Evaluation of Community Resilience Aspects of Sri Lankan Coastal Districts

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***Abstract*— This research is carried out to evaluate important community resilience aspects of coastal districts in Sri Lanka and to provide suitable recommendations to strengthen them. After carrying out an indepth literature survey and interviewing key personnel who are involved in the field of Disaster Management and Disaster Risk Reduction, existing status of the coastal hazards, multi-hazard assessments, early warning mechanisms, national policies, guidelines and efforts and regional cooperation were identified. During the literature survey, it was observed that Sri Lanka has developed a Hazard profile for the country and has an Early Warning Dissemination System which seems to function quite well by the book. What is more, the country is in the process of orienting the existing national policies and guidelines with the post 2015 global standards such as the Sendai framework and Sustainable Development Goals. Sri Lanka being a member of Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) and Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) depicts that the country has a good regional cooperation in terms of Early Warning. Even though Sri Lanka lacks efficient and sustainable resilience mechanisms focused on the coastal communities, national efforts are underway to build up the coastal resilience. Training and public awareness campaigns, efficient funds, properly maintained hierarchy and concern to the coastal ecosystems are some of the enablers identified in this study which are associated in building coastal resilience. Developing and updating a multi-hazard map, improving the interagency cooperation and driving towards a people-centred Multi-Hazard Early Warning System (MHEWS) are some of the recommendations given after the analysis**

***Keywords*— coastal resilience; early warning systems; hazard assessments; Sri Langkan coastal.**

I. INTRODUCTION

The effect of climate change has led to considerable losses due to climate-induced disasters in the world making most of the regions vulnerable to multiple hazards [1]. Recently, Asia compared with the other countries in the world has suffered from several disasters, which have made a significant impact on both the livelihood and the economy of the affected states. Sri Lanka being a tropical island has a coastal belt around the country comprising primarily congested communities, infrastructure, and fauna and flora, which are exposed to various hazards caused due to natural occurrences and human-induced phenomena. Cities in the coastal belt are rising the ladder of economic development and are under severe pressure resulting from various scenarios of development, population growth, human-induced vulnerability, frequently increasing coastal hazards of larger magnitudes and impacts of global climate change. These unrivalled changes are placing coastal communities at increasing risk from various hazards such as severe storms, storm surges and tsunamis leading to coastal erosion, flooding and environmental degradation.

Indian Ocean Tsunami of 2004 is the major coastal disaster, which devastated the infrastructure and livelihood in most of the coastal belt of the island. Then the Disaster Management Centre (DMC) and together with other agencies implemented several programmes to improve the community awareness and resilience with the increased capacity in tsunami-prone districts [2]. Furthermore, 2016 floods and landslides affected Colombo, Puttalam and Gampaha districts severely, while the number of affected families raised up to 800,000 in total [3]. 2017 floods and landslides, which occurred a year later, affected Kalutara, Galle, Matara, and Hambantota districts in the southern coastal belt of the island [4]. These events show that risk perception of the communities should be changed to encourage protective action against multiple hazards [5]. The lack of awareness about hazards, vulnerability, and deficiencies in capacity and response has led to this study to

address the intellectual and normative challenges in placing multi-hazard assessments, early warning and preparedness in the broader trajectories of societal behaviour in communities at risk.

II. Material and Method

To assess the condition of the community resilience of the coastal districts in the island, initially, an in-depth literature survey was executed to find out the plans, policies, assessments, and programmes prepared by several government bodies, research institutions, and nongovernmental organizations. Then the study was strengthened by interviewing eleven key professionals and experts who are actively involved in Disaster Management (DM) activities including academic staff of several Higher Education Institutes (HEIs). They were presented with a detailed questionnaire followed up by a discussion to gather information and knowledge. Altogether eleven expert data were collected, which provided sufficient information to come to a proper conclusion and provide necessary recommendations. The thematic content analysis was used to analyze the data under the key themes identified in assessing resilience in the study namely; coastal hazards, multi-hazard assessments, early warning systems, national policies and guidelines and regional cooperation. Then several conclusions were made and provided adequate recommendations to improve the community resilience in coastal districts in Sri Lanka.

III. Results and Discussion

The results and information gathered from this study are discussed under the themes mentioned in the methodology above.

