KEY CHALLENGES IN BUILDING RIVER BASIN RESILIENCE TO WATER-RELATED DISASTERS: THE CASE OF THE KELANI RIVER, SRI LANKA

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Abstract. Water-related disasters have severely affected human life, the economy, and the environment. In recent decades, especially in the second half of the 20th century, water-related disasters have attracted extensive worldwide attention. Recently, it has become a significant issue in Sri Lanka. Both floods and droughts have spread widely throughout the country, and flood influence is more common every year. This study was conducted in the Kelani River Basin (KRB), Sri Lanka, and examines the problems and challenges in building river basin resilience to water-related disasters. Through a comprehensive methodology that included a literature review, focus group discussions, and semi-structured interviews, this study identified eight key challenges in the risk management process in the KRB, such as population growth and pressure, the absence of proper plans**,** insufficient funds etc. The data was analysed using conceptual content analysis, ranking methods, and problem tree analysis. Based on these findings, we developed an integrated risk management framework designed to minimize the risk of water-related disasters in the region. The framework proposes strategic policy changes and provides several practical methods to improve existing risk management practices. This research serves as a valuable scientific reference, offering concrete solutions for future comprehensive decision-making processes. To manage the risk of water-related disasters, policy changes should be accommodated in the risk management practices, and this study has suggested several practice methods; this will be a popular science measure that can provide scientific references and solutions for the comprehensive decision-making process in the future.

1. INTRODUCTION

Water-related disasters or hydrological extremes (HEs) are mainly caused by people living in conflict with the environment (Budhakooncharoen, 2003; Dieperink *et al.*, 2016; Kalantari *et al.*, 2018; Stanković *et al.*, 2019). HEs, floods and droughts are often seen as opposite ends of the water spectrum, but they're both complex symptoms of a deeper, more complicated issue than just having too much or too little water (Grobicki *et al.*, 2015). Unplanned urban expansion, population growth, poverty, climate change, and environmental degradation make human society more vulnerable to floods and droughts (Budhakooncharoen, 2003; Dordi *et al.*, 2022; Francesch-Huidobro *et al.*, 2017; Kalantari *et al.*, 2018). HEs have risen considerably worldwide in the past few decades due to different physiographic and anthropogenic causes, and it has recently become a significant worldwide issue (Tan *et al.*, 2019; Ahn & Palmer, 2016). Anthropogenic activities in most river basins are unplanned and unlimited and pave the way to countless physical, social and economic risks on hydrological processes in river basins. Most river basins are highly vulnerable to HEs due to rapid human intervention. Significantly, land use and

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land cover (LULC) changes, unplanned urban expansion, population pressure, human encroachment, waste disposal, other lifestyle changes, and human-induced global changes and emission have affected the frequency and severity of the water-related disasters in river basins (Manawadu & Wijeratne, 2021). This increases other vulnerabilities, such as economic collapse, poverty, food shortages, water scarcity and water pollution, which are further triggered by the occurrences of water-related extreme floods and droughts (Manawadu & Wijeratne, 2021; Wijeratne & Li, 2022). In recent years, water-related stresses have been a topic of interest to scientists and decision-makers, because they may cause significant damage and impact on the environment, society and economic systems (Budhakooncharoen, 2003; IPCC, 2012; Kalantari *et al.*, 2018; Munyaneza *et al.*, 2011; Stanković *et al.*, 2019).

"Natural disasters are the primary causes of poverty in disaster-vulnerable households, and they are also the primary causes of poverty in those areas" (Wanders, 2015; Winsemius, *et al.*, 2016; Gari, 2019). Moreover, natural disasters kill, at a global level, 60,000 people on average annually. Floods, droughts, cyclones, heatwaves, and large storms have contributed to 80/90% of all-natural disaster events reported in the previous decade. Water scarcity, in particular, affects 40% of the world's population, with drought threatening to displace 700 million people by 2030 (World Health Organization, 2020). Floods and droughts caused $596 billion in damage in the early 21st century, affecting over 3.4 billion people between 1995 and 2015 (He *et al.*, 2020). Natural disasters have increased in frequency by 250% since 1980, and the number of people affected has more than doubled. The majority of current research indicated that HEs would become more common in the twenty-first century due to global warming and the impact of anthropogenic activities.

HEs management and building river basin resilience usually involves modifying natural systems to achieve better social and economic outcomes (Osti, 2018). HEs management practices advocated by many countries to address floods and droughts risks, exposures and vulnerabilities tend to focus excessively on flood and drought mitigation and on the long-term consequences for local and regional natural environments. Focusing solely on floods and droughts through risk management methods may produce good results in the short term, but it does not always produce sustained progress unless the flood and drought risk and environmental footprint of each development activity are taken into account (Osti, 2018). However, these water-related extremes management is still a fairly young paradigm over river basins in the world (Hartmann, 2022). Risk management planning in integrated flood and drought management requires a clear understanding of existing and future flood risks. If people are not aware of the risks they face, they cannot mobilize local forces to build river basin resilience to water-related disasters. Understanding risks is critical (Dulo *et al.*, 2010). Therefore, significant challenges related to the implementation of water-related disaster risk reduction can be identified (Dissanayaka & Sangasumana, 2017a; Jonkman & Dawson, 2012; Malalgoda *et al.*, 2010), especially at the river basins level. In this rapidly changing world, it is necessary to recognize the major challenges and problems in building river basin resilience faced by policymakers, practitioners and modern scientists.

Scientists that have explored the problems and challenges in floods and drought management throughout the world and discussed it at the river basin level are few and far between. As pointed out by Hartmann, (2022), building resilience or HEs management is still a fairly young paradigm. Kalantari *et al.*, (2018) mentioned that, it is very essential to understand the issues and opportunities for efficient solution to mitigate the disaster vulnerability. Widely recognized literature has identified challenges and issues in building resilience to flood disaster rather than drought disaster throughout the world. Dieperink *et al.*, (2016); Dissanayaka & Sangasumana, (2017); Francesch-Huidobro *et al.*, (2017); Hartmann, (2022); Ishiwatari, (2019); Jonkman & Dawson, (2012); Mysiak *et al.*, (2013). Dieperink *et al.*, (2016) have reviewed and discussed the recurrent governance challenges of flood risk management. This study clearly mentiones that there is a large amount of literature on the implementation of specific flood risk reduction strategies and more generally collaborative and participatory water governance. However, what is lacking is a clear understanding and systematic overview of flood risk management strategies' ambition to diversify and deal with a series of complex governance challenges. In this rapidly changing world, it is necessary to expand the definition of flood risk management to recognize the major

challenges faced by policymakers, practitioners and modern scientists. Flood risk management must recognize the increasingly close interrelationship between physical infrastructure and economic systems, as well as the important role of human factors in determining flood risks (Jonkman & Dawson, 2012).

In addition, Jonkman & Dawson, (2012) has indicated a number of challenges of implementing flood management in the 21st century that have been recognized from the current extreme events and scientific researches. Moreover, they have mentioned that innovative technologies are emerging to help flood risk management, but they are not always easy to implement and technology alone is not enough to meet all challenges in this area. Malalgoda *et al.*, (2010) pointed out that the implementation of disaster risk reduction initiatives faces enormous challenges, and interdisciplinary strategies, tools and approaches are therefore needed to ensure the proper management of and the resources for risk reduction.

Dissanayaka & Sangasumana, (2017) has studied issues and challenges of urban flood management and highlighted that there are many challenges that can be recognized throughout the world. The study has discussed different issues and challenges of implementing risk management and further mentioned that there are both direct and indirect challenges in the risk management process. As Osti (2018) mentioned, the water-related disaster management practices advocated by many countries to address the risk of HEs, exposures and vulnerabilities tends to focus too much on mitigating the risk the long-term consequences for local and regional natural environments. However, there are many issues and challenges to minimizing the risk, as well as consequences of risk management. Therefore, studying the management challenges of disaster planning in river basin areas is crucial for the future planning of various major urbanized river basins throughout the world, because this type of research has the potential for international scope and importance. Gaps in the current legal framework must be filled to meet these challenges. The measures to overcome these challenges need to be fully proved by the empirical evidence of follow-up research (Nguyen *et al.*, 2018).

