funding for disaster management increased over time, the number of deaths, injuries, and property losses decreased. Thus, lower observed damages are linked to increased financial support (Khan et al., 2022). The findings indicate that the number of deaths, injuries, and damages from disasters declined over time, suggesting that greater funding in disaster management correlates with reduced impact. This validation of the benefits of increased investment not only provides strategic guidance for disaster management but also underscores the need for ongoing financial support and innovation to mitigate disaster risks (Griffith-Jones and Tanner, 2016). It highlights how proactive policies and initiatives can significantly reduce both human and infrastructure costs associated with disasters.

The proactive approach in disaster management has become a critical component across the world to mitigate the impact of disasters. The study revealed that there is a significant correlation between the number of developmental projects initiated in disaster management, pre- and post-disaster investments, and the impact they have on disaster impacts (Shamkhi and Ebraheem, 2020; Srividhya et al., 2020). Recent studies suggest that taking preventative measures, such as allocating more funds and carrying out projects before the onset of a disaster, may effectively lessen the effects that follow (Izumi and Shaw, 2014; Kapucu, 2020; Olu et al., 2016; Righi et al., 2021). This is consistent with the notion that reducing the effects of disasters requires preparedness and proactive measures (Khan et al., 2022; Raikes et al., 2019; Tabish and Syed, 2015). Overall, the results present a compelling narrative: increased investment in disaster management appears to effectively reduce the severity of disasters, lower death tolls, and decrease the number of injuries. These findings strongly advocate for a coordinated and proactive fiscal approach for DRR.

5 Limitations and future recommendations

While the study offers valuable insights into the effectiveness of DRR investment, the study has limitations that need to be considered while interpreting the results, such as the study is focused on developmental projects that are carried out in disaster management in the KP province. This has not taken into account the regular budget reserved for disaster management, which needs to be assessed in combination with the developmental budget in the forthcoming studies. Similarly, sectoral investment in disaster management is key to sustainable disaster management, and for this reason, sectoral investment may also be figured out to gain an overall oversight of sectoral resilience.

Key stakeholders, including the Planning and Development, Finance, Establishment and Administration Departments, and the Provincial Reconstruction, Rehabilitation and Settlement Authority (PsRRSA), should implement risk-sensitive planning, allocations, expenditures, and development practices under a risk-informed development framework across all sectoral departments at provincial, district, and local levels. The government shall focus on integrating DRR and climate change adaptation within all

departments. This can be achieved by mainstreaming DRR into development planning and requiring all organizations to consider disaster risks when making decisions, designing both developmental and non-developmental activities, and allocating budgets. For better disaster governance in the province, there is a dire need for establishing an inter-departmental task force on DRR for effective coordination, ensuring policies are harmonized and DRR inclusive. Similarly, the government should invest in communitive-led DRR initiatives, and capacity building of local/district government staff and key stakeholders including volunteers from communities. Parallel to this, integrating DRR and climate change adaptation into urban and regional planning in such a way that ensures new developments are risk-informed and account for future disaster risk.

6 Conclusion

The study evaluated funding in annual developmental programs in DM, the budgetary shift from reactive to proactive DM, and the effectiveness of this funding in relation to disasters and disaster-related damages during the period 2000–2022. The study used financial data of the developmental projects, which aimed at prevention, mitigation, preparedness, emergency response, relief, rehabilitation, recovery, and development after disaster. In the second phase, disaster and damage data were obtained from various online platforms, such as EM-DAT, Dis-Inventor, and government departments, such as the National and Provincial Disaster Management Authorities. For statistical analysis, SSE, MK, linear regression model, and correlation coefficient techniques were used. The study findings reveal the critical role of investing in DRR measures in strengthening resilience against disasters. Increased DRR investment was found associated with decreased damages despite the fact that the current disaster management system is response-based and the paradigm shift from a reactive to a proactive disaster management approach is yet to take place. These investments would have saved more lives and infrastructure if risk-informed measures were considered while allocating funds to developmental schemes.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: 1- https://pndkp.gov.pk/adp/ 2- https://www.emdat.be/ 3- https://www.desinventar.net/ 4- http://www.ndma.gov.pk/ 5- https://pdma.gov.pk/.

Author contributions

IK: Conceptualization, Data curation, Formal Analysis, Methodology, Writing–original draft. AA: Conceptualization, Formal Analysis, Methodology, Supervision, Writing–review and editing. WU: Formal Analysis, Funding acquisition, Supervision, Writing–review and editing. MJ: Validation, Visualization, Writing–review and editing. SU: Conceptualization, Formal Analysis, Methodology, Validation, Writing–review and editing. FL: Validation, Writing–review and editing. SK: Software, Validation, Visualization, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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