A. Coastal Hazards

Coastal districts of Sri Lanka are vulnerable to several hazards including floods, sea level rise, coastal erosion, storm surges, tropical cyclones, oil spills, droughts, landslides and Tsunamis [6]. Variability of the return periods associated with respective hazards is the main characteristic to be considered in the coastal multi-hazard approach. When considering Sri Lanka, erosion and storm surge set off by the North East & South West monsoons have an annual return period, storm surges unleashed by cyclones are multi-centennial, and a significant tsunami can be even multi-centennial to millennial [7]. Floods are the most frequent disaster in Sri Lanka (37%) followed by strong winds, landslides, and cyclones [8]. Furthermore, when looking at the disasters in a percentage of a number of deaths point of view Indian Ocean Tsunami has the highest number of deaths with 39,143, which is a significantly higher value compared to all other disasters combined [6]. Furthermore, it has led to the decrease of a number of people who are involved in fishery-related industries and coir industry in the coastal belt of Sri Lanka [9]. Colombo floods, which occurred in May 2016 affected 54,248 families [3], and the floods in 2017 caused significant damages to the city of Galle where 40184 families have reportedly been affected [4]. Furthermore, coastal erosion has been identified as a major hazard along the densely populated southwest coastline of the country [10]. Moreover, Salinity intrusion in Colombo and Gampaha districts is becoming a primary concern at present [11]. The number of affected people due to various disasters from 1965 to 2017 shown in Fig 1 provides sufficient evidence that a significant impact was made to the coastal districts as well as to the country as a whole.

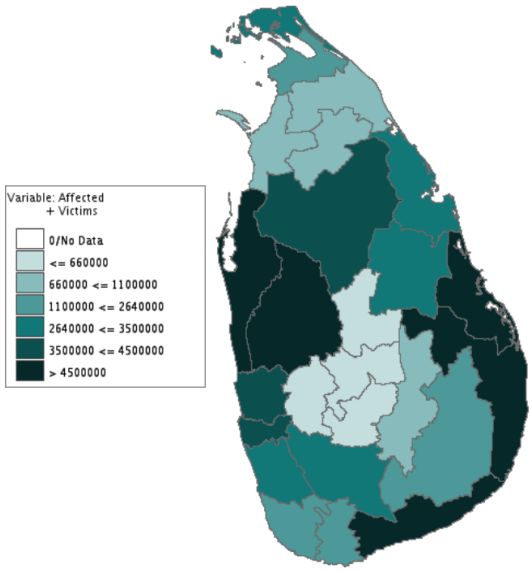

Fig. 1 Affected people from disasters (1965 - 2017)
Source: http://www.desinventar.net/DesInventar/profiletab.jsp

Also, M V Meliksha Incident was one of the leading oil spill events occurred near the Bundala coast which released fuel and fertilizer damaging the marine environment [12]. Furthermore, due to the sea level rise, National Hazard Profile shows that the Puttalam district will have additional 1113 ha inundated in 2037 [6].

The distribution frequency of the events, number of people affected, and loss of life due to disasters throughout the islands show that coastal districts are the most affected [13].

Information gathered throughout the interviews show that economic loss, displacement of the coastal communities, the effect on the water quality, and loss of habitats in estuaries are some of the critical impacts of the coastal disasters. Also, drought and saltwater intrusion, loss of beachfront properties, damage to the population, and rapid loss of land have also made a significant impact on the coastal belt of Sri Lanka. Additionally, the importance of handling Sri Lankan coastal hazards at both national and local levels was identified during the literature survey and interviews which is summarized in Table 1.

TABLE I
IMPORTANCE OF HANDLING COASTAL HAZARDS

National Level	**Local Level**
To issue accurate early warnings for the people to evacuate in time.	To evacuate and go for shelter during a disaster to reduce the loss of lives
By introducing proper policies, and legislation can protect the coastal	Community leaders can educate and guide people on policies and guidelines to be followed to make

communities from several hazards	them resilient
The tourist attraction can be increased to improve the economy of the country	Opportunities which will arise from tourism will ensure the development of the economy of the local villages
Can introduce advanced technology which will also assist the research and development work in the coastal hazards sector	Fishers, in local communities, can get early warnings in time for them to not to go fishing during storm surges or heavy rains
To make coastal communities aware of the hazards which they are vulnerable	Risk awareness and knowledge will help local communities to increase the preparedness and capacity