It is important to emphasize the need to expand the focus beyond floods and to implement Integrated Flood and Drought Management (IFDM). The current research acknowledges that this is a "fairly young paradigm" (Hartmann, 2022) and that basin-level studies on the challenges and problems of building resilience to *both* extremes are few. On the other hand, although numerous challenges in implementing disaster risk reduction (DRR) and risk management have been identified globally (e.g., governance, technological, interdisciplinary needs), the text indicates a need for empirical evidence to fully prove the effectiveness of measures intended to overcome these specific challenges within the legal and operational frameworks of river basins (Nguyen *et al.*, 2018). "While significant literature exists on the global socio-economic impact of hydrological extremes (HEs) and the governance challenges related to single-hazard flood risk management, there remains a critical research gap concerning the development of a comprehensive, systematic, and empirically-validated framework for Integrated Flood and Drought Management (IFDM). Despite increasing vulnerability to hydrological extremes (HEs) in urbanized areas, the existing body of research fails to provide a clear overview or a strategic roadmap for addressing the complex, recurrent governance and implementation challenges of diversified flood and drought resilience strategies at the river basin level. Current studies remain generalized, leaving a critical need for context-specific, empirical evidence that systematically analyses the governance failures and practical operational obstacles within high-risk basins, such as the Kelani River Basin (KRB), to inform actionable policy and improve resilience."

The primary objective of this study is to assess the problems and challenges in building river basin resilience to hydro-extremes (HEs). To achieve this, the research focused on three supporting aims:

1. To identify existing risk management plans for hydro-extreme events in the study area
2. To examine the issues and challenges in building river basin resilience to water-related extremes within the Kelani River Basin (KRB).
3. To provide policy recommendations based on the findings, aiming to improve resilience.

The rest of this paper is structured as follows: Section 2 describes the study area, data collection, and methods. Section 3 presents the study's results, followed by a discussion of these findings in Section 4. The paper concludes with policy recommendations.

2. METHODOLOGY

2.1. Study area

This study was mainly conducted in the Lower Kelani River Basin (LKRB), Sri Lanka. Sri Lanka is an island in the Indian Ocean, and KRB is located in the southwest part of the country (Vuillaume *et al.*, 2018). Between the 2001 and 2012 censuses, its population surged from 161,247 to 190,687, an increase of nearly 29,440 people. This dramatic growth has led to a rise in population density of 1,051 per km^2, highlighting significant demographic pressure on the area (Dept. of Census and Statistics, Sri Lanka) (Manawadu & Wijeratne, 2021; Fernando, 2010). The Kelani River originates from the central highlands called Horton Plains and Peak Wildness Sanctuary (Dissanayaka & Rajapakse, 2018; Wijeratne *et al.*, 2019; Wijeratne & Li, 2022) and flows through the west coast of the capital Colombo (Dissanayaka & Rajapakse, 2018). The KRB is the fourth-longest river and second-largest river basin (Chandimala & Zubair, 2007; Wijeratne *et al.*, 2019; Wijeratne & Li, 2022) in Sri Lanka, contributing 2,292 square kilometres (Wijeratne *et al.*, 2021). The KRB is criss-crossed by the northern latitude 6^{o}47' to 7^{o}05' and eastern longitude 79^{o}52' to 80^{o}13', and the starting altitude is about 2,250m above MSL. It drains over an approximately 145-km distance from the upper stream to the lower stream (Dissanayaka & Rajapakse, 2018) and consists of twenty sub-basins (Dissanayaka & Rajapakse, 2018). The Kelani River basin extends across the Western, Central, and Sabaragamuwa Provinces, flowing through six districts: Colombo, Gampaha, Kegalle, Ratnapura, Kandy, and Nuwara Eliya. The location map of KRB is shown in Figure 1.

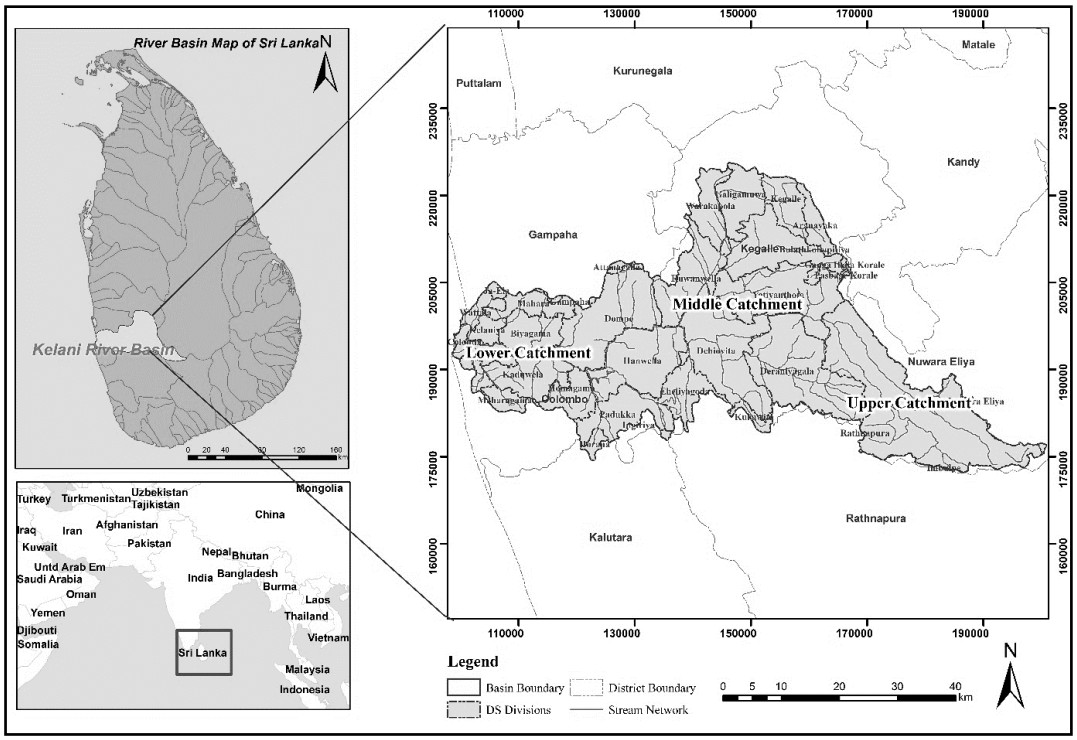

Fig. 1 – The location map of the study area.

Climate change and natural disasters, human encroachment and land degradation, industrial pollution, surface water and groundwater pollution, etc., can be recognized as critical issues in the LKRB (Goonatilake *et al.*, 2016). KRB is highly vulnerable to water-related disasters, and the severity and frequency of HEs have increased recently (Wijeratne & Li, 2022). A review of the disaster inventory database from 1974 to 2018 tragically confirms this, revealing regional flood impacts that include 458 deaths, 238 injuries, 7,038 house destructions, and 545,220 house damages, collectively causing millions in economic losses and profoundly underscoring the adverse toll of flooding on the area. Historically, it has functioned as the backyard of Colombo City, evolving into a multicultural and multiethnic society. It primarily hosts warehousing and service sector activities and serves as a residential area for the city's low-income, working population. Many residents are employed in port-related activities and retail trade within Colombo's main markets. Over time, the area has accommodated a substantial volume of non-residential activities essential to the national economy, such as stores, container yards, electricity substations, and a major oil storage tank complex, which also generate significant local employment (Manawadu & Wijeratne, 2021).

2.2. Data and Methods

The study was conducted mainly based on primary data collected through focus group discussions and semi-structured interviews. Accordingly, 10 focus group discussions were conducted with overall 30 people from 10 Divisional Secretariat (DS) Divisions, specifically chosen for having a high number of flood-affected families. The selected DS Divisions were Colombo, Kolonnawa, Kaduwela, Homagama, Hanwella, Wattala, Kelaniya, Biyagama, Dehiowita, and Ruwanwella. Within these areas, 15 community members were randomly selected from the most vulnerable Grama Niladhari (GN) divisions to participate in the FGDs. This approach provided more precise insights into the challenges of implementing risk management plans in the most vulnerable areas around the LKRB.

