

Citizen Science for supporting Disaster Management Institutions in Sri Lanka

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ABSTRACT

During 2016, 2017 and 2018, the country witnessed extreme rains which triggered flooding in several urban areas. The number of affected people by the 2018 floods was around 150,000 which shows a significant decrease compared to the events in 2016 and 2017. Several institutions provided their support via funding, relief, and rehabilitation mechanisms during these consecutive disasters. However, there are provisions which can further improve the performance of Disaster Management activities. Given this context, this study is carried out to investigate the application of citizen science concepts in several phases of Disaster Management in Sri Lanka. A scoping review supported by three case studies of floods was considered during the analysis. Limited participation of grass root level communities in decision-making and disaster planning, and issues related to data management are some of the main challenges identified in this study. Participatory mapping, Co-Design Projects, hackathons, and crowdfunding are some of the observed citizen science concepts which can be used to address the challenges and strengthen the Disaster Management activities in Sri Lanka. Further studies including interviews and questionnaire surveys were recommended to justify the findings.

Keywords

Citizen Science, Disaster Management, Crowdsourcing

INTRODUCTION

Citizen science is the participation of the general population in various stages of the scientific research process, such as data collection, classification, transcription, or analysis (Njue et al., 2019). Furthermore, it can be considered as a process where public communities engage in research design with professional scientists. Volunteer based monitoring (Deutsch & Ruiz-Córdova, 2015), crowdsourcing (Kankanamge et al., 2019), citizen observatories (Liu et al., 2014), participatory sensing (Guo et al., 2014), volunteered geographic monitoring are some of the many forms of public participation in science. Applying citizen science can take several forms, including top-down or bottom-up execution, implicit or explicit data provision, gathering of objective or subjective measurements, and the use of uni- or bi-directional communication paradigms between citizens and data processors. All these concepts share a broad perspective on the public's engagement in the co-generation of scientific knowledge and creates opportunities for collaborative learning (Wehn & Evers, 2015). History of citizen science dates to early 19th century as per the documentary evidence where volunteers in US were involved in rainfall measurements (Pfeffer & Wagenet, 2012). Due to the technological development in the past decades the growth of citizen science was exceptional due to the availability of smartphones equipped with web-based mapping tools and global positioning systems. The need for citizen involvement in environmental monitoring and decision-making has been further bolstered by the limited capacity and scope of monitoring because of reduced organization budgets in recent decades, increasing public awareness, the democratization of science, and concern about human induced impacts on biodiversity. According to the degree of influence and engagement in the scientific process, the common types of citizen involvement can be divided into five models as shown in Table 1 (Bonney et al., 2009).

Table 1. Five models of citizen involvement

	Description
Contract Projects	Communities hire experts to carry out a particular scientific investigation and report on the findings.
Contributory Initiatives	Typically created by scientists and mostly rely on data provided by the general population
Collaborative Projects	These are created especially by scientists, public provides data but also aids in project design refinement, data analysis, and/or dissemination.
Co-created projects	Jointly created by scientists and the public, in which at least some of the public participants actively participate in most or all stages of the research process.
Collegial contributions	These are made when people do independent research with varied levels of expectation of recognition by experts or institutionalized science

METHODS

Looking at these five models it is evident that they can be used effectively in Disaster management activities in Sri Lanka. Communities from both the urban and rural areas were affected by floods caused by severe rains in the past few years. To conduct the analysis for this research, three flood events which occurred in 2016, 2017 & 2018 were selected as case studies which caused a significant impact on both the livelihood and infrastructure in most of the administrative districts in the country. Following the methodological framework developed by Arksey H et.al, a five-stage, scoping review was carried out to find literature related to the study. The main research question was: *how to apply the citizen science concepts to support Disaster Management Institutions in Sri Lanka*. The relevant studies included several research papers, post-disaster needs assessments, guidelines, and incident reports. The documents were mainly extracted from electronic online databases and existing networks and organizations. The types of documents referred to are presented in Table 2 below.

Table 2. Types of documents studied during the analysis

	Description
Indexed Publications	ScienceDirect, Scopus, Web of Science, Wiley Online Library, and various other academic databases were searched to identify the white papers related to citizen science and the disasters which occurred in the country
Local Acts & Public Policies	These refers to the Acts by the Parliament and the other related policies published by the GoSL which have reference to Disaster Management (DM). National Disaster Management Act is one such example
Assessment reports	After each disaster, several agencies in Sri Lankan DM publish rapid and integrated post disaster needs assessments and situation reports. In this study the reports related to 2016,2017 & 2018 rains were referred. Furthermore, data collection surveys were also referred
National Guidelines & Maps	These are technical documents published by leading institutions in Sri Lankan DM which gives design guidelines and directions for various aspects in community resilience
International Reports & Indexes	Documents published by several international agencies like European Union, Red Cross, US- IOTWMS, ADPC etc were referred to get further information