B. Multi-hazard assessments

At present, there are no any specific multi-hazard assessments being done for the coastal hazards in Sri Lanka. A multi-hazard map for the whole country by combining the individual hazard indexes for droughts, floods, cyclones, and landslides, with weighing hazards in different ways was developed in 2006, which is outdated now due to the climate change, potency and frequency of the disasters [14]. In the National Policy on Disaster Management under the section "Multi-dimensional approach," it has been highlighted that multi-hazards should be given consideration [15]. At present individual natural hazard mapping and assessments are finalized, and hazard profiles for coastal erosion, floods, drought, sea level rise, storm surge, tropical cyclones, and Tsunami were produced [6]. Furthermore, the deterministic analysis undertaken for Tsunami hazard focusing on the south-west coast of Sri Lanka [16], GIS-based flood risk analysis was done for a 50 year rainfall to develop an information systems for flood forecasting in the Kalu river [17] and the flood hazard mapping done for the lower reach Kelani river basin [18] are some of the hazard assessments done considering individual impacts of the hazards. The hazard prediction calendar in Sri Lanka prepared by Disaster Management Centre and other line agencies identifies the monthly variation of several hazards which provides a guideline for stakeholders to prepare for impending risks [19].

During the interviews, it was noted that Disaster Management Centre (DMC) and relevant technical agencies at National level carry out the hazard assessments. Sri Lanka as a country can carry out the hazard assessment work but what lacks is the advanced modeling software. Hence, most authorities work with the international agencies to carry out the assessments. Making hazard maps for selected districts available online assist the authorities and other interested parties to update and use them [20].

C. Early warning mechanisms

When handling a coastal disaster, Early Warnings (EW) play a crucial role to reduce the impact on the vulnerable communities. Department of Meteorology (DoM), Irrigation Department (ID) and National Building Research Organization (NBRO) are the leading technical institutions which are mandated to provide early warning messages to DMC. When severe weather conditions like heavy rainfall are expected, officers of National Meteorological Centre (NMC) and directors share the information, and a warning signed by the forecaster is issued to relevant agencies and media. The warnings are disseminated to DMC and pertinent other stakeholders [8]. DoM also gives marine forecast and city forecast on their web page so that users can quickly get the weather forecast online [21]. The ID informs the DMC the observed water level and rainfall by using FAX. The frequency of data transmission is once a day during normal times or every 3 hours during flood situation [8]. Also, flood warnings are issued based on the observed water level at 34 gauging stations [8]. NBRO manages over 100 rain gauges throughout the country. Based on rainfall data collected in these rain gauges, NBRO issues landslide warnings to DMC and public through the NBRO homepage [8]. Sometimes the vulnerable community can become the primary source of information to the responsible agency regarding an impending disaster.

Dissemination of the said early warnings from National level up to the grass root level is divided into four layers as shown in Table 2 [19].

TABLE II
EARLY WARNING DISSEMINATION LEVELS

Level	**Description**
National	EW messages from International and Regional Technical Agencies are received by the Emergency Operation Center (EOC) of the DMC. A national level EW message is sent to the emergency response committees where they have to pass the messages to the relevant organizations. Intra Governmental Network (IGN), Satellite and Radio Communication are some of the dissemination methods used
District	EW is conveyed via District Disaster Management Centre Units (DDMCU) to the District Secretariat, stakeholder agencies, and political authorities
Divisional	DDMCUs pass the EW messages to the Divisional Secretariats who will send the message to Search and Rescue teams, police and relevant local authorities
Grama Niladhari (GN)	Last mile communication tools such as sirens (Hand and Electric), temple and church bells, riders/ push bicycle and motorcycles/messengers and Early Warning Committees (Door to door) are used to send the EW messages to the vulnerable communities

Role of media is also significant as they cover the entire island easily through television and FM radios with more than 50 channels. During disaster situations, mass media notify the public with timely and factual information including guidance for the actions to be taken [19]. Furthermore, Technical Advisory Committees (TACs) which are appointed by National Council of Disaster Management (NCDM) must establish a proper chain of early warning of the disaster.