In addition, 20 semi-structured interviews were conducted among experts in the disaster management field and community leaders in the study area. Eight experts were selected based on their knowledge and experience in the field, alongside four disaster management officers and two academics. Moreover, six community leaders selected from the vulnerable areas were interviewed regarding the possibility to recognize challenges in building community resilience in the study area. All selected individuals had a minimum of five years of experience. The core research questions addressed the major difficulties in making river basins resilient to water extremes. A questionnaire survey was conducted to directly gather information on an array of topics, including extreme characteristics, the causes and impacts of frequent events, post-event conditions, short- and long-term effects, the reasons for wetland decline, and the migration patterns of inhabitants in the study area. The ultimate goal was to use the findings to formulate actionable policy recommendations for improved resilience.

The conceptual content analysis, ranking methods, and problem tree analysis were used to identify the key issues and challenges based on aims of the study. A problem tree is an effective tool for identifying and analysing the core problem, its causes, and its consequences.

This was achieved by engaging stakeholders during the FGDs and interviews to collaboratively build the problem tree. Participants in the FGDs shared their perceptions of the main issue, defining it as the central problem. Through guided discussions, they collectively brainstormed and prioritized the underlying causes (the roots of the tree) and mapped out the visible effects (the branches), exploring their social, economic, and environmental consequences. The interviews with key informants complemented the FGDs by providing deeper insights and contextual knowledge that might not have emerged in a group setting.

The collected information from both methods was then visually organized into a tree diagram. The causes were placed at the bottom, the central problem in the middle, and the effects at the top, which allowed for stakeholder validation and consensus-building on priority areas for intervention. To supplement the primary data, the study also included a literature review to identify the existing disaster management plans aimed at building community resilience throughout the study area.

3. RESULTS AND DISCUSSIONS

3.1. The Existing Water-related Risk Management Plans in the KRB

The structural and non-structural measures for flood and drought protections are recorded in the earlier histories of the country's establishment while still applying many measures to control and minimize the impact of water-related disasters. The structural steps are prevalent in Sri Lankan River basins. As the main river basin belongs to the country's capital city, many protection measures for the HEs could be identified from the past. Many national, international and river basin level structural and non-structural plans, decisions and contributions could also be examined. Resilience to disasters is the collective responsibility of all sectors of society, including governments at all levels, enterprises, non-governmental departments and individuals (Disaster Management Centre, 2015).

Both central and local governments in Sri Lanka are responsible for minimizing the risk of any disaster in the country. The Ministry of Disaster Management, the National Building Research Organization (NBRO), the Central Environment Authority, the Urban Development Authority, the Department of Meteorology and its sub institutes, alongside the Irrigation Department of Sri Lanka have primary responsibility as central government institutes together with the local government have also been recognized as the significantly responsible institutes for minimizing the negative impacts of floods and droughts.

"When recognizing the system of the Sri Lankan government, it consists of the multi-level system since the past. The current government system in Sri Lanka can be divided into 3 levels, including the President, Parliament and the Cabinet" (Country Profile, 2017). "The second tier consists of the Provincial Councils (PCs) headed by the governor and the Chief Minister, whom the citizens elect. The third is made up of the Local Government Institutes, led by the Chairperson or Mayor. The latter selects the citizens of the wards. The Sri Lankan local government system consists of Pradeshiya Sabha, Urban Councils and Municipal Councils. It currently functions with 276 Pradeshiya Sabhas, 24 Municipal Councils and 41 Urban Councils" (Country Profile, 2017). When considering the local government institutions, they have to play a vital role in city development and service delivery at the grassroots level.

"Local government institutions have been functioning under the Municipal Councils Ordinance No. 29 of 1947, Urban Councils Ordinance No. 01 of 1939 and Pradeshiya Sabha Act No. 5 of 1987. According to the list of the ninth schedule of the 13th amendment to the constitution of the Democratic Socialist Republic of Sri Lanka, PCs are established as a second-tier government in between national and local levels. Local government authorities will have the powers vested in them under the existing law. Provincial Councils started implementing some of their functions through Divisional Secretariats instead of supporting local government authorities" (Country Profile, 2017). The participation of local governments is more important than other governments because they are very close to the community and are responsible for the development of the city. Local governments are also better able to ensure that new developments comply with the flexibility of legislative towns and improvements in development activities (Chamindi Malalgoda *et al.*, 2010).

Under the structure of the above-mentioned government, the KRB has much experience in hydrological extreme management and water resource development, and flood control history could be identified from many years ago. Embankments/floodwalls and storage reservoirs were more critical. Flood control measures are more common in the KRB than drought control methods.

It is essential to discuss the national level decisions and actions taken for HEs, and an Act was introduced in 1955 for flood protection by the Irrigation Department of Sri Lanka. Later it was revised by the Ministry of Disaster Management of Sri Lanka. The maintenance of irrigation canals, drainage networks, illegal constructions, and unauthorized land reclamation have been considered in this Act (Dissanayake *et al.*, 2018; Wijeratne & Li, 2022). This Act is valid at the national level, and was also essential for the KRB. In addition, several flood control projects were implemented during 1930 and 1960 to protect the lower basin from floods. Significantly, the minor flood protection scheme for the left bank was deployed between 1930 and 1960. This flood protection scheme has been constructed in

Ambatale, Ranala, Bomiriya, Hewagamuwa, Henpita,Weliwita, Akarawita areas, and Kaluaggala-Berendi. Eighteen minor flood schemes have been set up during this period as well as another minor flood protection scheme on the right bank from 1934 to 1959 in the KRB. Mainly ten minor flood protection schemes have been undertaken for Talawaththa, Patiwila, Yabaruwela, Pahuru Oya, Mora Ela, Welgamuwa, Giridara, Nikawela, Pugoda, and Minimaru (Arumugam, 1969).

In 1948, San Francisco, the international engineering company, deployed the flood protection proposal. This was for flood control in the KRB and the hydropower reservoir at Glencourse combined with a levee system downstream of the Kelani River. However, the study done by Dr. Mylvaganam in the Irrigation Department rejected the above proposal considering that inundation of land can occur after construction at Glencourse, and has proposed instead the construction of four reservoirs further upstream and a levee on the lower river basin (M. L. S. Dissanayaka & Sangasumana, 2017b).

Moreover, the Colombo North and South flood protection scheme is also essential, and this has been implemented for the KRB in 1925 and 1926, respectively. As high and densely populated lowland areas, Colombo's north and south required more protection from floods. Therefore, the Colombo North flood protection scheme has implemented two floodwalls with four lock gates and a storm water drainage system. To prevent and minimize the impact of floods, the Kolonnawa Bund, containing four pairs of lock gates, has been established in the Colombo South. Preventing floodwater from entering the homelands and the evacuation of stream water during the flood events are the main targets of these constructions (Arumugam, 1969). The Colombo South has been implemented to drain Thalangamuwa, Nawala, and Battaramulla.

The other main minimization project proposed for the KRB flood control was the diversion canal project in 1950. The Irrigation Department of Sri Lanka has proposed a 1,000m-wide canal to divert the flooded water to the sea from Peliyagoda so as to minimize the impact of extreme floods in the lower KRB. The literature has indicated another KRB scheme in 1961. This scheme was for the multi-purpose development of the KRB, and three dams in Holombuwa and Nawata-Pusella area have been proposed. The flood control of the whole basin will partially retain the flood discharge in the dam while building a 100 km long dam system from Pugoda to Colombo (the distance between dams is 600 to 900 meters). The construction of the dam system alone required the relocation of 32,100 people. None of the recommendations made in the above-mentioned report have been implemented, mainly due to the high cost and social impact (Ministry of Disaster Management and Human Rights and Department of Irrigation, 2009).

Additionally, the Kelani River flood protection study was conducted in 1992. As the first stage, a mathematical modelling technology was applied, and DHI operated this under the Danish International Development Agency from 1990 to 1992. Flood control measures are proposed by dividing the target areas into three categories: Colombo and its surrounding areas, rural population centres and agricultural areas. It is worth noting that the study decided to focus on providing separate flood protection for some particular areas rather than providing flood protection for the whole river basin in the initial stage. According to the preliminary research results, the construction of a flood control reservoir and river embankment was rejected (Ministry of Disaster Management and Human Rights and Department of Irrigation, 2009). Furthermore, the western river basin sector project in 1999 also considered flood management and land use and environmental conservation in the KRB.

The national disaster management plan introduced in 2014 mentioned that the Disaster Management Centre (DMC) of Sri Lanka should be incorporated into the Disaster Impact Assessment (DIA) in the Environmental Impact Assessment (EIA) procedure for every construction in the disaster risk zones in Sri Lanka. This was very important for the flood-prone and drought-vulnerable areas in the overall KRB (Dissanayake *et al.*, 2018). Furthermore, the Parliamentary Consultative Committee of the Land and the Land Development Ministry has drafted a national policy to protect water resources.

