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Assessing Community Perceptions on Urban Flood Resilience in Sri Lanka

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Abstract: Urban communities' perceptions about flood disasters can help better understand the resilience level of specific communities. This paper examines community-specific flood resilience by looking at Sri Lanka's most flood-prone areas: the Kolonnawa and Kaduwela divisional secretariat divisions of Colombo. We conducted field surveys and a questionnaire survey among 120 community members. The collected questionnaire data were then analyzed partly by conducting multiple regression analyses. The results of our research identify varied perceptions about flood vulnerability and resilience by the community. Overall, our respondents regarded flood incidents as a high-risk disaster to their livelihoods, but some communities appeared to have higher coping strategies than others within the same administrative division. The respondents generally perceived that proximity to flood sources would increase flood vulnerability and frequency. Compared to other communities, Sedawatta community experienced most frequent floods, and 93% lived within 100 m from the river. The respondents had taken measures to mitigate floods mostly by elevating houses. Through multiple regression analyses, we found that education, income, household structure, distance to flood sources, and flood frequency had significant correlations with flood resilience and vulnerability in varying degrees by community. In conclusion, we argue that government flood management policies focus more on community-specific needs.

Keywords: flood vulnerability; resilience; community participation; Sri Lanka; climate disaster; urban resilience

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1. Introduction

The increasing frequency and intensity of natural disasters have required urban communities to strengthen their disaster resilience and preparation [1]. The Hyogo Framework for Action 2005–2015, for example, placed a heavier emphasis on reducing regional vulnerability [2,3]. The ensuing Sendai Framework for Disaster Risk Reduction 2015–2013 reiterated this point by emphasizing education, participation, cooperation, and preparation [4].

Globally, flood risk has increased markedly, and it has become the most common and severe disaster in terms of loss and damage to communities [5]. From 1998 to 2017, floods were the most frequent disaster with 3148 events or 43.4% of global disasters. Of the total global-disaster-affected people, 45% or 2 billion people were affected by floods [6]. In the same period, floods displaced 8.6 million people and caused USD 656 billion in economic loss, which constituted 23% of the total economic losses from disasters [6]. The Global Assessment Report on Disaster Risk Reduction estimated the annual average loss from floods to be USD 104 billion [2]. Similar to the global trend, floods are the most common natural disaster in Asia in terms of occurrence and affected communities. From 1990 to 2019, of total global flood disasters, 39% or 1688 events occurred in Asia. During the same period, an average of 98 million Asian people were affected by floods annually [7].

In different parts of the world, urban riverine communities, especially low-income residents, are vulnerable to flood risks [8,9]. Brouwer et al. [10] approached the community

flood resilience of Bangladesh through a community survey and found that poorer segments of society near rivers faced a high flood risk. In Vietnam, Houng et al. [11] showed that environmental, economic, and social factors determine the flood risk and vulnerability of riverine communities. Poor communities in cities often fail to learn from past disasters due to their socio-economic vulnerabilities [8]. Community preparedness for and awareness of flood disasters can reduce community vulnerability [12]. Many countries strengthen coordination and partnerships with local communities to enhance their awareness of flood risk as they are the immediate victims of floods [13]. For the riverine and coastal communities, the low flood risk means a relatively low vulnerability and high resilience to floods [11,14].

Community resilience was defined in many ways. The United Nations Office for Disaster Risk Reduction defined resilience as "the ability of a system, community or society exposed to hazards to resist, absorb accommodate to and recover from the effect of a hazards in a timely and efficient manner, through the preservation and restoration of its essential basic infrastructure and functions" [15]. However, this definition does not help us understand how a community, society, or organization perceives resilience and plans for disasters [16]. Considering this point, Mayunga [1] defined resilience as a capacity or ability of a community to anticipate, prepare for, respond to, and recover quickly from the impacts of disasters.

Similarly, flood resilience was defined somewhat variably, depending on how past studies placed emphases on current and future protection, prevention, and preparedness [17]. Analyzing seventeen flood resilience frameworks, Bulti et al. [18] defined it as the ability of a community to maintain or return to normal functions from food events while adapting to changes. The Zurich Flood Resilience Alliance focused on the ability of a community to pursue its development and growth objectives while managing its flood risk over time [19].

For some scholars, measuring flood resilience was an important question to be investigated. They applied various methods and indicators in doing so. Moghadas et al. [20] took a multi-criteria approach for assessing urban flood resilience in Tehran, Iran. Their composite index consisted of social, economic, institutional, infrastructural, community capital, and environmental dimensions. Tayyab et al. [21] developed a GIS-based urban flood resilience assessment model to understand resilience in Pakistan. Bosher et al. [22] focused on stakeholders' proactive participation in assessing UK's urban flood resilience. They found that public values, participation, and perceptions are vital for community risk assessment, management, and resilience [23]. Jha et al. [24] similarly highlighted the need for examining a community's disaster risk reduction participation in assessing flood resilience.

In Sri Lanka, floods are the most severe disaster in terms of the number of affected people [25]. Here, riverine urban floods have become more frequent and devastating, and Colombo, Sri Lanka's capital, has been particularly affected [26]. In the last 40 years (1980–2019), 1.47 million people in Colombo district alone were affected by floods. Out of this, more than half of the floods (52.75%) occurred in the last 10 years [25]. The flood in 2016 was the worst and it cost USD 277 million to the district [27]. The social sector had USD 206.2 million of damage. The housing sub-sector suffered from USD 203 million of damage which constituted 73% of the total loss and damage [27,28].

The existing literature provides little about Sri Lanka's community flood resilience in terms of preparation, responses, and perceptions [29]. Past studies in Sri Lanka mainly focused on developing flood inundation maps [30,31], hazard maps [32], emergency response maps [33], and early warning systems [29].