Disaster and Emergency Warning Network (DEWN) is the first GSM-based EW system which generally uses

accessible mobile communications technologies like short messages service (SMS) for early warning and cell broadcast (CB) to provide an efficient and reliable mass alert system. DEWN links relevant stakeholders including the general public to the EOC at DMC [22]. Even though the quick transfer of EW message is present in this method, the effectiveness is reduced due to the vague and unfocused information sent to the public. In addition, the community based early warning system project initiated by Sri Lanka Red cross identifies the importance to prepare the coastal communities to receive early warnings in time [23].

The existing early warning mechanism shows an increased response capacity where entire Eastern coastal community was evacuated within 55 minutes (March 2006) and 90% of the coastal communities were evacuated in 1.5 hours (April 2012) after issuing the Tsunami early warning [24]. Even though the Tsunami early warning mechanisms are strengthened the Post Disaster Needs Assessment of floods and landslides which occurred in May 2016, apparently identifies poor early warning and lack of flood modeling resulted in the almost total loss of household assets of the affected households [3]. Furthermore, Dodanduwa and Hikkaduwa fishery harbors not receiving the official red warning in time during the devastating weather hit on 29th November 2017 provides sufficient evidence of severe gaps in EW system [21].

During the interviews, it was noted that the locally available techniques and methods could be used effectively to manage village level early warning systems. In addition, providing training to community leaders in early warning mechanisms is also highlighted [25].

D. National Policies, Guidelines, and efforts

Before 2015, Sri Lankan government has taken necessary actions to amend the relevant Disaster Management (DM) plans and programmes to Hyogo Framework for Action [26]. At present, the country is in the phase of aligning the national policies and programmes with post-2015 global frameworks such as the Sendai Framework for Disaster Risk Reduction, Paris Climate Change Agreement, and Sustainable Development Goals. Also, according to the Asia Regional Plan [27], which provides a detailed guideline to implement Sendai Framework, alignment of national policies with Sendai principles is necessary; focusing on adherence with the international agreements for the development and climate action. To do proper amendments, professionals are in the process of evaluating existing DM frameworks in Sri Lanka [28].

According to the Sendai Framework data readiness review, Sri Lanka is planning to have Multi-hazard monitoring and forecasting systems at the beginning of the year 2020 which refers to the Global target G of the Sendai Framework [29].

Even though Sri Lanka signed the Paris Climate Change Agreement on 22 April 2016, the impacts of climate change to hazards were considered in the Comprehensive Disaster Management Programme which was prepared in early 2014 [2]. National Council for Disaster Management (NCDM), National Disaster Management Coordination Committee (NDMCC), Ministry of Disaster Management (MDM), Disaster Management Centre (DMC) and National Disaster Relief Services Centre (NDRSC) are the primary stakeholders, which are involved in the implementation process of global standards in Sri Lanka. Table 3 shows the existing policies and guidelines available in the country for Disaster Management (DM).

TABLE III
POLICIES AND GUIDELINES AVAILABLE FOR DM IN SRI LANKA

Name	**Description**
Disaster Management Act No. 13 (DMA)	Provide for the initiation of the NCDM and DMC to appoint TACs and to prepare disaster management plans [30]
National Policy on Disaster Management (NPDM)	Make Sri Lanka as resilient and safe as possible from disaster risks [15]
Comprehensive Disaster Management Programme (CDMP)	Ensure the Disaster Risk Reduction of the country which minimizes impacts on livelihood and the economy by providing a detailed investment plan with eight strategic components [2]
National Disaster Management Plan (NDMP)	Reduce disaster impact on communities, critical infrastructure, facilities, shelter, public properties, economic and development activities in Sri Lanka [31]
National Emergency Operations Plan	Provides Standard Operating Procedures and mechanisms allocated to all line agencies and emergency operation mechanisms during a disaster [19]
National Climate Change Adaptation Strategy for Sri Lanka	Lays out a prioritized framework to systematically guide Sri Lankans towards a disaster resilient future by identifying action and investment for the 2011- 2016 period [32]
Coast Conservation Act	Provide the legal guidance to formulate and execute strategies and plans for coast conservation within the coastal zone [33]
Coastal Zone Management Plan (CZMP)	Provides for Capacity building for management, control coastal erosion, facilitate integrated management of coastal resources, operating permit system and setback standards, monitor coastal water quality [34]
The Sri Lanka National Oil Spill Contingency Plan	Gives the scope, geographical coverage, and responsibilities related to the emergency response which may result due to an oil spill event which can harm the coastal belt of Sri Lanka[35]
Hazard Resilient Housing Construction Manual	The purpose is to promote the use of engineering design and correct construction practices to build hazard resilient houses. It is aimed at the national level [36]