The inclusion criteria were related to the types of citizen science projects and the year of flood events. Abstracts were not considered in the study as only full articles and reports were referred. Selected documents included references for citizen science projects around the globe and most of the reports related to the said floods were from Sri Lankan DM institutions. The documents were analyzed thoroughly to identify related practices and issues in DM sector of Sri Lanka. Findings were listed under the key aspects in Disaster Management namely; Development of Maps & Guidelines, Awareness campaigns, Policy Formulation, Multi-Agency Collaboration, Post Disaster Recovery, Mitigation measures and Community Relocation. The observations were mainly focused on the institutional engagements in the past and during these disaster events. On the other hand, global literature related to working citizen science projects and concepts were analyzed to identify how they can be of assistance for the proper functioning of the said themes. After the analysis, key areas where the citizen science concepts can

be included were identified and summarized. Since this is a working topic, further investigations are planned to identify the applicability of various citizen science concepts in Sri Lanka which include surveys and interviews with stakeholders from the grass root level to the top professionals. Then after these inputs, a pilot citizen science model will be designed and implemented in a selected vulnerable area, and it will be monitored to do further modifications.

RECENT DISASTER EVENTS IN SRI LANKA

The Gulf of Mannar and the Palk Strait divide the island of Sri Lanka from the Indian subcontinent, which is situated across the Indian Ocean. The country has a total land area of 65,610 km², which is likewise not very large. The island still contains a range of natural zones, including mountains, lowlands, tropical forests, and unique coastal belts. Most of the nation is made up of lower plains with an elevation range of 30 to 200 meters. The Indian Ocean Tsunami which occurred in 2004 is the most severe example of the frequent natural disasters that Sri Lanka experienced. Furthermore, tropical cyclones can occasionally cause storms, flooding, and landslides. Due to the timing and the number of monsoon rains affected by climate change, droughts are becoming more frequent recently (CFE-DM, 2021). Furthermore, Sri Lanka's overall disaster risk in the 2021 INFORM Global Risk Index was 3.6/10, placing the country in the medium risk category.

During 2016, 2017 and 2018 the country witnessed extreme rains which triggered flooding in several urban areas. The number of affected people by the 2018 floods was around 150,000 which shows a significant decrease compared to the events in 2016 and 2017 (Relief Web, 2019). 2017 flood event which damaged both the infrastructure and communities of the densely populated districts in Sri Lanka raised the number of affected families up to 630,000 (UNDP, 2017). In 2016, Kelani River, Kaluganga, Mahaweli River, Deduru Oya, Yan Oya, Maha Oya and Attanagalu Oya, observed increasing water levels, which caused widespread flooding. In 2017, Kalu, Nilwala and Gin rivers and their tributaries caused floods while the water levels reached 6m high and remained for a week. Kalu Ganga, Maha-Oya, Attanagalu-oya reached their flood levels during the monsoon rains that occurred in May 2018. Looking at these incidents it is evident that the Western and Southern Provinces are severely affected. Figure 1 shows the cumulative number of affected people and deaths in the administrative districts of the country due to the consecutive floods from 2016 till 2018.