Our past study on equity in flood prone urban areas showed that the poorest parts of the city had received scant attention from government in terms of flood preparation, mitigation, and adaptation actions [34]. We then suggested to conduct a further study on urban community needs to clarify a policy gap and regional resiliency. This paper, therefore,

discusses how disaster-prone urban community members perceive flood resilience. In particular, it focuses on two of the most flood-affected urban areas of Sri Lanka.

2. Methodology

2.1. Study Location

In order to conduct this research, we visited regional offices of the National Disaster Relief Services Centre and the Disaster Management Centre in Colombo. Based on information and insights from them through interviews and field visits, we used purposive sampling methods to select four specific communities in Kolonnawa and Kaduwela divisional secretariat divisions (DSDs). Communities in DSDs are administratively termed grama nildhari division (GND). Kolonnawa and Kaduwela are the most flood-affected DSDs in Colombo district during the last 10 years [27]. A GND is a cluster of villages or a sub-division of a DSD. Two GNDs we selected, Sedawatta of Kolonnawa and Kaduwela of Kaduwela, mainly house offices and business centers. The other two GNDs, Rajasinghegama of Kolonnawa and Pahala Bomiriya of Kaduwela, are largely residential areas (Figure 1). In varying degrees, these GNDs experienced severe flood incidences. For example, in the 2016 flood, almost all the residents in Sedawatta GND were displaced. Both the 2016 and 2018 floods severaly damaged houses in Kaduwela and Pahala Bomiriya GNDs [35].

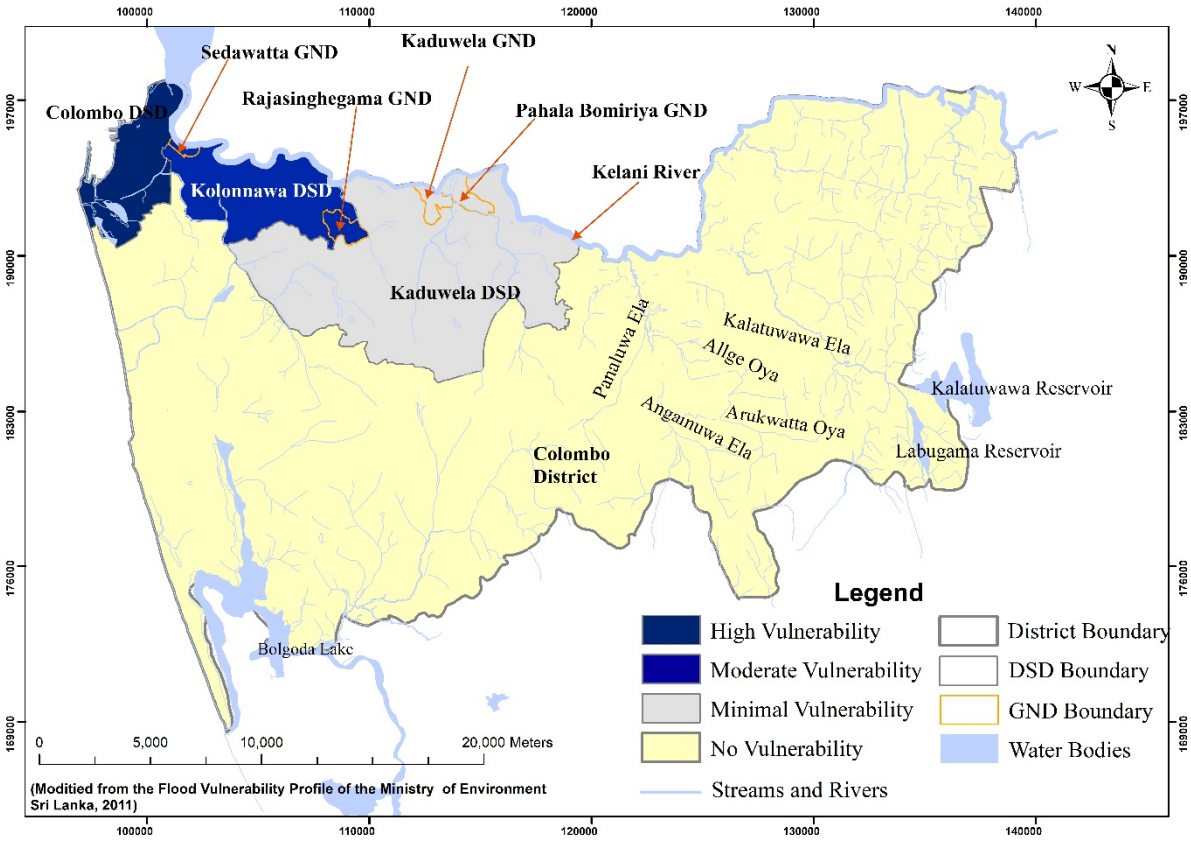

Figure 1. Study locations.

According to the 2012 Census, 77.6% of the population in Colombo district resided in urban areas which is the highest in Sri Lanka. All the residents in Kaduwela DSD and 33% of those in Kolonnawa DSD were considered as residents in urban communities [36]. Our survey mainly targeted urban communities in these DSDs.

Kolonnawa DSD has a high population density of 7183 persons per km^2, whereas that of Colombo district is 3489 persons per km^2 [36]. About 70% of the Kolonnawa DSD area is

below sea level [37]. In 2016, the worst flood in 25 years hit this area and affected about 155,062 people or 81% of this DSD population [27].

Another study area, Kaduwela DSD, experienced drastic changes in population and land use [38]. The population of Kaduwela doubled from 126,053 in 1981 to 252,041 in 2011 [39]. This rapid increase led to the expansion of residential areas. As a result, wetland areas, which mitigate flood damage, shrank. From 1956 to 2016, wetlands in Kaduwela and the surrounding Capital area decreased by 43% [40]. The 2018 flood damaged 1950 houses in this area [25].