Moreover, the 2014–2018 Sri Lanka Comprehensive Disaster Management Programme was introduced by the Ministry of Disaster Management to build a safer Sri Lanka. The main objective was to ensure the resilience of communities through long-term disaster risk reduction, and integrate them

into development planning processes at all levels. In addition, risk governance and increased investment in building resilience are the main areas of the Sendai framework for disaster risk reduction (SFDRR 2015–2030). The government of Sri Lanka has agreed to work to build a safer country (Disaster Management Centre, 2015).

The settlements established in the floodplain areas could be identified as the main problem of incrementing the severity of floods. Therefore, many decisions were taken and a plan was built for the displacement of settlements distributed along the river flood plains several times over. As a result of this, in 2001, the National Involuntary Resettlement Policy (NIRP) has been approved by the Cabinet for recognizing the shortcomings of the Land Acquisition Act, which can take action to protect people who will be displaced following any projects (Dissanayake *et al.*, 2018). In addition, following the tsunami, Sri Lanka established, in 2005, the National Disaster Management Committee under the Disaster Management Act No. 13 of 2005. In 2007, the resettlement authority was established under the resettlement Authority Act No. 09 of 2007. The National Housing Development Authority also empowers and enables the resettlement of displaced and potentially displaced persons. "The Ministry of National Housing (MNH), the Ministry of National Housing Development (MNHD), the Greater Colombo Economic Commission (GCEC), the Urban Development Authority (UDA) and some agencies also retain various authorities to formulate housing policies and organize housing projects on behalf of the government to target the affected population. Despite these Provisions, these institutions have developed a number of local and international resettlement guidelines" (Sidarran *et al.*, 2018; Manawadu & Wijeratne, 2022). However, these plans were not successful. It is essential to have new measures and plans for implementing displacement programmes and standardize minimizing anomalies in infield practice. Furthermore, a directive on landslides and housing was launched in 2017. However, these many management and resettlement plans at the national level for HEs have triggered different issues in the KRB. Still, the KRB is highly vulnerable to HEs.

More recent comprehensive studies and projects can also be recognized for mitigating the risk of floods and droughts in the KRB. In 2009, comprehensive research on disaster management in Sri Lanka was conducted by the Ministry of Disaster Management and Human Rights and the country's Department of Irrigation with the collaboration of the International Cooperation Agency of Japan. This was done to identify the current channel capacity, the experienced maximum flood peak discharge and future land use conditions. This master plan would be in place for 15 years, from 2010 to 2024. Activities related to flood management were expected to remove the vulnerability and risk of floods in the KRB. This study identified the unprotected areas of the KRB by comparing previous studies and projects conducted in the KRB. Different criteria have been included in this master plan, mainly made up of an early warning and monitoring system (with the installation of automatic water level and rain gauges in association with community-based involvements), dam and reservoir schemes (considering proposed plans in the past), and minor flood protection schemes (improvement of existing 44 structures in Colombo and Gampaha side and new constructions). This study was very detailed and practical because this has developed considering the previous studies, plans and projects of the KRB. However, according to the follow-up, the KRB is still facing the same problem, and new techniques and construction methods have been introduced after this study.

Forty-four existing sluices can be identified in the Kelani River, divided into 20 locations for the right bank and 24 for the left bank. In addition, with the results of the abovep-mentioned plans and studies, flood bunds have been constructed along the Kelani River between Talwatta, Peliyagoda in the North Side (Gampaha). Moreover, two dams can also be recognized. However, as the Ministry of Disaster Management and Human Rights and Department of Irrigation (2009) mentioned, a total of seven sluices out of the 44 had been damaged, and flood bunds were seriously eroded and need to be reconstructed and repaired. Therefore, the above-mentioned comprehensive study conducted in 2009 has proposed a new flood bund for the Kelani River. However, this has still not been implemented.

Moreover, as non-structural measurements, the early warning and evacuation system has been installed in the KRB following the JICA project. In addition, eight rain gauges and six water level gauges

have been installed in the KRB. However, the Department of Irrigation still only issues data for the seven stations. If there were more studies and plans for flood mitigation in the KRB, many gaps and problems could be identified.

Although flood mitigation studies are prevalent in the KRB, a lack of drought mitigation plans was identified. The most recent studies and plans are for flood and drought mitigation in the KRB due to the recent drought trend of the area, as discussed in Chapter 4 of this study. The most recent ongoing project of Strategic Environmental Assessment (SEA) for the KRB focuses on proposing HEs controlling methods. This study was conducted by the Climate Resilient Improvement Project (CRIP) with the support of the World Bank for the lower KRB (CRIP, 2018; Ministry of Agriculture, Rural Economic Affairs, Livestock Development, 2019; Wijeratne & Li, 2022). This project targets mainly diversion channels, embankments through the critical lower Kelani River, reservoirs to be introduced, and potential river regulation to improve conveyance through improved reservoir operations. Although the primary phases of this study have been concluded, the implementation part is still not complete, and due to the issues of funds, it has been temporally stopped. This has been confirmed following the expertise resulting from the interviews conducted during the study.

Another ongoing project for HEs management in the KRB is to construct a pumping station, and new stormwater tunnels for Colombo Metro have been implemented by the Ministry of Defence and Urban Development. This will help stormwater discharge to the sea and minimize the disproportionate impact during the flood seasons in the lower KRB. Furthermore, the Kolonnawa stormwater drainage and environmental improvement project also can be identified as another recent project to conduct for flood control in the KRB. There are stormwater drainage systems in the area, namely the Kittampahuwa and Salalihini Mawatha canal systems. All of these main targets are to minimize the floods in the KRB. This can be identified in two ways in the KRB. The first is overland flooding caused by the overflowing of the Kelani River, which was studied by CRIP, and the second was inland flooding caused by high rainfall in an area studied at a macro level by the Metro Colombo Urban Development Project (MCUDP), which is now implementing channel improvements to the Kiththampahuwa Canal. Kolonnawa is the most vulnerable area for floods in the KRB, and the current flood management planning is implemented in the Kolonnawa area by SLLRDC.

In addition, further projects currently being implemented and completed by the Metro Colombo Development Project for Flood Control can be recognized as the construction of a floodgate with the culvert near Thalangama tank, the construction of a culvert at Baudhaloka Mawata, a pump station at St. Sebastian South Lock, Kolonnawa canal diversion scheme – stage I, II, III, and IV, a pump station at Ambatale and the improvement of Norris Canal.

Despite the fact that many studies, plans, and projects were conducted to control the impact of floods and droughts, the KRB is still facing the most severe floods and droughts every year. As Dissanayake *et al.* (2018) pointed out, there are many weaknesses in implementing measures for minimizing HEs and future sustainability. The government has announced that it will take the necessary steps to dismantle unauthorized buildings, which are the leading cause of many victims of recent HEs. Without enhancing the powers of local governments and corrupt practices, the delegation of responsibility to local governments has been recognized as the leading factor of illegal encroachments in Sri Lanka. This has led to blocking the implementation of disaster management plans.

As overviewed by the Ministry of Disaster Management and Human Rights and Department of Irrigation (2009), implementing disaster management plans is challenging on the short-term. It requires long-term studies, while also blocking these implementations on time due to different social and environmental issues. The terms “flood control” and “flood Management” are misleading, at least for the public. The essence of extreme events is that the protection or control of really violent floods is never complete but always partial. The effectiveness of each flood control dam or wall and each reservoir is limited. This also varies with national and local government policy and according to the prevailing geographical conditions. Therefore, very practical and successful studies/plans are necessary to control the risk of human-induced water-related extremes in the KRB. Without controlling the pressure of different anthropogenic activities on the river basin environment, the risk of HEs and impact cannot be controlled.

3.2. Main issues and challenges to build river basin resilience to water-related extremes in the Kelani River Basin

Disaster management is not a new concept to the KRB, and the flood control methods have been deployed and identified since 1920. However, people are still suffering from hydrological extremes in the river basin. The most severe recent flood after 1989 took place in 2016. However, many minor flood events occur every year in the KRB. Based on the community's answers, more than 50% confirmed that the annual floods in the KRB, and around 15% (those who live in the urbanized areas) are experiencing floods often. People in drought-prone regions have said that they face meteorological droughts every year, but that they are not as severe as floods in the KRB.