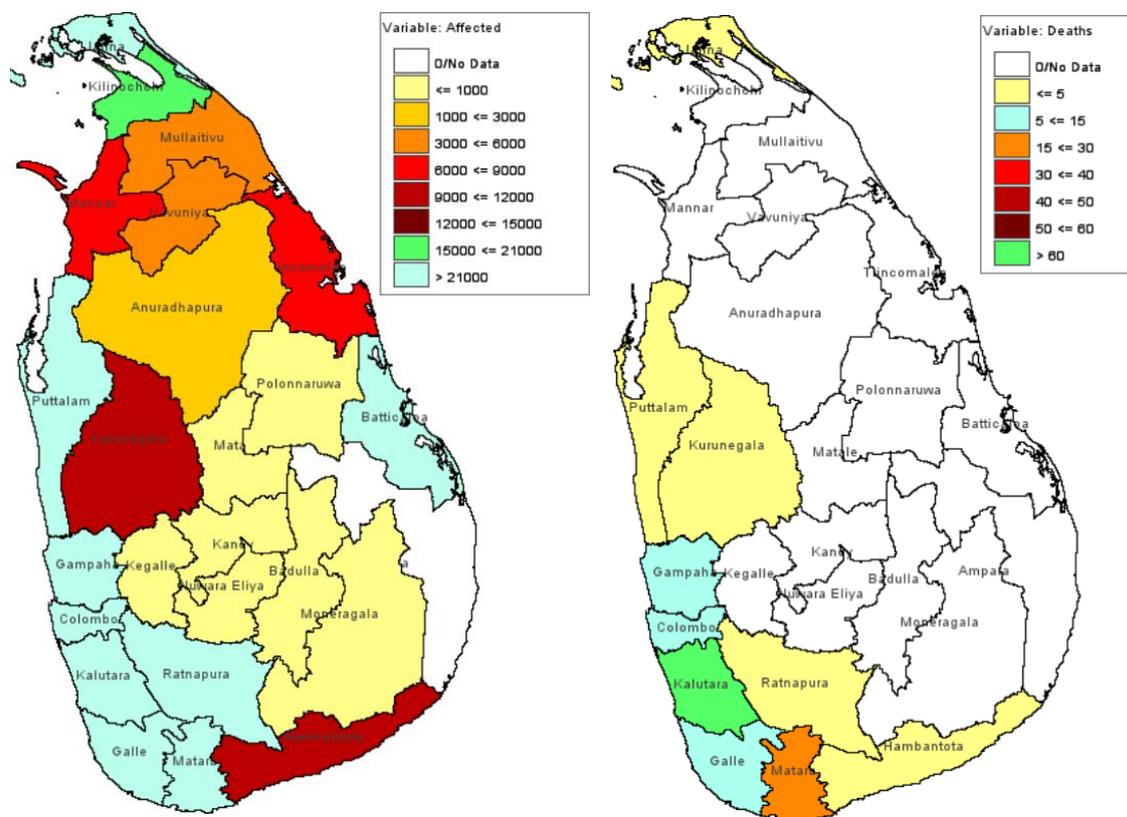


Figure 1. Affected people (left) and Number of Deaths (right) due to 2016, 2017 & 2018 floods (Source: <http://www.desinventar.lk>)

INSTITUTIONS IN SRI LANKAN DISASTER MANAGEMENT

Given this context, Sri Lanka is in the process of establishing a fully functioning multi-hazard disaster management infrastructure with the inclusion of both governmental, non-governmental and foreign institutions. The government institutions play the leading roles in every phase of the DM cycle. National Council for Disaster Management (NCDM) is spearheading the government authorities followed by the Ministry of Disaster Management (MDM) which was absorbed into the Ministry of Defense recently. The MDM, both in its day-to-day operations and during emergencies, must coordinate within its own Ministry, with line institutions in other ministries, and with the armed forces. As shown in Figure 2, during emergencies, the MDM is a centre of public attention, which performs a coordinating role in assisting other agencies, government, non-government, and private to contribute to the response, relief, and rehabilitation. Disaster Management Centre (DMC), National Disaster Relief Services Centre (NDRSC), Department of Meteorology (DoM) and National Building Research Organization (NBRO) are the leading technical organizations which function under the MDM for the implementation of government policies to achieve the global and national targets in Disaster Risk Reduction (DRR) for Sri Lanka. (CFE-DM, 2021).