National Guidelines for School Disaster Safety	Gives a detailed School Disaster Safety Plan which includes identification of hazards and resources, hazard assessments and awareness and training [37]
Implementation Framework for the Resettlement Programme in Kalutara, Galle, Ratnapura, and Matara	Guides the resettlement programme for the information of the responsible officers, who are involved in the resettlement process to ensure successful implementation [38]

In addition to the above District Disaster Response plans and divisional disaster response plans are also available. All the documents are available online for the public to access whenever they need to gather information.

Furthermore, Disaster resilient city development strategies for Sri Lankan cities have been introduced by UN-Habitat program to strengthen the community resilience of the cities and townships in disaster-prone regions of Sri Lanka. Mannar [39] and Batticaloa [40] are such two coastal towns, which will be made resilient under those strategies. Improving the physical environment of the city by developing sustainable urban drainage systems and adapting to the built environment as well as integrating social and economic development by enhancing community networks are necessary for city resilience [39].

Furthermore, Community Resilience Framework developed by DMC identifies governance and risk knowledge as the two main essential aspects of a resilience community [41]. In addition, a guide to assess the community resilience to coastal hazards which was developed by the US – IOTWS identifies several benchmarks for the resilient components mentioned in the guidelines for Sri Lanka [42].

When looking at the integration of these policies, guidelines, and frameworks to improve EW and coastal community resilience, interviewees mentioned that it is at a minimum, but provisions do exist. Considering the present status, Sri Lanka is mostly involved in post-disaster activities while the authorities must be proactive and focus more on Disaster Risk Reduction. Furthermore, DoM believes that for specific weather forecasting local area modeling is required. High-performance computer systems are needed to do said local area modeling to run high-resolution models. At least one model is needed for each province for better performance. Sri Lanka is included in the Regional Models and forecasting, but downscaling is required to give a localized prediction. Furthermore, weather dynamics in the tropical areas are not understood very well thus forecasting has become difficult to greater accuracies.

DoM believes that the application developed by DoM is said to be more accurate for weather forecasting in Sri Lanka compared to the "Accuweather" which is used worldwide. However, DoM needs to make it more attractive and user-friendly. DoM also have developed a High Heat Index (HHI) with the Ministry of Health that can be used efficiently in months April and May.

National Insurance Trust Fund (NITF) covers lives and properties up to LKR 2.5 million each in respect of damages (per event) caused to their property and contents due to cyclones, storms, flood, landslide, hurricane, earthquake, Tsunami and any other similar natural perils, excluding drought [40]. CCD believes that even though NITF is present, a focused insurance method for coastal hazards does not exist. Furthermore, National Planning Department (NPD), has not given priority to the coastal zone when making plans for public hazards. The professionals involved in Disaster Management sector believes that the release of dams and resulting sudden additions of water to the coastal area due to climate-induced floods; ocean acidification due to climate change and temperature relationship with EW must be considered when designing the Early Warning systems for Sri Lanka.

E. Regional Cooperation

There are several regional stakeholder partnerships to support effective EW systems and increase the disaster resilience of coastal districts in Sri Lanka. The island is one of the member states of Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) where DoM acts as the National Tsunami Warning Centre for the country [43]. Furthermore, Sri Lanka is one of the twelve member states of The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) which aims to establish a regional early warning system within a multi-hazard framework to initiate and convey early warning information, and build capacity to prepare and respond to trans-boundary hazards [44]. In addition, the country is also a partner of Regional Specialized Meteorological Centre (RSMC) for cyclones over North Indian Ocean, which will issue tropical weather outlooks and tropical cyclone adversaries in the WMO/ESCAP panel region [45]. The Coastal Community Resilience (CCR) is a focused initiative funded by Asian Disaster Preparedness Center (ADPC) that promotes tsunami and other hazard readiness via the dynamic cooperation of state and provincial emergency management agencies, coastal managers, training institutions, and local communities. Sri Lanka being a part of it will increase public awareness, create required standards and promote sustainable livelihood in the country [46]. Furthermore, Sri Lanka is a member of the Asia Pacific Alliance for Disaster Management (APADM), which is an agreement among the stakeholders in order to implement effective and efficient relief and recovery activities [47].