Vulnerability increases when looking at the annual impact of floods and droughts in the river basin. Therefore, it is essential to examine the problem and challenges of controlling the risk of human-induced HEs in the KRB. According to the literature, community perception, and expert interviews, ten significant issues and challenges were recognized. They are as follows: the continuous human-induced impact, legality and political issues, insufficient funds, the lack of adequate technology, guidance, and physical resources, development and planning, the inadequate involvement of human resources, instructional problems, the lack of knowledge and dissemination, the lack of social capacity. Many of the issues and challenges identified above can be mitigated by implementing risk management plans and developing infrastructure that is durable and adaptive to future challenges (Fig. 2).

These problems and challenges, summarized in Table 1, are detailed in the next sections.

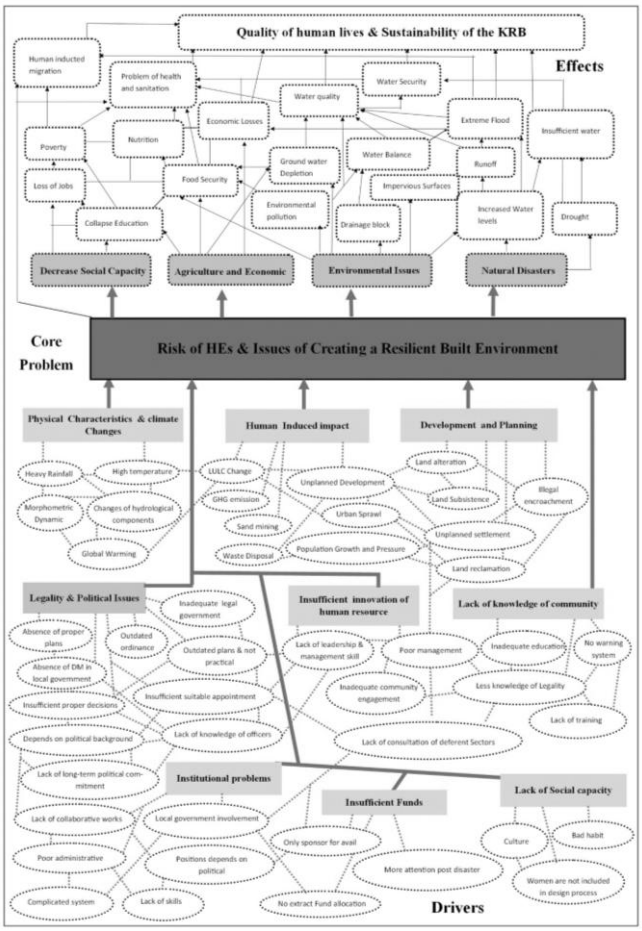

Fig. 2 – Results of Problem Tree Analysis.

Table 1

Key issues of and Challenges to build river basin resilience to water-related extremes in the Kelani River Basin

Issue	*Cause in the KRB*
Insufficient Funds	**Lack of Pre-Disaster Funding** Funds are mostly allocated for post-disaster assistance (calamities) rather than critical pre-disaster plans (e.g., prevention, awareness, long-term construction).
Legality and Political Issues	**Outdated and Inadequate Ordinances** Municipal Council Ordinance (e.g., No. 16 of 1947, last updated 1987) lacks disaster management as a prominent role for local government. **Political Interference** Decisions, appointments (often unsuitable), and the continuity of disaster plans are frequently changed based on political shifts, hindering long-term commitment.
Institutional Problems	**Poor Inter-Agency Collaboration & Mandate Gaps** Central and local governments, NGOs, and other sectors (e.g., waste management authority) work separately on floods and droughts. The local government fails to enforce core mandates like **non-maintenance of drainage systems** and **unplanned solid waste disposal**, which directly increase urban flooding.
Insufficient Involvement of Human Resources	**Lack of Skilled, Technological Capacity, and Continuity** Appointments, especially in local government, are often based on political decisions, leading to officers lacking the required **skill, training, and experience** (e.g., weak leadership). High turnover and poor record-keeping (e.g., lack of computerized data or even basic five-year records) sabotage long-term planning.
Development and Planning Issues	**Uncontrolled Lowland/Wetland Reclamation and Encroachment Absence of systematic urban planning** has led to rapid urbanization, land alteration, and widespread **illegal and legal construction in lowlands and floodplains** (e.g., low-income settlements along flood bunds). **Urban-to-Suburban Migration Pressure** is stressing the middle catchment.
Continuous Human-Induced Impact	**Unmanaged Land Use/Land Cover (LULC) Change** Conversion of natural vegetation to impervious built-up surfaces increases surface runoff (aggravating floods) and raises surface temperature/dry days (aggravating droughts).
Lack of Knowledge and Dissemination	**Absence of Community Awareness & Warning Systems** The vulnerable community (especially low-income groups) lacks knowledge on the nature of HEs, legitimacy of land use, and, critically, **does not receive effective flood warning alarms** (e.g., only police inform city areas; some are damaged while sleeping).
Lack of Social Capacity	**Behavioural and Cultural Barriers** Social groups exhibit varying responses to risk (e.g., reluctance to move to safe areas), poor sanitation/waste disposal habits, and exclusion of certain groups (e.g., women) from the decision-making process, all of which hinder collective resilience efforts.

3.2.1. Human-induced impact

Significantly, the land use and land cover (LULC) changes impact HEs, which can still not be managed within the river basin. Most of the natural vegetation has been converted to build-up lands, industrials or homelands. This has caused an increase in impervious surfaces, and directly impacted the

increment of surface runoff. Therefore, flood extremes cannot be prevented with these LULC changes in the KRB. The lack of natural vegetation has caused an increase in the surface and air temperature of the river basin and it has increased the number of dryland days in the river basin. Unplanned development and urban expansion are other significant problems in the river basin created by human intervention. The urban sprawl of the river basin is increasing rapidly. Land alteration and land subsidence have a negative impact on extreme wet and dry events in the river basin. This is also very difficult to manage and a significant challenge of implementing the risk management plans in the KRB.

In addition, the population growth and pressure exerted on the basin from the urbanized area are other main challenges of HEs management in the KRB. This area is the highest population density area in a long time. However, recently, population pressure has been exerted from the urbanized areas to the suburbs in the river basin. This has created many issues around the city, and the river's floodplain has been covered with unplanned low-income settlements.

Solid waste disposal has also mainly influenced floods in urban areas, and it has caused the drainage system to block. Therefore, without waste disposal management methods, disaster management is challenging in the river basin. A long-term impact has created short-term or sudden management plans that are unrealistic in the KRB. Without proper strategies or activities for rapid human intervention, creation and sustainability efforts will not succeed. Therefore, human intervention in the KRB is a major problem in implementing risk management plans.

3.2.2. Legality and political issues

The "legality and political issue" group identified eight significant challenges, including the following: lack of proper plans, outdated plans, outdated ordinance, inadequate legal framework, decisions based on political background, insufficient suitable appointments, poor appropriate decisions, lack of disaster management in local government, and a lack of long-term political commitments.

The legality and political issues are the significant challenges of risk management in the KRB, and according to the community perceptions, the major challenge is ***the absence of proper plans***. Therefore, proper techniques should be introduced considering all the causes influencing HEs in the KRB. Most of the ***plans are outdated*** and cannot be implemented with the current situation of the river basin. As an instance, flood bunds plans implemented around 1920 are very much suitable for that time, but in present day, those plans cannot be executed. Because the problems of the basin have changed and human intervention has increased, most plans are implemented after a long-time with management, funds and processing problems. Therefore, the output is not succeeded with such outdated methods.