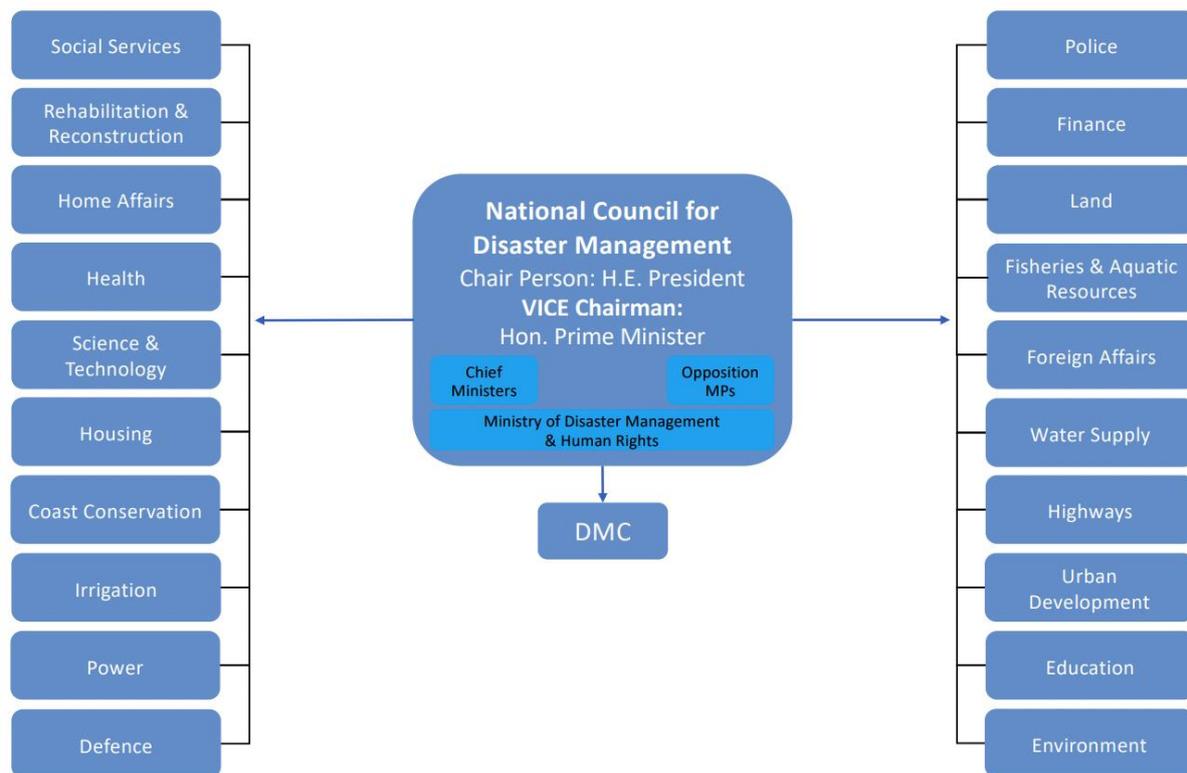


Figure 2. The organizational structure of the current Sri Lankan Disaster Management

DMC carries out several tasks including the formulation National Disaster Management Plan (NDMP) and National Emergency Operations Plan (NEOP), hazard mapping and risk assessment, development of preparedness plans, early warning, and dissemination activities. NDRSC is responsible for the support of disaster-affected people. It has dispatched Disaster Relief Coordination Officers to all the District Secretariats and Disaster Relief Officers to all the DS Divisional Secretariats. NDRSC could access the field disaster information immediately during a disaster with the information collection and recording system established. DoM is responsible for meteorological observation which became an affiliated semi-governmental agency of MDM in February 2006 (JICA, 2017). DoM issues the early warnings on heavy rainfall and cyclone and oversees issuing the tsunami warnings based on international meteorological information. The forecasting and Decision Support unit operates its 24/7 operation room while the Katunayaka airport office functions as the backup of the Colombo main office in case of the breakdown of the Colombo office. DoM also has 37 automatic weather systems which are deployed at regional Meteorological Stations and collaborative stations. DoM offers weather forecasts which include expected rainfall, temperature, and relative humidity. Furthermore, NBRO is the responsible agency for landslide countermeasures. NBRO installed automatic rain gauges and alarm systems in landslide-prone areas while forecasting based on rainfall, geological factors and other data helped vulnerable communities to evacuate in an event if the centrally issued early warnings fails. It also implements early warning, hazard mapping and structural and non-structural measures on landslides. Looking at flood management, Irrigation Department is responsible for the operation of rivers and reservoirs. It implements flood control via structural and non-structural measures.

While the government organizations play the leading role in DM, several Non-Governmental Agencies, and international organizations such as Red Cross, Sarvodaya, Asian Disaster Preparedness Centre (ADPC), United Nations & World Bank aid to build community resilience as well as aid in relief activities (CFE-DM, 2021). Furthermore, Higher Education Institutes (HEIs) also play a major role in DM. Their contributions to education and awareness, expertise, advocacy, research, and innovation are highly appreciated by the other organizations who are involved in DM. The tri forces and mass media are also actively involved in DM activities as well.

Each of these institutions is actively involved in every phase of a disaster event at their maximum capacities overtaking the difficulties they face. The next section of the paper describes their involvement in the said flood events, and they are summarized under the four themes of DM.

INSTITUTIONAL ENGAGEMENT IN CONSECUTIVE FLOOD EVENTS FROM 2016 TO 2018

Development of Maps & Guidelines

Preparing for a disaster while building community resilience is important and it is not a task to be done by the government alone. Multi-stakeholder participation is essential in achieving the intended outcomes. Preparation of Hazard and Vulnerability maps plays a major role in preparing for a disaster. In Sri Lanka, the National Hazard profiles (DMC, 2015b) were prepared in collaboration with several stakeholders including the expertise of HEIs. When looking at the limitations mentioned in the studies it is evident that most of the map's accuracy and coverage were an issue. Apart from preparing maps, there are several guidelines prepared by government agencies to transfer disaster knowledge to the communities. Hazard resilient construction manual (NBRO, 2015) is one such guideline which gives several tips to the communities on how to build resilient houses which could withstand floods.