2.2. Data Collection and Analysis

To better understand the perspectives of residents in the four communities, we conducted a paper-based questionnaire survey from March to June 2020. Kellens et al. [23] highlight the importance of questionnaire surveys in community-perception studies on floods. The questionnaire was designed based on the Community Resilience Framework of Sri Lanka which emphasized the need for local community participation in disaster-risk reduction [41]. Here, we attempted to collect information about socio-demographic characteristics, vulnerability perceptions, and exposure to the hazard. The disaster risk is identified as a function of possible hazard and vulnerability (Risk = hazard $\times$ vulnerability). It is defined as the probability of harmful consequences resulting from interactions between possible hazards and vulnerable conditions within a social or community system [42]. We also adopted disaster-risk-management approaches that were introduced by the United Nations Framework Convention on Climate Change [43]. Among them, we selected risk reduction and risk transfer approaches. Accordingly, the questionnaire was divided into three sections, and in total we asked 29 questions. Section one attempted to understand the socio-demographic characteristics of the respondents. Section two was to identify flood experiences and vulnerability. Section three focused on risk reduction and risk transfer.

In selecting communities for sampling, we focused on communities who lived in the most flood-vulnerable areas. The population of selected GNDs varied from 6000 to 4000. For example, the population of Sedawatta (6934) was the highest, and that in Pahala Bomiriya was the lowest (4224) [44]. Considering the population size of the DSDs and variations in the GNDs, we randomly selected 120 respondents, 30 from each GND.

Our questionnaire mainly consisted of closed-ended questions with multiple choice options and a five-point Likert-scale. All answers were found valid. For analyzing the collected data, we used Microsoft Excel, including a multiple regression analysis to find significant influences, if any, between socio-demographic characteristics, proximity to flood sources, insurance ownership, and perceptions about flood experience. To use categorical variables to explain variation in the dependent variable, it is necessary to code categories through a multiple regression analysis. Here, we used dummy variables as a numerical representation. For example, in gender, the coded values of 1 for male and 2 for female were assigned. Our results were presented in descriptive analysis such as tables, figures, and graphs.

In addition to the questionnaire data, we collected information from the National Census Reports of 2012 and 2020, the Post Disaster Need Assessment Reports of the 2010 and 2016 floods, the Desinventar website of the Disaster Management Centre (DMC), and DSD and GND reports of the study locations. We interviewed grama niladari officials (government appointed village heads) of Sedawatta and Rajasinghegama GNDs, a National Disaster Relief Services Centre officer at Kolonnawa DSD, DMC field officers at Kaduwela DSD, and field officers at the Kaduwela Municipal Council in March 2020 to understand disaster management practices and situations in our study areas better.

3. Results and Discussion

3.1. Socio-Demographic Characteristics

The first section of our questionnaire survey focused on identifying socio-demographic characteristics of the respondents (Table 1). We found a similar age distribution pattern

in all four communities; those who were between 30 and 59 years old consisted of the majority. In Kaduwela DSD, these age groups consisted of 75%, whereas Kolonnawa DSD had 62%. This age group concentration was much higher than the national average, in which about 40% belonged to 30–59 age groups in 2012 [39]. The youngest respondents were in Sedawatta GND, and 20% of them were below 29 years old. The percentage of those who were more than 70 years old appeared to be relatively high in residential communities of Rajasinghegama GND (13%) and Pahala Bomiriya (7%). These figures were above the national average of 5% [39].

Table 1. Socio-demographic characteristics of the respondents.

Demographics		Kaduwela DSD (%)			Kolonnawa DSD (%)		
		Kaduwela	Pahala Bomiriya	DSD Average	Sedawatta	Rajasing-Hegama	DSD Average
Age	Under 19	0%	0%	**0%**	3%	0%	**2%**
	20–29	10%	17%	**14%**	17%	10%	**13%**
	30–39	30%	30%	**30%**	23%	34%	**28%**
	40–49	30%	27%	**28%**	20%	13%	**17%**
	50–59	20%	13%	**17%**	17%	17%	**17%**
	60–69	10%	6%	**8%**	17%	13%	**15%**
	Above 70	0%	7%	**3%**	3%	13%	**8%**
Gender	Male	40%	57%	**48%**	23%	40%	**32%**
	Female	60%	43%	**52%**	77%	60%	**68%**
Marital Status	Single	17%	23%	**20%**	13%	10%	**13%**
	Married	83%	77%	**80%**	87%	87%	**87%**
	Divorced	0%	0%	**0%**	0%	3%	**2%**
Household Size (person)	2	7%	13%	**10%**	0%	20%	**10%**
	3–4	70%	60%	**65%**	23%	63%	**43%**
	5	23%	20%	**22%**	20%	10%	**15%**
	More than 5	0%	7%	**3%**	53%	7%	**30%**
	1	0%	0%	**0%**	4%	0%	**2%**
Highest Education	No education	10%	3%	**7%**	0%	0%	**0%**
	Primary	27%	17%	**22%**	34%	3%	**18%**
	Ordinary level	20%	57%	**38%**	53%	13%	**33%**
	Advanced level	33%	20%	**26%**	13%	50%	**32%**
	Technical collage	3%	0%	**2%**	0%	0%	**0%**
	University	7%	3%	**5%**	0%	30%	**15%**
	Postgraduate	0%	0%	**0%**	0%	4%	**2%**
Work/Income Source	Government	23%	10%	**17%**	0%	3%	**2%**
	Semi-government	0%	3%	**2%**	4%	0%	**2%**
	Private sector	23%	33%	**28%**	7%	27%	**17%**
	Self-employed	27%	27%	**27%**	27%	23%	**25%**
	Unpaid family worker	0%	7%	**4%**	0%	0%	**0%**
	Unemployed	3%	7%	**5%**	3%	0%	**1%**
	Student	7%	0%	**3%**	3%	0%	**2%**
	Pensioner	7%	10%	**8%**	0%	20%	**10%**
	Household chore	7%	0%	**3%**	53%	27%	**40%**
	Elder	3%	3%	**3%**	3%	0%	**1%**
Average Monthly Income (LKR)	Less than 15,000	7%	13%	**10%**	10%	3%	**7%**
	15,000–25,000	20%	20%	**20%**	10%	0%	**5%**
	26,000–35,000	40%	34%	**37%**	9%	10%	**8%**
	36,000–45,000	10%	20%	**15%**	3%	3%	**3%**
	46,000–55,000	3%	4%	**3%**	3%	10%	**7%**
	55,000–65,000	3%	3%	**3%**	0%	10%	**5%**
	Above 65,000	0%	3%	**2%**	3%	37%	**20%**
	No income	17%	3%	**10%**	62%	27%	**45%**
Housing Structure	Single house with 1 floor	43%	77%	**60%**	10%	30%	**20%**
	Single house with 2 or more floors	34%	20%	**27%**	0%	70%	**35%**
	Row house/ line room	0%	0%	**0%**	90%	0%	**45%**
	Hut/shanty	23%	3%	**13%**	0%	0%	**0%**
Type of House	Cement block/stone	70%	67%	**68%**	80%	70%	**75%**
	Brick	10%	26%	**18%**	3%	30%	**17%**
	Plank/metal sheet	20%	0%	**10%**	17%	0%	**8%**
	Other	0%	7%	**4%**	0%	0%	**0%**
House/Land Ownership	Owned by household	80%	87%	**83%**	57%	100%	**78%**
	Rent or lease	3%	10%	**7%**	3%	0%	**2%**
	Government owned	17%	3%	**10%**	40%	0%	**20%**