Outdated ordinances are the other major challenge to implementing risk management plans in the KRB. This is a very common challenge for disaster management in the country. The expertise discussions have confirmed that most ordinances or Acts related to risk management are outdated. This is very well agreed for by the local governments. Local governments have a significant role in disaster management because they closely work with the community. However, due to these outdated ordinances, their role in minimizing the risk of HEs is insufficient in the study area. As Chamindi Malalgoda *et al.* (2016) pointed out, municipal councils are governed by the municipal council ordinance no. 16 of 1947, which was updated in 1987. However, disaster was not the main topic of this ordinance. Therefore, as confirmed by the expertise, the ordinance should be revised by adding disaster management as the prominent role. That will be more effective than the enrolment of the central government to minimize the risk of HEs in the KRB. In addition, ***the inadequate legal framework*** is the other main challenge in this risk management implementation. According to most interviewees involved in disaster management, the central government holds most of the authority, while local governments lack sufficient capacity to manage risks effectively. These gaps are highly impacted by reducing the effectiveness of the disaster management plans in the area. As the community of the study area confirmed, there is a significant lack of contribution on the part of the local government (Pradeshiya Sabha). They mainly deal with post-

disaster management and are responsible for calamities during that period. However, an adequate legal framework should be introduced to implement a sustainable management plan in the study area. According to expert opinions, although the central government has sufficient authority for risk management, they have not shown enough involvement to minimize the risk. In terms of the community perceptions of the study area, the central government (Disaster Management Centre officers at the local level) contribute more during the disaster but not in the pre-disaster period. All community leaders have further confirmed that most impact can be prevented if they apply proper plans during the pre-disaster stage.

Furthermore, according to the interviewees, ***disaster risk management should be added to the local government***. As mentioned above, they have a limited contribution during the post-disaster stage in the study area but and a practically non-existent contribution regarding proper plans. This post-disaster contribution is also insufficient, and there were have been complaints from the community for this improper service. According to experts, the idea is to introduce an appropriate role and authority for the local government so as to implement proper plans in order to minimize the risk of HEs in the study area.

The other main challenge is that most ***decisions depend on the political background***. Disaster management plans are changing according to the political climate. The disaster management supportive institutes, funds, ideas, and officers will change alongside the new government decisions. This is very common in the local government, and sometimes, unsuitable officers will be replaced. Therefore, ***sufficient proper decisions*** will not result from the ***unsuitable appointment*** in the disaster management sector. These legality and political issues can be recognized as significant risk management challenges in the KRB.

3.2.3. Development and planning issues

The Kelani River flows through the country's Capital, and has been the primary business centre for a long-time. Therefore, it is very common to have many developments and significant construction around the city. However, due to the ***absence of systematic planning and development*** in the urban and suburban areas, HEs are on the rise. Unplanned urban development and ***land alterations*** directly impact the water balance components and the hydrological process. Another major challenge consists of ***lowland reclamation and illegal human land use*** in the river basin, as well as unplanned urban development. As community leaders of the study area confirmed, there were many lowlands/wetlands in the area around the 1970s and 1980s.

Moreover, they have mentioned that the population is increasing and land alteration has started after the 1990s, leading to a rise in illegal constructions and settlements in the area. The government has tried several times to displace these illegal constructions, but it was not possible due to the political commitments in the area. The experts who participated in the interviews confirm that most of the study area's illegal and legal human encroachment is a significant challenge impacting the implementation of the risk management plans in the study area. For example, the observations confirmed that most low-income settlements are established along the floodwalls or bunds. According to the respondents of most interviewees, there should be a proper and long-term plan to control these illegal or legal constructions in the lowlands and floodplains in the KRB. This is a challenging task and should be allocated more funds for the resettlements, while the social and economic impact of the vulnerable people should be taken into account. As mentioned by the experts in this field, this is a long-term process, and without taking any suitable decisions to control this problem, minimizing and preventing the negative impact of this is not successful.

The most recent problem is ***population pressure as exerted from the urbanized area*** on the suburbs, and given the rapid development, the demand for land has increased. Therefore, most people are drawn to the suburbs. Thus, suburbs (the middle catchment of the river basin) are becoming the most prone to the risk of HEs in the KRB. The rural-urban migration concept has converted recently into the urban-suburbs migration. People are migrating due to the inadequate facilities in the rural areas, and most institutes in the country have aggregated to the Colombo district. As a result, people from all over

the country are drawn to the city, and the population pressure in this area is growing by the day. According to the interviewees, the facilities and administrative procedure should be equally distributed throughout the country to minimize this problem, as this is a significant challenge regarding disaster management implementation in the KRB.

3.2.4. Insufficient funds

Disaster management requires considerable fund allocation, and as a developing country, Sri Lanka still cannot allocate sufficient self-funds. However, during this time, many international fund sources can be identified for disaster management in the KRB. Still, these funds are also not permanent. As confirmed by the interviewees, some projects in the KRB have stopped due to funds issues. Therefore, insufficient funds are a significant challenge for implementing disaster management plans in the KRB. If the local government has funds, those cannot be allocated due to lack of authority. The community of the study area mentioned that they "*do not know the responsible officers for the disaster management and most of them come to our area after floods-provide disaster relief. However, these are also not equally distributed among the people. In addition, NGOs' contribution to this area is minimal. However, after the flood of 2016, most of us received money assistance for rebuilding after the huge impact, but it was not sufficient*". Therefore, many issues could be identified regarding funds allocation in the area.

According to experts in the field, adequate funding is generally available during the post-disaster phase, mainly through contributions from local governments, NGOs, and individual or community initiatives. However, there are also no proper plans, and all of them depend on the political needs of the different areas. Therefore, the government should be allocated enough funds for risk management in the KRB. The most important thing is preventing the risk of HEs in the area, and the fund allocation is more critical during the pre-disaster plans than the post-disaster assistance.

As confirmed by the questionnaire survey, there is no insurance plan for the vulnerable community, no bank loan methods or any other way to receive enough funds for rebuilding and adapting to the risk. Pre-preparation is essential for minimizing the risk of HEs in the study area. The government should allocate funds for deploying the pre-awareness programs to make people aware of the risk in the area.

However, as confirmed by all the interviewees, the insufficient funds allocated for risk management are the major challenge for implementing management plans and creating a resilient building environment in the KRB.

3.2.5. Insufficient involvement of human resources

Sufficient and suitable human resources are the primary requirement of risk management. However, many deficiencies can be recognized. As discussed above, most appointments of the disaster management sector (especially in the local government) are assigned by political decisions. Therefore, most of them do not have the skill, training, and experience for disaster management. As confirmed by the ***interviewees, the leadership and management skills of the new appointments in this field are very weak***. As they mentioned, "*they do not even have a map of the risk area, and most statistics have still not been computerized. Proper risk analysis and implementation are very weak in the study area, with the majority lacking continuous five-year records, which is a dire situation*". This could be confirmed by speaking with disaster management officers stationed in the study area. "*We still don't have a computer at the office*," they said. "*We have only written logs*". When asked about the previous data, some offices said, "*I am newly appointed to this area, and the previous officers did not keep records. So, I can only give you two- or three-years' records only*". This is the current situation of disaster management in the KRB. More than 75 respondents to the questionnaire have confirmed that they did not become aware of the data, maps or work available in the offices. The expertise of the field has identified ***that lack of technology usage*** and ***lack of technological knowledge*** is a significant challenge of risk management in the KRB. In addition, as expertise shows, qualified appointments are the primary requirement of disaster management in the study area. They should be appointed after the training on disaster management.

Moreover, ***the lack of consultation of the community*** is the other challenge in disaster management in the area. The community has many experiences about the situation. The expertise also confirmed that the community involvement of the disaster management sector is essential. Because it is simple to communicate with the community through community leaders, however, this has not worked well in the study area in recent times. Some areas have started forming and training community groups, but several issues still remain. As community leaders mentioned, "*Recently, in our area (Kolonnawa), disaster management officers and development officers in the Divisional Secretariat Office have conducted a training session for a young group for disaster management. In our opinion, this group should consist of people of different ages. Most mature persons have experienced disasters and can quickly react to them. The other problem is that most very young people can leave the area with a different purpose. Therefore, another group should be trained. That will lead to wated funds. The officers should also consult the community. Then we can assign a suitable person for this. Officers are assigned for this post not for the long-term, and after they get transferred, new officers start the same task from the beginning all over again. Therefore, appropriate human resources are needed to minimize this risk of floods*".

Therefore, assigning the most suitable appointments with outstanding qualities for leadership, management, and disaster risk analysis with technological capabilities is essential to implementing long-term risk management plans.