Formulation of Policies and plans

In addition to the flood inundation maps and guidelines prepared by several stakeholders, the policies, plans and programmes related to Disaster Management play a pivotal role in the preparedness of the communities. At present, Sri Lanka is in the phase of aligning itself with global standards. National Emergency Operations Plan is a document which assigns clear responsibilities to the organizations and individuals on how to perform during a disaster (Disaster Management Centre, 2015c). Furthermore, the National Guidelines for School Disaster Safety (Ministry of Education, 2008) is another key document prepared by the MDM and DMC with the collaboration of the Sri Lankan-German Development Cooperation which provides guidelines to establish a school disaster safety plan. Evaluation guide of the coastal community resilience prepared from a collaborative project between local institutions including DMC, DoM and USAID give a detailed evaluative platform for the decision makers to assess the community resilience of the coastal belt of Sri Lanka (US IOTWS, 2007). The community resilience framework prepared by DMC also provides guidelines to assess the capacity and preparedness of local communities (Disaster Management Centre, 2015a). Even though these documents exist there seems to be a gap in using them effectively for the benefit of the communities in high-risk areas. Most of these guidelines are not fully implemented and understood at the grass root level. Due to this, even the most educated people in the communities seem to lack knowledge of disaster preparedness.

Multi-Agency Collaboration

Institutional fragmentation in the Sri Lankan DM sector has led to poor coordination of data management which hinders the effective preparedness of the country for disasters. Sharing of data between agencies is important to prepare effective community plans. Most government technical institutions lack the tendency to exchange data and technology which is necessary for the beneficial outcomes of the communities. Due to this scenario, the Colombo municipality area has several overlaps in functions and responsibilities when managing the drainage and canal system which was affected by 2016 floods (DMC, 2012). Furthermore, university-industry partnerships which enhance the involvement of HEIs with the industry can help in capacity building in both the technical institutions and academia in the field of Disaster Management.

During the 2017 & 2018 flood events, Dialog held a national campaign to receive customer donations for relief services. UN agencies and other national and international NGOs always come to aid during a disaster by providing funds for food security, provision of water and sanitation facilities and emergency livelihood support. During the 2017 floods as per the request of GoSL many foreign countries aided via the Ministry of Foreign affairs while countries like Bangladesh and Ireland provided direct financial support (UNDP, 2017). Several popular local and international agencies were involved in major recovery activities like cleaning wells, providing dry rations, supplying bedding and kitchen sets, distributing water bottles, non-food items and educational materials

and facilitating.

Chinese International Search and Rescue Team (CISAR), dispatched by the Red Cross Society of China (RCSC), set up relief camps in a suburb of Colombo during the 2016 floods. They gave quick training to 40 Sri Lankan soldiers and 10 reserves on the same day. The Chinese government provided emergency humanitarian aid which included camps, and folding beds to the flood-affected people. Also, Indian Navy officers sent relief items for the victims as well. In addition, relief donations were collected via social media. The public who was not affected by floods sent their donations to the flood victims via social media campaigns and mass media. The relief activities are well coordinated by NDRSC while using online methods to inform the public about which rations are necessary. In addition, some of the taxi services offer free rides during emergencies so that the affected people can evacuate quickly.

During the disasters relief operations are done with national and international assistance. Considering the recent floods, immediate rescue operations were undertaken with the aid of tri forces. Furthermore, the Government of Sri Lanka (GoSL) allocated around LKR 1 billion for immediate relief services which included the cleaning of interrupting roads and infrastructure (Relief Web, 2019). In addition, MDM opened a bank account to receive donations from private organizations and individuals which had a balance of around LKR 17 million at the end of July 2017. Other governmental organizations have also come forward to give donations, even though their main objective is not to cater for disaster crisis management activities. Some of such agencies are Sri Lanka Tourism Bureau, Divisional and District secretariats, Ministry of Science, Technology and Research, Ministry of Mahaweli Development and Environment, Presidential Secretariat, Government affiliated trade organizations and Ceylon Fisheries Corporation. These organizations have given their helping hand by providing dry rations, and essential items as well as by providing facilities and equipment such as boats, generators, and tents. Also, Sri Lanka tri-forces has been actively involved in many activities in man powering, from cleaning activities to facilitating the affected with transport arrangements while ensuring the security of the area

Awareness Campaigns

All these multi-stakeholder partnerships and guidelines would become a waste without proper community awareness. At present most of the awareness programmes are led by DMC and MDM, which sometimes are funded by Non-Governmental Organizations (NGOs) as well. Red Cross and Sarvodaya are two leading NGOs that conduct awareness programmes in Sri Lanka. These programmes include mock drills, participatory hazard mapping, first aid training, boat handling, camp management and identification of safe evacuation routes as well. The two-week disaster preparedness programme initiated by DMC during the mid of May focusing on eleven districts provided great assistance via transmitting knowledge to the local communities on how to respond to a flood event (Relief Web, 2019). This programme helped in reducing the number of affected people due to the 2018 rains drastically. In addition, when the 2018 monsoon rains occurred people started packing the most valuable things to them so that they can evacuate safely while carrying their belongings. This showed that people were aware of how to respond to an emergency.