Table 1. *Cont.*

Demographics		Kaduwela DSD (%)			Kolonnawa DSD (%)		
		Kaduwela	Pahala Bomiriya	DSD Average	Sedawatta	Rajasing-Hegama	DSD Average
Household Water Supply	Tap	83%	60%	**72%**	80%	100%	**90%**
	Well	7%	23%	**15%**	3%	0%	**2%**
	Outdoor tap	10%	13%	**11%**	17%	0%	**8%**
	Other	0%	4%	**2%**	0%	0%	**0%**
Ownership of Communication Equipment (multiple choice)	Radio	90%	7%	**48%**	63%	63%	**63%**
	Television	93%	83%	**88%**	100%	100%	**100%**
	Fixed phone	40%	7%	**23%**	3%	53%	**28%**
	Mobile phone	80%	33%	**57%**	97%	100%	**98%**
	Computer/laptop	27%	3%	**15%**	10%	70%	**40%**
	None	3%	7%	**5%**	0%	0%	**0%**
Do you receive Samurdhi assistance?	Yes	13%	16%	**28%**	33%	0%	**17%**
	No	87%	84%	**72%**	67%	100%	**83%**

In terms of gender distribution, women represented more than half of the respondents. In particular, in Kaduwela and Sedawatta, where business/office areas are predominant, more females participated in the survey than males. About 80% in Kaduwela DSD and 87% in Kolonnawa DSD were married. Regarding marital status, about 77% of the respondents were married in Pahala Bomiriya GND which is the lowest among our other study areas. More than 60% had the household size of 3–4 persons except the result from Sedawatta GND, where 53% of the respondents had more than five household members. The national average of household size was 3.6 persons [44].

Education is often considered as a social asset to improve one's coping capacity [11]. It also determines the flood adaptation capacity. The respondents in Rajasinghegama (84%) showed a much higher tertiary education level than the other communities, which is above the national average of 18.2%. Sedawatta GND had the lowest percentage of those who completed tertiary education (13%). Here, 87% of the respondents had primary or secondary education as their highest education. About 10% in Kaduwela GND had no formal education, whereas those who did not receive formal education at the national level was 4.7%, and the Colombo district level was 2.6% [39].

A steady source of income helps reduce disaster vulnerability [45]. It is also an essential factor for determining flood resilience [46]. In Sedawatta, 53% of the respondents were mainly engaged in household chores, the highest among the four GNDs. In Pahala Bomiriya, 33% of the respondents were engaged in private sector jobs, the highest among other communities. The self-employment rate varied from 23% to 27%. The self-employment category includes informal sector businesses, which are not administratively registered. Government jobs consisted of 23% among the respondents in Kaduwela GND. The unemployment rate was 7% in Pahala Bomiriya, which is higher than the Colombo district average of 4% [36].

In 2018, the mean monthly income in Colombo district was LKR 51,962 (or equivalent to USD 289) [36]. Except those respondents in Rajasinghegama (47%), the respondents in Kaduwela (97%), Sedawatta (97%), and Pahala Bomiriya (94%) earned below this income. The income level of the Sedawatta respondents was lowest among the four communities partly because 62% had no income. The Rajasinghegama respondents received the highest income in comparison. This is the neighborhood in which 84% of the respondents had completed tertiary education. The government of Sri Lanka provides a social safety-net program called *Samurdhi* for those who had a monthly income of less than LKR 6000 (USD 33) per person in a family [47,48]. The respondents in Sedawatta had the highest percentage of Samurdhi receivers (33%), whereas a smaller percentage of the Pahala Bomiriya (16%) and Kaduwela (13%) respondents also received it. None of the respondents in Rajasinghegama received *Samurdhi* assistance due to their relatively higher income level compared to others.