3.2.6. Lack of knowledge of the community

Community awareness is an important part of risk management. Unfortunately, the community of the KRB's knowledge of disaster management is deficient. As mentioned by almost all the respondents, they ***have never had any awareness programme or training*** for disaster management in the study area. Most of them are willing to participate in such programmes. As confirmed by the expertise, awareness programmes are vital to minimize the risk of the river basin. Most people who live in low-income households do not have a proper educational background and have no idea of the nature of HEs and their long-term impact. Therefore, it is essential to be aware of them. Due to the improper education background, people lack knowledge about the legitimacy of lands. Consequently, they are tempted to settle and construct illegally. Most experts have confirmed this, and the lack of community knowledge is a significant issue in the risk management of the study area.

In addition, there should be a warning system for flood alarms. However, the community of the vulnerable area does not know about that. The community explained, "*we have never experienced the flood warning system, and during the 2016 flood the police informed the city areas, but not us. We knew about the flood and its magnitude by experiencing it ourselves, and sometimes the GN Officer helps us be aware of such events. We care to know about the floods during the heavy rainy days so that we may move to safe areas. Sometimes floods come and cause damage while we are asleep*". Therefore, community awareness is essential to minimize the risk and impact of HEs in the KRB.

3.2.7. Institutional problems

As identified with the help of the interviewees, ***some institutes do not complete their tasks***, which means that they can indirectly impact the risk for the area. For example, unplanned waste disposal has led to the increase in floods in the KRB. The waste management authority has been given to the local government, and they are responsible for it. As mentioned by a community leader, "*The major problem for floods in this area is a non-maintenance drainage system and the unplanned waste disposal. The responsibility for these lies with the local government, which is not dealing with this properly. We have informed them several times, and sometimes we post this problem on social media. However, we still do not have a proper answer to this issue. This waste and drainage problem has increased the risk of floods in this area, and we need a proper solution to control them*". Adequate funds and responsible authorities have been allocated within local governments to promote and maintain a clean urban environment.

However, this is not appropriately conducted in the area. This is also the main challenge for risk management in the KRB. As confirmed by the expertise, the government should pay more attention to the drainage and waste problem in the study area.

As identified through the expert interviews, the ***lack of collaborative work*** is another major problem for implementing risk management plans in the KRB. The central and local governments work separately on this subject, as do NGOs and other private sectors, which are also making a separate contribution to disaster management. There are many plans for floods and droughts at different institutional levels. As a good example, during the post-disaster period, the local government worked separately and distributed calamities. The central government has also done this separately and provided their own contributions, according to availability, as have NGOs and other entities. The opinion of all experts contacted for this study mentioned that collaborative work is essential for disaster management, and the ***poor administration*** of each institute creates these issues. Their plans and systems have changed according to their political commitments. The institute's ***complicated systems*** create a barrier to implementing risk management in the study area.

3.2.8. Lack of social capacity

As some interviewees explained, some social barriers negatively impact risk management and the sustainability of the KRB. According to the ***culture*** of different people in the country, the involvement in and responses to the risk are very different. Sometimes people do not understand the situation. For example, some groups do not like to move to a safe area during the disaster, and some need individual attention. Their contribution also varies when it comes to minimizing the risk. In addition, sometimes ***women are not included in the decision-making process***, which causes issues with the management plan implementation in the study area. Moreover, some people living in urban areas do not care about sanitation, waste disposal, and ***bad habits***. These social barriers also negatively affect the risk management of the river basin.

Without overcoming these problems in the river basin, it is challenging to implement a sustainable plan to minimize the risk of HEs in the KRB. Due to these problems, many other effects can be recognized as having the risk of HEs. This risk has negatively affected the social capacity, agriculture and economic sectors, and the environment. Consequently, it will lead to a depreciation of the quality of human life and the natural environment of the KRB.

3.3. Recommendations for building a resilient community in the study area

Considering all of the challenges and recommendations made during the data collection process, the study proposed risk management strategies for reducing the risk of HEs in the LKRB. The KRB has a long history of disasters. However, there is still a risk and it has not been mitigated successfully. Therefore, this study has identified eight key areas in which a proper risk management framework for the LKRB may be developed. The seven key areas have been defined based on observations, literature reviews, previous studies, expert knowledge, and community perceptions. The seven key areas are *identifying and assessing*, *reviewing gaps and issues*, *planning*, *implementing*, *mitigating and adapting*, *monitoring and examining*, and *continuous learning and updating*. They are illustrated in Figure 3 below.

The first strategy deals with ***(1) identifying and assessing integrated risk profiles*** in the KRB. As a highly urbanized area, the risk assessment and management approach should be unique. Therefore, before introducing any mitigation measures, the risk of the study area should be identified, and risk areas ought to be assessed. The vast reorganization of collaborative risk profiles is essential for risk management in the study area. The current situation of HEs, frequency, magnitude, severity and future characteristics should be assessed for developing a sustainable plan. The risk of the past, current and future should be concerned with the collaboration of expert analysis. In addition, risk areas should be recognized for risk management implementation.

Moreover, there is a requirement to identify the previous work in the study area and current strengths, opportunities and issues under the risk profile. The broad overview of the risk of HEs in the study area is beneficial for sustainable risk management in said area. Therefore, the first component is very important for continuing the disaster management process in the study area. This should be done at the study area level, and it leads to a high effectiveness of the disaster management plans.

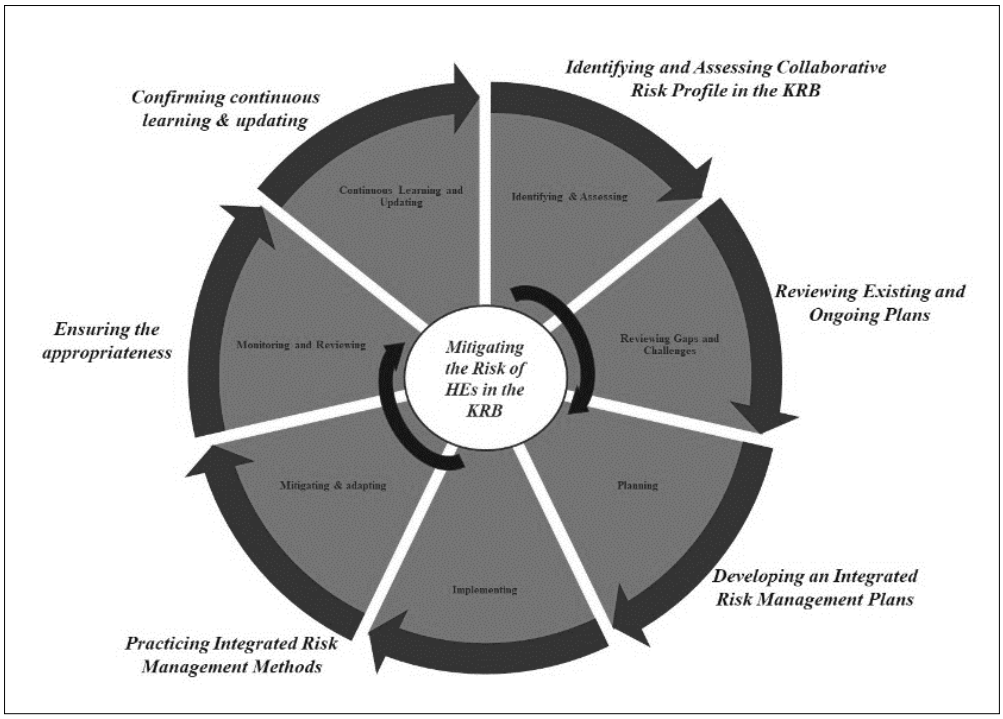

Fig. 3 – Results developed using FGS and interview data. Developed by author to present the recommendations.

The second is ***(2) reviewing gaps and challenges***. The historical view of the disaster management process can be reviewed at international, national and river basin levels. The review of international risk management plans can be beneficial for developing a more effective one and identifying previous mistakes. The global setup and guidance should be incorporated into the local risk management plans. In addition, there were many studies and implementations for risk management in the county and the KRB. However, the risk is increasing on a daily basis. Therefore, we need to review previous studies and plans, which have been implemented at the national and study area level. This is very important for identifying gaps in previous plans and all the challenges caused by implementing risk government plans for minimizing the risk of HEs. All the gaps in and challenges to implementing risk management plans in the KRB have been identified in this study so as to develop this integrated risk management plan. Rapid human intervention has been recognized as the main challenge, as other instructional, political, and social problems were identified. This new risk management framework has attempted to consider all the challenges and potential sustainability.