Early Warning and Evacuation

It's crucial to comprehend how to get over the information hurdles that government and military organizations experience throughout a regular disaster response mission. The Joint Task Force leaders and staff will benefit from knowing the Humanitarian Assistance and Disaster Response (HADR) resources that are available while planning missions. Since no single responding body, NGO, international government organization (IGO), helping country government, or host government can be the source of all necessary information, information sharing is essential. During the flood incidents in 2017 and 2018 responses from the external parties have made a huge impact in reducing the number of affected people. Accurate Early Warnings (EW) are necessary for vulnerable communities to evacuate safely. The threshold level for issuing a flood warning is identified as the time at which the water level reaches the flood level in rivers or reservoirs which will be declared by the assigned technical agencies.

Both DoM and ID play the leading roles in issuing early warnings related to floods. Several stakeholders are involved in this early warning coordination process from the national level up to the grass root level. While DMC and other technical agencies work at the national level District Disaster Management Coordination Units (DDMCUs) operate at the district level while conveying information to the divisional level stakeholders. At the grass root level, NGOs and several other agencies provide their assistance to disseminate the early warning messages. The Emergency Operations Centre (EOC) of DMC acts as the centre for emergency services (Wijesinghe et al., 2011). There are standard operating procedures prepared for all the responsible agencies which guide them on how to act during an emergency. In addition, the Disaster Early Warning Network (DEWN) which was produced from a collaborative project between the University of Moratuwa and DMC provides a sustainable

GSM platform between DMC and Mobile network providers to send EW messages quickly to the key stakeholders via SMS (Wijesinghe et al., 2011). The DMC Call Centre is assigned with an emergency telephone number (117) which can be accessed free of charge for disaster-related assistance. EOC will provide appropriate advice and will link up additional resources, as required. The community-based early warning system initiated by the Red Cross also assists the local villages to support DMC to develop an effective early warning mechanism which eventually increases the knowledge of a respective community (Sri Lanka Red Cross, 2018).

Furthermore, the media plays a prominent role in the dissemination of early warnings in Sri Lanka, covering the entire island easily through television and FM radios with more than 50 channels. In addition, DMC directly coordinates with tri forces and police to pass the early warning notices to vulnerable communities. Military and Police posts which are located around the entire country to support this process. Even though Sri Lanka has proper coordination mechanisms as mentioned above, during the recent floods it was observed that there was no clear difference between the “Warning” issued by the central agencies and the “Evacuation Order” by the local administration. According to the Post Disaster Needs Assessments (PDNAs) done for the floods early warning systems should be enhanced by revitalizing DDMCUs with the participation of all ministries. Furthermore, when looking at the history, the inaccuracy of the early warnings can be observed which creates a tendency for the people to not trust the evacuation notices. Most people do not have any experience with evacuation drills which sometimes create chaos during evacuation. In Sri Lanka, most evacuation shelters are religious places since there are situated in hilly areas. Most people do not have a clear idea about the fastest route to those shelters. At the grassroots level Grama Niladhari (GN) plays an important role in disseminating early warning messages and establishing evacuation shelters and local EOCs. However, there were several deaths during these floods which could have been prevented if they have trusted the authorities and evacuated (UNDP, 2016). People should be made aware that their life comes first, and their belongings should be given minor recognition during a disaster.

Post Disaster Recovery

After a disaster occurs well-coordinated recovery activities will ensure the return of the local economy to a sense of normalcy. When comparing the 2016 and 2017, flood recovery needs in both the social and infrastructure sector were risen by a considerable margin (UNDP, 2016). GoSL is always leading the recovery, reconstruction and rehabilitation processes following the Build Back Better approach in the Sendai framework. In addition, the health facilities are looked after mainly by the Ministry of Health (MoH) supported by DMC. During these floods health personnel quickly mobilized for emergency patient services for the victims while establishing mobile health camps and undertaking preventive measures to contain the spread of diseases Disease surveillance is strengthened in the affected districts while the generated reports were transferred to MoH for monitoring and action. Cleaning of wells in the affected houses will ensure the supply of clean water to the communities. The Sri Lanka Red Cross engaged in these activities with the aid of the Sri Lankan and US armies. National Housing Development Authority (NHDA) is taking care of the reconstruction of the houses for the affected communities. During the initial recovery phase, damaged sluice gates and irrigation canals were repaired to enable the recultivation of crops. Ministry of Agriculture (MoA) is leading the role of executing the recovery plans for crops which were supported by MDM, Ministry of Mahaweli & Environment and Ministry of Irrigation. The monitoring team ensures that collected data is shared with the respective parties such as UN agencies like FAO and WFP. The education facilities were assisted by the Ministry of Education (MoE) while collaborating with UNICEF and other NGOs. Army troops also came forward to sew uniforms for flood-affected Students in Kolonnawa, which included a total of 7000 students in 10 schools during the 2016 floods (Sri Lanka Army, 2016).