The quality, affordability, and location of houses can affect one's exposure to flood damage and coping capacity [1,11,49]. More than 80% of the respondents in both DSDs had houses that were made of cement block/stone or bricks. In residential areas of Ragas-

inghegama (100%) and Pahala Bomiriya (97%), almost all the respondents had reasonable quality houses with single, two, or more floors. In Rajasingegama, 70% of the respondents said that they would use their upstairs during floods. In Sedawatta, on the contrary, 90% lived in row houses/line rooms and huts/shanties. About 23% of the Kaduwela respondents lived in huts/shanties. Those respondents who lived in plank/metal sheet houses consisted of 20% in Kaduwela and 17% in Sedawatta. The ownership of house/land was high among the respondents in Ragasinghegama (100%), Pahala Bomiriya (87%), and Kaduwela (80%). However, 40% in Sedawatta and 17% in Kaduwela lived on government lands. In Kaduwela, these houses were built on encroached wetlands.

As floods sever residents' essential water supplies [11,27], we asked how the respondents obtained water for domestic purposes. Colombo residents tended to use both wells and taps. Our questionnaire survey found that water supplies varied widely by community. The national water pipe network reached 100% among the Rajasinghegama respondents, whereas only 60% of the Pahala Bomiriya respondents received access. As the Colombo district's average pipe network coverage is 62.7% [27], and the national average is 21.1% [39], we can reasonably conclude that the respondents had fair accessibility to the national water supply. However, 40% in Pahala Bomiriya, 20% in Sedawatta, and 17% in Kaduwela obtained water from wells and outdoor taps.

We also asked the respondents if they had sufficient access to communication equipment such as mobile phones and information sources (e.g., television) as these are main sources of information at the time of disasters. All respondents in Rajasinghegama had television and mobile phones. They also had computers/laptops (70%), radios (63%), and landline phones (53%). The Pahala Bomiriya respondents had televisions (83%), followed by mobile phones (33%), radios (7%), landline phones (7%), and computers/laptops (3%). For reference, we list the national average of ownership for these devices: television (78.3%), mobile phones (78.9%), radios (68.9%), computers/laptops (20.6%), landline phones (42.4%) [39]. Mondal et al. [50] found that communication devices such as mobile phones are important for receiving early flood warnings.

3.2. Vulnerability and Flood Exposure

In the next section of the survey, we asked about the flood experience of the respondents. More than half of the respondents in Kaduwela (60%), Pahala Bomiriya (57%), and Sedawatta (53%) had lived in their communities for 20–50 years. About 13% of those in Pahala Bomiriya and Sedawatta had lived for more than 50 years. The Rajasinghegama respondents had the least experience with 57% having lived in the community for 1–10 years.

We then asked them about their motivation/incentive to live in their localities with the following multiple choices: (1) affordable land price, (2) close to the city center, (3) inherited land, (4) close to school/job opportunities, (5) close to relatives, and (6) others. The responses differed widely by community. Inherited land (87%) was the main factor for the Sedawatta respondents. Affordable land price (53%) was the main determinant for the Kaduwela respondents. The Rajasinghegama respondents were motivated to live closer to the city center (47%) and the calm and quiet natural environment (40%). Both affordable land price (30%) and inherited land (30%) influenced Pahala Bomiriya respondents' decisions. Except those who were motivated by inherited land, all other respondents were not aware of their flood vulnerability before they purchased their houses. Those who inherited land in Sedawatta were informal settlers who migrated to the study area, engaging in non-taxable business activities. In our interviews with some of these settlers, we learned that they settled on the Sri Lanka Railways land without formal land surveys for residences. However, some households claimed to have used their lands for more than 100 years.

Past studies showed that proximity to a river, canal, or water body is one of the important factors to determine flood vulnerability [10,11,14,50]. Moreover, some studies highlighted that proximity to flood sources will increase behavioral intentions of the affected communities by taking mitigation and preparedness measures [23,51]. Considering these findings, we asked the respondents how far their residences were from water bodies

(Figure 2). All the respondents of Sedawatta were within less than 500 m, and 93% of them lived within less than 100 m from the Kelani River. When the 2016 flood affected the Colombo region, the entire community was adversely affected [27]. In the other three communities, 20% to 23% of the respondents lived within 100 m from the River. In Kaduwela and Rajasinghegama, 43 and 40% of the respondents lived within 1 km from flood sources.

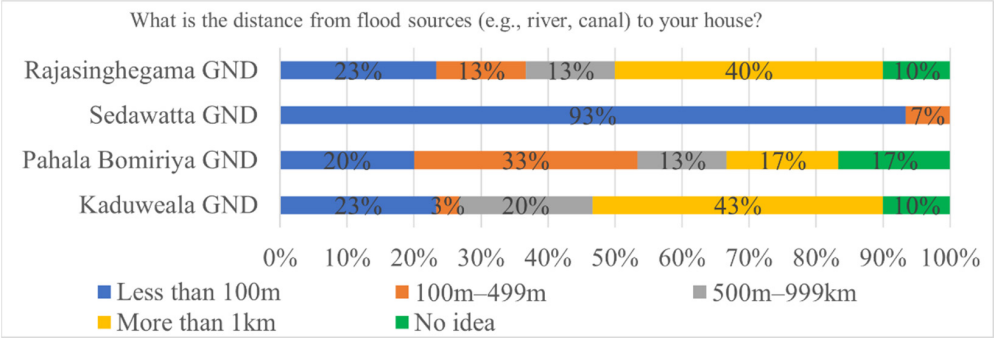

Figure 2. Distance from flood sources (e.g., river, canal) to respondents' houses.