Sri Lankan experts also contributed in preparing the Tsunami Risk Assessment and Mitigation for the Indian Ocean to inform and assist relevant stakeholders at both local to national levels in assessment of the tsunami risk [48]. Coast Conservation Department (CCD) has taken part in several workshops where most of them were focused on Coastal and Marine Risk Mitigation Plans. During some these workshops, it was identified the fact that low-lying areas of Sri Lanka which are just above the sea level are likely to be hard hit by a sea level rise [49]. Also, CCD is also working with the Indian Ocean Ring Association (IORA), which has Disaster Management as one of the priority areas. Its member States are considering the cooperation in three main areas namely; early warning, disaster risk reduction and the establishment of regional response capabilities.

Some of the primary objectives of the regional cooperation of CCD is erosion maintenance, management of river outlets, Implementation of Coastal Zone Management Plan (CZMP) and obtaining assistance in the preparation of CZMP and guidelines. Sri Lanka should engage in regional dialogue and have mechanisms to incorporate geographical knowledge into the national efforts. Regional stakeholder partnerships can be efficiently used in capacity building and disaster response as well. Oil spills are one specific example that requires regional alliances and corporation. During the interviews, it was further noted that for slow-onset disasters like water or air pollution, efficient information sharing and related capacities are needed.

IV. Conclusions

The said results and discussion led to several conclusions regarding the community resilience of the coastal districts of the country. Productivity and efficiency of the existing EW systems are questionable considering the recent disasters while the identification of the impacts of coastal hazards at all levels is vital in upgrading them. The early warning mechanisms must be people-centered so that the relevant stakeholders will be adequately benefitted.

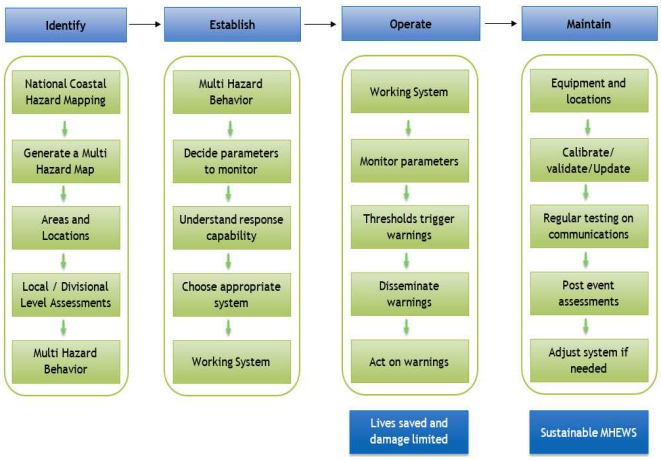

Fig. 2 Schematic representation of MHEWS

The suggested schematic representation of the people-centered Multi-Hazard Early Warning System (MHEWS) following the methodology stated in the Caribbean Handbook on Risk Management is given Fig 2 above [50].

In addition, the necessity of a multi-hazard assessment focusing on the coastal zone is identified which will lead to the upgrading of the existing hazard profiles, developing a vulnerability profile and a risk profile.

Furthermore, it can be concluded that current National policies and frameworks related to coastal hazards are yet to be aligned to the post-2015 global standards. When aligning the tendency to re-invent strategies and plans must be omitted, and the continuity is the key, which will eventually lead to a stable implementation. It was also noted that both soft and hard resilience mechanisms for coastal hazards must be upgraded to increase the capacity and preparedness of the coastal communities.

Training and public awareness campaigns, adequately maintained hierarchy, concern to the coastal ecosystems, diversifying possible hazard responses plays a pivotal role in capacity building of coastal communities. Furthermore, multi-stakeholder and multi-agency cooperation, coordination for the exchange of data and integrating local knowledge for Disaster Risk Reduction measures are some of the enablers identified from the discussion to improve community resilience of the coastal districts in Sri Lanka.

Disclaimer

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