When looking at the compensation amounts allocated for floods, GoSL had decided to give LKR 10,000 to each flood victim in Colombo and Gampaha areas in 2016 and the amounts paid for compensating deaths is about LKR 100,000 (UNDP, 2016). In addition, the Cash-for Work project done collaboratively with Oxfam provided satisfactory revenue to around 80 flood-affected people during 2016. Furthermore, people who worked 6-day jobs received relief supplies in addition to a cash payment. Flood-affected women were happy to receive kitchen utensils which replenished a part of what they had lost. Sri Lanka Navy personnel also assisted in helping the clean-up process. Furthermore, more provisions were given to the families who were estimated to have damages worth less than LKR 10,000, also the small and medium enterprises were compensated as well, in a similar method in which the damaged houses were compensated.

Mitigation Measures

After each flood incident, several mitigation measures were undertaken in several districts following the global agendas including the Sendai Framework and Goal 11 of Sustainable Development Goals backed by the Build Back Better approach. In the PDNAs prepared by DMC the importance of mainstreaming DRR in the construction industry has been highlighted to build disaster-resilient houses. Under the Metro Colombo Urban Development

Project, several measures were undertaken to convert Colombo into risk free city of floods. Implementation of two micro-drainage projects, improvement of primary canals and increasing the drainage capacity of the gravity system by 100 cubic meters are some of the objectives of the project. Under this project Beddagana wetland was turned into a park which will aid in flood control and temperature moderation for Colombo (Denipitiya & Udalamaththa, 2020). Flood risk modelling and identification near the Kalu ganga basins are carried out by the funding assistance of Japan International Cooperation Agency (UNDP, 2017).

Community Relocation

Despite the actions taken by the governmental authorities, community engagement plays a vital role in the success of the mitigatory actions. However, it was evident that at several places, people are reluctant to change their place of livings from the near riverbanks to another place. It should be noted that these groups of people are illegal residents in the riverbanks. Although the relevant divisional secretariat proposed a compensation scheme of LKR 5000.00 per family per month for six months to facilitate families with rent, until they get a permanent place to live, in a safer place, that scheme was rejected, reasoning that the compensation is not adequate, and claiming that they won't be able to continue their livelihoods as before. At the same time, there were complaints against some individuals of the affected community, for being unconscious about the hazard situations and for not taking the precautionary actions against floods. Therefore, it is highlighted that the awareness of the people should be enhanced in some cases, and forcible actions should be taken where necessary as well, by the authorities.

HOW CAN CITIZEN SCIENCE ASSIST?

After the analysis of the engagement by the institutions in these events, it was identified that the efficiency of most of the key activities can enhance by utilizing citizen science concepts. In this section, the suggested improvements based on the documentary study are expressed in Table 3. In addition, references of the successful citizen science projects outside Sri Lanka were given, so that decision-makers can get input when they are developing local citizen science models and projects.

Table 3. Citizen Science Concepts to improve the current practices

Current Practice/ Issue	Suggested Improvements
Preparation of Hazard, Vulnerability and Risk Maps are done mostly by the technical institutions individually (Development of Maps & Guidelines)	A community-based participatory mapping can be initiated to reduce the cost of travelling in distant areas. People who are willing to engage can be equipped with modern technologies and trained to update the data online to a common platform. OpenStreetMap is one such platform which can be used effectively (Brovelli et al., 2020).
Development of guidelines and plans are done with the limited participation of grass root level communities (Formulation of Policies & Plans)	Since these are designed to serve the vulnerable communities, their input is essential. A cross disciplinary approach is needed and can implement a Co- Design project where a government institution can take the lead while the community groups can share their personal experience. However, precautions should be taken to avoid hindering of sustainability outcomes of the projects due to Citizen involvement. (Wamsler et al., 2020)
Data Management is mostly within a particular institution and multi-agency collaboration is minimum (Multi-Agency Collaboration)	Institutions like DoM can educate citizens and encourage them to establish voluntary rain gauges and use the GPS locations of their mobile devices to do local area modelling, where the citizens can also provide data to other institutions when needed. CoCoRaHS (Reges et al., 2016) and mPING (Elmore et al., 2014) are two such working models which can be used as a guidance develop a new model for Sri Lanka
Awareness campaigns are led by government organizations and NGOs and most of them are organized in a central location (Awareness campaigns)	If the decentralized awareness campaigns are not feasible, with the help of a crowdsourcing platform; relevant institutions can collect citizen reports on disaster incidents which will make them aware about the incident as well. SkyTruth is one such platform originated in US where anyone with an internet connection can monitor the dates and location of the trackable commercial fishing (Washington et al., 2016). Furthermore, creating online citizen science games like Foldit (Curtis, 2015) can easily make school children aware of disasters and risks.
Implementation of Community based Early Warning (EW) Systems	A bottom-up approach like this is essential rather than relying heavily on technology. However proper measures should be taken to reduce the