As flood frequency is one of the indicators to measure risk [11,14], we asked the respondents how often they had experienced floods (Figure 3). In response, about 50% of the Sedawatta respondents said that they experienced floods after every heavy rain. The same answer was obtained from 33% of the Rajasinghegama respondents, 27% of the Kaduwela respondents, and 7% of the Pahala Bomiriya respondents. The percentage of those who experienced floods every year reached 53% in Rajasinghegama and Kaduwela. In Pahala Bomiriya, about 70% of the respondents experienced floods once in two years.

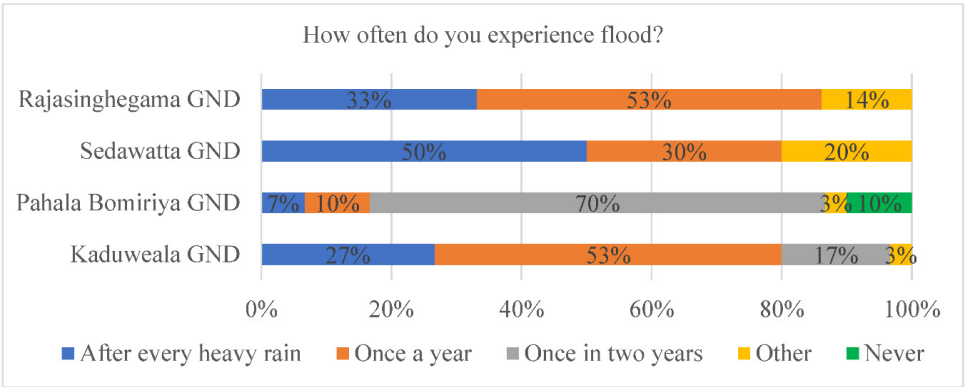

Figure 3. How often respondents experience floods.

Next, we asked the respondents whether flood occurrence had increased in the past 10 years. Most of the respondents in Rajasinghegama (77%) and Sedawatta (57%) observed that floods have increased. However, 67% of the Pahala Bomiriya respondents and 63% of the Kaduwela respondents had not observed any change.

3.3. Risk Reduction and Risk Transfer Approaches to Flood

In the third section, our questions focused on understanding perceptions about community risk reduction and risk transfer approaches. According to the past studies, risk management strategies (e.g., early warning, social safety nets, insurance, structural/non-structural measures) can reduce vulnerability and increase the adaptive and coping capacity of communities [16,43,49,51]. The Warsaw International Mechanism for Loss and Damage highlights the importance of enhancing the knowledge and understanding of comprehensive risk management approaches for resilient communities [52].

In this section, first, we asked the respondents whether they had taken any actions to minimize floods. About 90% of the Rajasinghegama respondents had done so, whereas only 47% of the respondents in Sedawatta were positive. Brouwer et al. [10] found that communities that face the highest risk of flooding seem to be the least prepared. This point can be said about the Sedawatta community in our study.

Then, we asked the respondents about their immediate flood responses with the following multiple choices: (1) lock the house and move to safe locations with family, (2) move valuables to safe locations in neighborhood, (3) cover immovable household items with plastic or water-resistant material, (4) move all household items to non-flooded areas with the support of neighbors, and (5) wait until the government issues an evacuation order. Locking the house and moving to safe locations with family was the action nearly all respondents would take: Sedawatta (100%), Rajasinhagama (97%), and Kaduwela (73%). About 70% in Sedawatta, 60% in Rajasinghegama, and 27% in Kaduwela would also move their valuables to safe locations in the neighborhood. About 47% of the Pahala Bomiriya respondents would rather move all household items to non-flooded areas.

Next, we asked whether the respondents were aware of community volunteer programs against floods as past studies confirmed that social networking and coordination among community members are important to reduce flood risks [1,11]. The result shows that 70% of the Pahala Bomiriya respondents answered positively. About 40% of the Rajasinhagama respondents and 27% of the Sedawatta respondents were also aware of the programs. However, none in Kaduwela knew about community volunteer programs.

In the next question, we asked if the respondents had insurance to deal with disasters (Figure 4). The Warsaw International Mechanism for Loss and Damage identified insurance as one of the effective risk transfer mechanisms [52]. The result showed that, in Sedawatta, 97% did not have insurance. However, we found that 23% in both Kaduwela and Rajasinghegama had life insurance. Only 17% of the Pahala Bomiriya respondents had house and property insurance. Except for 3% of the Pahala Bomiriya respondents, none of the respondents had disaster insurance. In Sri Lanka, disaster insurance is not mandatory for the residents. Natural disaster insurance coverage is offered as an extension to fire and lightning insurance policies in Sri Lanka [53].

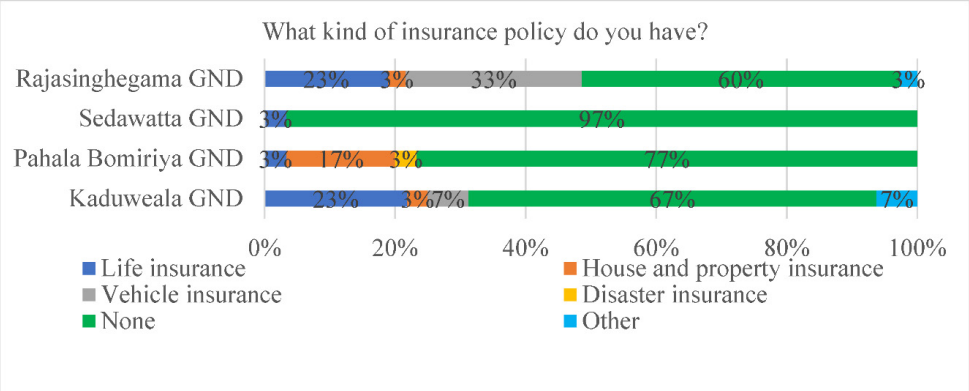

Figure 4. Types of insurance policy communities had.