(3) Planning is the third strategy of this risk management framework. After assessing the risk and reviewing gaps and challenges, the following process should be developed as an integrated risk management plan for the KRB. There is a long process for planning the risk management in the study area.

The first step of the planning process is developing a national policy framework for HEs. The national-level new policy framework is essential for river basin level plans. However, international attention is significant when introducing a new policy framework. Therefore, the global policy and

agreement introduced for risk management should be considered before introducing a new national policy framework because the policy framework should be specific for the mitigation of HEs.

Before developing a risk management plan, all rules and regulations should be specified and updated because there are many issues with the country's policy, rules, and regulations. As previously mentioned in this chapter, there is no disaster management among the local authorities and many political commitments. These challenges should be minimized by introducing a new national-level policy framework, rules and regulations before planning the risk management in the study area.

After verifying all policies, rules and regulations at the national level, the next step is to confirm the National Sustainable Development Goals (NSDGs). Those should be achieved through the policy frameworks and risk management plan. Therefore, the policy framework should be considered, alongside environmental policies, risk management policies, land use policies, and development and institutional policies for a sustainable management. The management process ought to relate to the following nine out of the seventeen NSDGs in Sri Lanka in order to build future sustainability in the KRB by implementing the risk management plan.

Goal 01: *Find poverty in all its forms everywhere*
Goal 02: *End hunger, achieve food security, improve nutrition and promote sustainable agriculture*
Goal 03: *Ensure healthy lives and promote well-being for all people of all ages*
Goal 05: *Achieve gender equality and empower all women and girls*
Goal 06: *Ensure the availability and sustainable management of water and sanitation for all*
Goal 09: *Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation*
Goal 11: *Make cities and human settlements inclusive, safe, resilient and sustainable*
Goal 13: *Take urgent action to combat climate change and its impact*
Goal 15: *Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, end and reverse land degradation, and stop biodiversity loss*

(Department of Census and Statistics, 2018)

The use of all NSDGs, as mentioned above, will lead to sustainability.

After finishing the policy-making process, a comprehensive river basin master plan can be introduced. The river basin master plan should consist of a specific plan for urban development, land use, lowland management, resettlement, and risk management. Achieving sustainability and disaster risk-free river basins is not enough to implement only disaster management plans. It should be integrated with other development plans. The reason is that, as identified in this study, rapid human intervention and land alteration is the main problem, and practical strategies are needed to minimize such issues in the river basin. Recent concerns regarding wetland degradation, illegal encroachment, land subsidence, unplanned waste disposal, and non-maintenance drainage problems can be minimized by implementing a sustainable urban development plan. In addition, land use and low-land management plans need to introduce sustainable land management, and resettlement plans should be introduced for all displaced low-income households established in the floodplains and lowlands. The combination of all these elements will be essential for future sustainability.

The next step is to introduce thematic plans through the master river basin plan. The thematic plans for the risk areas can be introduced through the DS Division level. Specific sub-risk management plans need to be identified, and the resettlement and risk management in the DS division level in the KRB should be considered as the goals.

The planning process will take time, and all relevant government and non-government sectors, NGOs, experts in the field, community leaders, and the study area community should communicate during this stage. This collaboration consists of gender, race, religion and other social equality.

(4) Implementation is the fourth strategy, which can be carried out after developing both a comprehensive river basin master plan and thematic plans. However, practical exercises or pilot testing are needed before full implementation. This should be achieved using different social groups in the study

area. Making mistakes during practical application is an essential part of the learning process. Following all modifications and corrections, the plans for ***(5) mitigating*** the risk of HEs in the KRB can be implemented. The situation can change over time. Therefore, ***(6) monitoring and reviewing*** are essential during this time. This will help to achieve long-term success. The expert group responsible should be assigned to the ***(7) continuous learning and updating*** of the process and planning in the KRB for minimizing the risk of HEs. This will be processed in a circulatory fashion.

The above process has been described in Figure 4. The proposed strategies will be helpful for practical use and for the decision-maker to take any action in the future so as to mitigate the risk of HEs in the KRB.

To sum up, the study adapts these nine SDGs by integrating them into the planning stage of the risk management framework, effectively transforming them from abstract national objectives into specific, measurable outcomes for the Kelani River Basin. The key to adaptation is ensuring the River Basin Master Plan and its constituent plans (urban development, land use, resettlement) are designed to achieve these goals *specifically* through the lens of HE mitigation. By aligning the master plan with these nine goals, the study ensures that development activities in the KRB are not just short-term fixes, but contributors to long-term environmental and social sustainability, thereby preventing human actions from continuously increasing the risk for HEs.

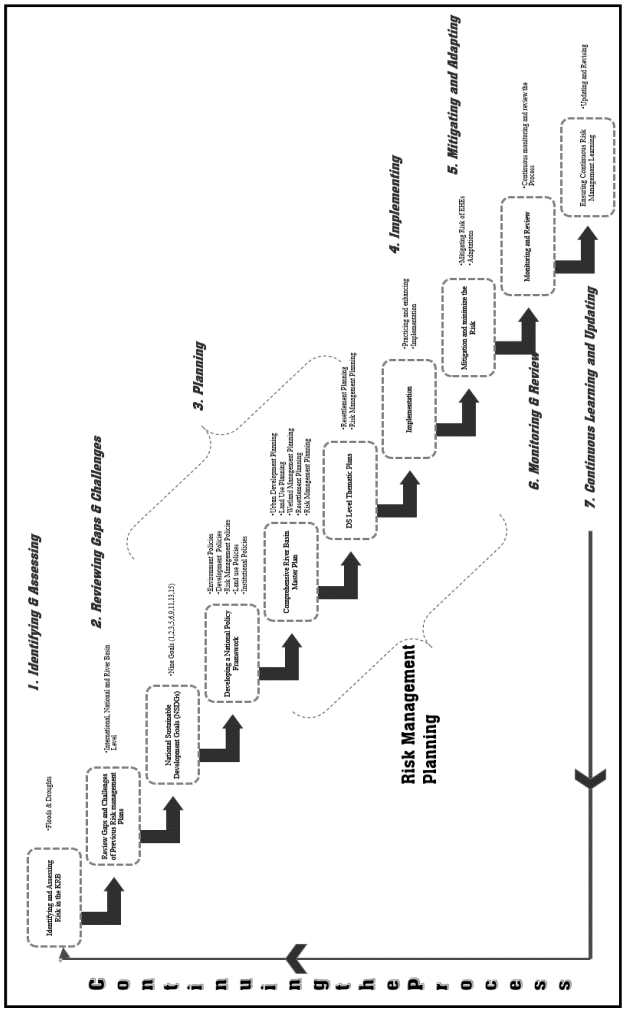

Fig. 4 – The Detailed Risk Management Framework for Mitigating the Risk of HEs in the KRB.

4. CONCLUSION AND POLICY IMPLICATIONS

The risk of HEs in the KRB increases on a daily basis due to rapid human intervention. Despite the many studies and plans for mitigating this risk, the KRB is still at high risk. This study mainly examined the problem and challenges for implementing risk management in the LKRB, and the framework to minimize HEs through field observations, literature reviews, focus group discussions, and interviews conducted in the area. The problem has been summarized using the problem tree analysis and eight critical challenges of the risk management process in the KRB have been identified. In addition, under those eight key challenges, the study recognized more than fifty sub-challenges in the study area. The key challenges were identified as follows: human-induced impact, development and planning, legality and political issues, insufficient involvement of human resources, lack of community knowledge, institutional problems, inadequate funds, and the lack of social capacity.

In addition, based on community perceptions, experts' and community leaders' opinions, and previous studies, this study recognized the most appropriate recommendations to minimize the challenges identified above. Finally, this study introduced seven key strategies: identifying and assessing, reviewing the gaps and challenges of existing studies and plans, planning, implementing, mitigating and adapting, monitoring and reviewing, and continuous learning and updating. The findings and the proposed framework will be essential for decision-makers to take the necessary action to reduce the risk of HEs and build future sustainability in the KRB. The framework must directly address the identified core challenges, including human-induced impacts, development planning flaws, legal/political issues, insufficient human resources, the lack of community knowledge, institutional weakness, and funding issues. Overall, effective risk reduction for hydrological extremes (HEs) in the Kelani River Basin (KRB) requires a comprehensive, integrated, and continually adaptive framework that shifts focus from isolated disaster response to addressing the root causes through coordinated planning and governance.

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