(Early Warning and Evacuation)	institutional vulnerability. In addition, existing systems can be enhanced by introducing latest mobile technology and communication systems. Like in Nepal physically interpretable time series models will assist the responsible agencies to increase the lead times in EW (Smith et al., 2017).
Information sharing among institutions is minimum and sometimes the same information is communicated twice (Early Warning and Evacuation)	Authorities can enlist volunteers locally, where they can register in a nationally managed database to collect real time data and conduct damage assessments within the allocated region. These data can be shared in a web-based platform which has access to all the institutions. OpenStreetMap (OSM) could be an ideal solution in this case where countries like Bangladesh are using for Disaster Response (Latif et al., 2011). Furthermore, social listening models can be implemented to track the comments and feedback of the public who are using social media (Anderson et al., 2017).
Accuracy of the early warnings are questionable and most of the dissemination methods are analog. (Early Warning and Evacuation)	Utilization of multiple voluntary groups in a particular area can increase the accuracy and by using social media platforms the EW can be easily disseminated. However, in the rural sites' community projects can be initiated to enhance the communication networks
Trust of communities on evacuation notices is very less (Early Warning and Evacuation)	Building Trust on evacuation notices is a timely process. In Sri Lanka due to the prediction inaccuracies, public react merely to these. To improve the accuracy, a hackathon can be introduced to in developing solutions. Codevid-19 (Vermicelli et al., 2021) is one such model introduced during Covid 19 pandemic to support crisis response where local developers can get inputs to their models.
Relief operations are done by multiple parties and some communities experience repetition of services (Post Disaster Recovery)	During the relief operations inter agency coordination is a must. Furthermore, respective parties need to know priority areas for response. In this case a network of volunteers like PRN can be organized to analyze satellite imagery available in DMC to perform damage assessments (Simmons et al., 2022). In addition, sentiment analysis (Behl et al., 2021) can be performed on social media like Facebook and Twitter which are commonly used in Sri Lanka to assess the efficiency.
Most of the recovery funds are given by the GoSL or foreign parties as donations (Post Disaster Recovery)	Crowdfunding (Bouncken et al., 2015) projects can be implemented in Grama Niladhari (GN) divisions which are identified as high-risk areas to reduce the burden to the authorities if a disaster occurs.
Damage Assessments are not accurate due to the lack of data (Post Disaster Recovery)	Participatory Research Studies can be conducted with the affected groups to collect accurate data of their needs. During a flood event due to the overflows most of the water bodies get contaminated and due to the workload of the respective institutions sometimes they miss some data. Citizens in the affected areas can partner with relevant organizations to assist environmental sampling in this case. GRACE is one such project which used community-based participatory research for the chlorine gas disaster in Graniteville, South Carolina. (Svendsen et al., 2010).
Post Disaster Rectification activities are done mostly without consulting affected communities (Post Disaster Recovery)	Community generated data can make a huge impact to the decisions of the officials. Considering the high population density in some areas volunteer-based data collection is needed to assist the relevant organizations.
Precautionary actions and risk modelling are not interconnected. (Mitigation Measures)	Can introduce low-cost sensors and data collection mechanisms which can be easily managed by local communities to increase the spatial network coverage. Then these can be utilized to increase the accuracy of risk modelling (Pandeya et al., 2021).
Due to the forced relocation most of the families are not able to continue their livelihood as before (Community Relocation)	Authorities can establish small scale community aid projects among relocated families during earlier disasters to capture their experiences which can be utilized in future. RAP in North Carolina can be taken as a pilot project in this case (Farquhar & Dobson, 2008).

CONCLUSIONS AND RECOMMENDATIONS

After the analysis, it was revealed that Sri Lanka being a lower middle-income country, has been coordinating with several local and international organizations during the disasters. While the government institutions like MDM, DMC, DoM and ID are leading the DM activities related to floods Sri Lanka Red Cross and Sarvodaya are the leading local NGOs. Apart from that United Nations, and World Bank plays a major role when providing funding for Disaster Related activities which increases capacity building and community resilience. JICA and ADPC are some of the other foreign institutions which provide support. In addition, tri forces, mass media and social media play a pivotal role during the response stage of the DM cycle by disseminating early warnings to the public.

Even though Sri Lankan communities get assistance from several external bodies, it is evident that there are some gaps and provisions for improvement in the processes and activities they engage with. Citizen science concepts can be used to enhance and improve the efficiency of these activities. Participatory mapping, Co-Design projects, hackathons and crowdfunding are some of the observed mechanisms to incorporate the knowledge of the communities in Disaster Management of Sri Lanka. However, since this is a working paper further research and investigations are required to finetune the recommendations. The ideal scenario would be to develop a citizen science model in a selected area capturing all phases of a disaster and observing it's functioning to improve it further.

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