Flood information is vital for minimizing disaster risks as it is known to increase community awareness and improve disaster prepareness or response [23]. With this point in mind, we asked how communities obtain flood mitigation and prevention ideas with the following multiple choices: (1) neighbor/friend, (2) grama niladari officer, (3) community group, (4) field officer of the Disaster Management Centre, (5) NGO, (6) relative/family member, and (7) others. The responses varied widely by community. The Kaduwela respondents would largely follow information from a grama niladari officer (90%) and neighbor/friend (67%). A field officer of the Disaster Management Centre (37%) was the main information source for the Pahala Bomiriya respondents. The Rajasinghegama

community mainly trusted information from a neighbor/friend (47%) and grama niladari officer (37%). In Sedawatta, the respondents relied on relatives and family members (60%), a neighbor/friend (53%), and a grama niladhri officer (40%). A grama niladari officer is responsible for providing disaster and other information to the local community. He or she is the village head appointed by the central government to carry out administrative duties of GND [54,55]. However, we found that communities used various sources to obtain flood information in the study areas.

Then, we asked the respondents to rate the importance of current government flood protection measures. Here, we focused on both structural and non-structural flood protection measures. These measures are vital for community disaster risk reduction [43,56]. For this, we used a five-point Likert scale (1 = Not important; 5 = Very much important). The Kaduwela respondents regarded drainage maintenance (80%) and road improvement (73%) as very much important (Figure 5). They chose the following options as important and very much important: community education and awareness (93%), compensation and flood relief (87%), and flood protection walls/embankment (81%). Some respondents found the following options not important or less important: land use planning (12%), road improvement (14%), flood resilience houses (17%), relocation support for safer areas (17%), and early warning and evacuations (25%).

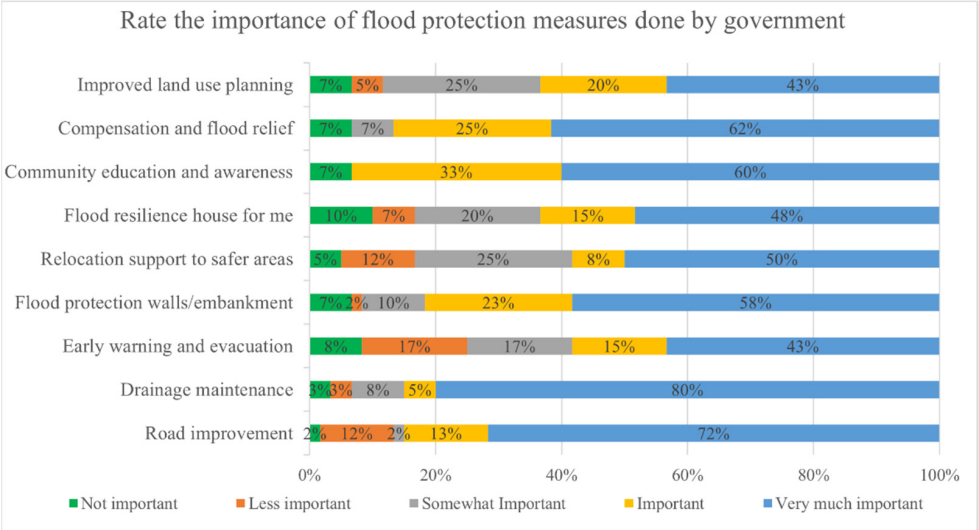

Figure 5. Importance of government flood protection measures conducted in Kaduwela DSD.

For the respondents in Kolonnawa, who lived very close to the Kelani River, the following measures were very much important: drainage maintenance (97%), compensation and flood relief (95%), flood protection wall/embankment (93%), early warning and evacuation (93%), improved land use planning (75%), and road improvement (75%) (Figure 6). They also rated community education and awareness (78%) and a flood resilient house (73%) as important and very much important. However, 48% in Kolonnawa were not interested in relocation support. On this relocation issue, we had interviews with DSD officials and community members. They told us about the Colombo Suburban Railway Project, in which the national government planned to relocate communities in Sedawatta GND to other areas. When we asked about this plan to the respondents, they showed their reluctance to comply with this relocation plan.

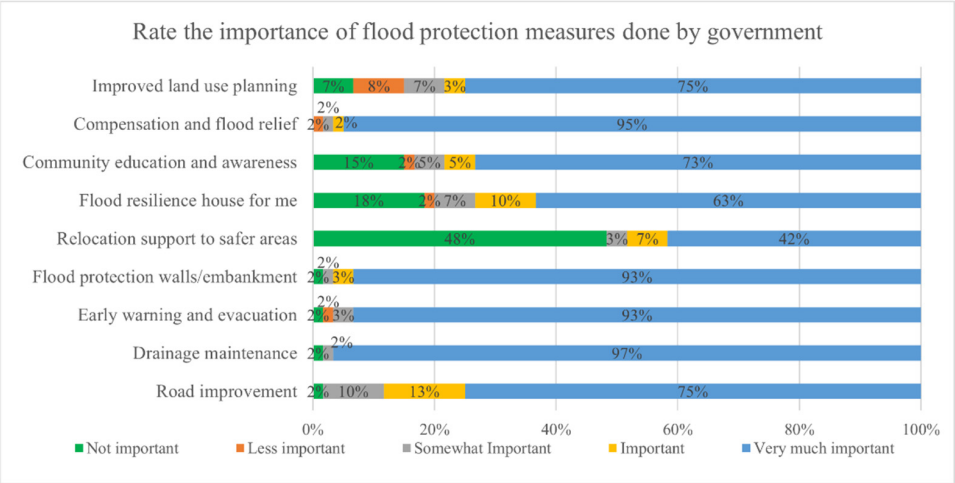

Figure 6. Importance of government flood protection measures in Kolonnawa.

3.4. Factors That Influenced Respondents' Perceptions about Flood Experience

After having these results, we attempted to identify factors that might have influenced the respondents' perceptions. For this purpose, we conducted a multiple regression analysis (Table 2) by pairing the respondents' perceptions about flood experiences with their age, gender, marital status, household size, education, average monthly income, housing structure, and housing type. We also added other independent variables such as distance from flood sources to the respondents' residence and the kind of insurance policy the respondents had.

Table 2. Factors influenced respondents' perceptions about flood experience.

Variable	Kolonnawa DSD		Kaduwela DSD	
	Rajasinghegama GND	Sedawatta GND	Kaduwela GND	Pahala Bomiriya GND
	p-value	*p*-value	*p*-value	*p*-value
Intercept	0.391	0.469	0.946	0.318
Age	0.824	0.010 *	0.676	0.063
Gender	0.559	0.529	0.128	0.597
Marital status	0.986	0.756	0.901	0.034 *
Household size	0.173	0.351	0.454	0.753
Education	0.766	0.000 *	0.006 *	0.169
Average monthly income	0.009 *	0.009 *	0.639	0.016 *
Housing structure	0.012 *	0.880	0.427	0.289
Type of house	0.005 *	0.000 *	0.049 *	0.605
Distance from flood sources to house	0.061	0.050	0.035 *	0.055
Insurance policy	0.391	0.604	0.007 *	0.007 *

* *p*-value < 0.05.

The results generally indicate communal variations. Among the Rajasinghegama respondents, for example, we found significant correlations with monthly income (*p*-value < 0.05), housing structure (*p*-value < 0.05), and housing type (*p*-value < 0.05). As mentioned above, the Rajasinghegama respondents had a higher income than those in other communities. All respondents had single- or multiple-floor houses that were made of cement, stones, or bricks.

In Sedawatta, we found significant correlations with education (*p*-value < 0.05), income (*p*-value < 0.05), age (*p*-value < 0.05), and housing type (*p*-value < 0.05). As we discussed in the socio-demographic characteristics section, the Sedawatta respondents did not have access to higher education opportunities. Compared to the other three communities, they had the lowest monthly income, and 62% did not receive income at all. We also found that 17% of their houses were made from plank/metal sheets that are relatively more vulnerable

to floods. Regarding age, the Sedawatta respondents were relatively younger than those in other communities. Past studies showed a positive correlation between respondents' flood experience and age [23,57,58].

In Kaduwela, we found significant correlations with education (p-value < 0.05), housing type (p-value < 0.05), distance from flood sources (p-value < 0.05), and insurance policy (p-value < 0.05). Among these respondents, 10% did not have formal education, and 20% lived in plant/metal sheet houses. About 67% did not have any insurance policy. Though 43% lived more than one kilometer away from flood sources, about 27% still experienced floods after heavy rain, and 53% experienced floods every year.

In Pahala Bomiriya, we found significant correlations with income (p-value < 0.05), marital status (p-value < 0.05), and the insurance policy (p-value < 0.05). About 94% of the respondents belonged to the income category below the Colombo district average, and 77% of them were married. Furthermore, 77% of them did not have any insurance policy with them.

4. Conclusions

This paper examined community perceptions about urban flood risk and resilience in four flood-prone areas in Colombo, Sri Lanka. Although the Sri Lankan government identified vulnerable areas to floods with its hazard maps and labeled our study areas as highly vulnerable areas, we found large disparities among communities even within a DSD. In general, we agree with the past studies that communities near flood sources face higher risks, but we also found that such other social factors as education, income, housing conditions, and flood preparedness affected communities' vulnerability perceptions. For example, the Sedawatta respondents, who experienced frequent floods, lived within 100 m from the river. We found that their flood vulnerability was exacerbated due partly to a lower level of education (13% with tertiary education, about 62% with no income, and 90% in poor houses). This is the area where informal businesses are predominant. On the contrary, Rajasinghegama, a residential area, showed substantial preparedness efforts to flood risks. Here, almost all respondents had good-quality houses with a good education background. Moreover, 47% had an income above the Colombo average. About 40% of them had insurance policies. The majority of them (90%) had taken measures to minimize floods by elevating houses, constructing walls, and cleaning drains around house/land.

The resilience disparity we found among communities means that DSD-level risk/vulnerability identification has serious shortcomings. The government's flood management policies should focus more on community needs and preparedness. The respondents were motivated by different factors to live in the study locations. The Sedawatta respondents largely lived on inherited land and were largely reluctant to be relocated. Those in Rajasinghegama wanted to live closer to the city center (47%) with the calm and quiet natural environment (40%). Affordable land price was one of the important reasons in Kaduwela (53%) and Pahala Bomiriya (30%). These people did not consider much about flood vulnerability when they decided to move to their current locations partly due to lack of information and awareness.

Drainage maintenance can be one of least costly but effective measures to take for the respondents. For those in Sedawatta, this is one of the most feasible actions to be taken as the residents were reluctant to comply with government's relocation programs. Our field observations also noted that drainages were not properly maintained. The respondents can be allowed to have more decision-making power about when to clean drains rather than largely depending on authorities for instruction. The community's voluntary flood mitigation actions were relatively low in our study areas.

Finally, this paper demonstrated that our in-depth examination of community perceptions can be of great help to identify and inform flood and other natural disaster vulnerabilities in rapidly growing urban areas and beyond. Community members with years of in-situ knowledge about flood incidents and local needs can supplement efforts carried out by the administration and experts in preparing for next disasters. Community

insights also can better inform government officials about what flood resilient actions are to be prioritized, given limited financial resources to be spent for infrastructure development and social-welfare support. Community perception studies further help the government to understand what types of information are needed for flood resilience and efficient evacuation in the future.

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