EVALUATION OF FLOOD DETERMINANTS: EVIDENCE FROM KELANI RIVER IN SRI LANKA

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ABSTRACT.
Floods are one of the meteorological occurrences that commonly record as serious catastrophic natural hazard in the world. Flooding ranks among the most devastating types of natural catastrophe in Sri Lanka. A well-known spot in the country for repeated floods may be found along the banks of one major river, the 'Kelani,' with incredible damages recorded for the human lives and property in the Kaduwela Municipal Council boundaries. Therefore, it is timely requirement for identification of determinants on the recurrent flooding in the area. This research aims to analyze the determinants of flooding based on Kelani River, in Kaduwela Municipal Council limits, focusing on both natural and man-made factors. The research was conducted within the mixed method approach. Sixty households were chosen by systematic random selection to reflect the most vulnerable Grama Niladari divisions, and the data was collected using a structured questionnaire by considering ten determinants and in-depth interviews with five experts. Collected data were analyzed using mean value analysis and content analysis to achieve the research objective. The findings revealed that man-made factors are the most affected factors for flooding in the area. Among them, the findings of both analyses indicated that the most significant reasons were non-availability of proper drainage system and violating the existing rules and regulation in the area. The study recommended, the necessity to implement adaptation measures and policies to minimize the flood risk of the area to achieve urban sustainability.

Keywords: Flood Determinants, Flood Risk, Man- made Factors, Natural Factors

1. INTRODUCTION

Natural catastrophes occur on a regular basis across the world, however most do not inflict enough damage to be classified as natural disasters. Floods are the most prevalent disaster among those. The growth of hydrological disaster, such as flooding has two causes of sever flood events and frequent occurrences (Bouwer et al., 2007; Kron, 2009). The first is a rise in the number of people living in flood plains and other high-risk regions, and the second is an increase in the frequency and severity of extreme weather events. Accordingly, flood has generated greater loss to the world annually. Shao et al. (2019) elaborated that, floods generated global yearly economic losses of 3.0×10^{10} USD throughout the twentieth century, accounting for one-third of overall economic losses produced by all forms of natural catastrophes. In most parts of the world, a significant increase in flood risk has been identified as a result of a combination of future flood hazards and information on global exposure and susceptibility (Alfieri et al., 2017). Flooding has already become a serious hazard to most of the continents in the world due to this scenario.

Flood hazard in Sri Lanka have become the most impacted catastrophic occurrence in terms of effect population, sequence, and time, resulting in significant economic and social difficulties inside the country. Due to the flood catastrophes of 2017, about 200,050 persons in eight districts of Sri Lanka lost their lives, while roughly 2,093 dwellings were entirely destroyed and 11,056 buildings were partially destroyed (Disaster Management Centre, 2017). Accordingly, one of such vulnerable areas to recurrent flooding, is the two sides of Kelani River in Kaduwela Municipal Council area. The recent flood which was occurred in 2016 was recorded as critical in this area. Meanwhile, according to Kaduwela Municipal Council documents, the annual average estimated cost of damages has been over Rs.10, 000,000 in recent years. This emphasized the alarming nature of the issue and there is no evidence on findings to identify the factors that are contributing to this recurrent flooding in detail. Screening through the literature it was noted that many scholars' views as flood is a result of extreme weather conditions such as heavy rainfalls (Farley et al., 2017) whilst, some arguments are there that it is not merely based on natural factors, however in some cases may be human activities also contributing which can be changed based on the location. Hence, it is vital to identify the determinants contribute to flooding in the particular area which is not discussed at a length yet. Therefore, the study aims to analyze the critical determinants for flooding associated in Kelani River in Sri Lanka from the point of view of the affected parties while also including the expert's views. Decision makers and planners will be guided by the findings of the study in developing adaptive measures and policies to minimize flood hazard in the area.

2. LITERATURE REVIEW

Flood and water logging have been one major threat for human survival since the ancient times (Shao et al., 2019). As explained by Khan et al. (2011), Floods are one of the most destructive and recurrent natural disasters, having a significant impact on human lives and economy across the world. Erena & Worku (2018) stated that "Flood is one of the leading natural hazards worldwide both in terms of the frequency of occurrence and the resulting damages to human lives, the environment, and economic assets". As per World Health Organization, flood can be classified in to three types: flash floods, river floods (mostly seasonal) and costal floods associated with tropical cyclones, tsunami and storm surges. Risk of such floods may increase due to a range of changes in the use of land, which induce changes of hydrological systems (Svetlana et al., 2015). Each year, the number of individuals impacted by floods increases, with the majority coming from developing countries. Sri Lanka, as a growing third-world country, has been hit by a slew of natural disasters in recent decades. Among all of these natural catastrophes in Sri Lanka, floods are the most prevalent and recurrent, posing a serious threat to human lives and property (Hetitiarachchi, 2020).

The flood danger is influenced by a number of factors. Natural and man-made variables can be roughly classified as determinants. Despite the fact that flooding is a natural disaster, its intensity and frequency can be exacerbated by direct and indirect human participation. Scholars have discovered a variety of man-made causes that produce floods or even enhance damages. As per the literature multiple man-made factors can be identified such as urbanization (Svetlana et al., 2015; Erena & Worku, 2018; Cirella et al., 2019), encroachments (Erena & Worku, 2018), increasing population (Svetlana et al., 2015; Cirella et al., 2019), improper land use changes (Al-Juaidi et al., 2018; Erena & Worku, 2018; Cirella et al., 2019), deforestation (Svetlana et al., 2015), blockage of drainages (Cirella et al., 2019), improper waste disposal (Cirella et al., 2019; Erena & Worku, 2018; Ijaz et al.,2021), reduction of wetlands (Svetlana et al., 2015) etc. On the other hand, natural factors such as heavy rainfall (Erena & Worku, 2018; Cirella et al., 2019; Al-Juaidi et al., 2018), topology (Erena & Worku,

2018; Al-Juaidi et al., 2018), soil type (Al-Juaidi et al., 2018; Cirella et al., 2019), wind (Hadipour et al., 2020) etc. are also cause to increase flood risk at a greater extent.
As per the empirical findings of different scholars were identified that most responsible flood causing factors can be different from place to place and time to time. Therefore, identifying the causes are very important to the relevant authorities to overcome or mitigate the problem. It can be reduced millions of monetary resources are spent on recoveries and compensations by saving the economy of the country. With that background, this study attempts to identify the flood causative factors in Kelani River Area in Sri Lanka which is significant from previous studies.

3. METHODOLOGY

Mixed method approach was used to achieve the research objective of analyzing the determinants of flooding based on Kelani River, in Kaduwela Municipal Council limits, focusing on both natural and man-made factors. The population of the study consisted with major four flood vulnerable Grama Niladari Divisions (Kaduwela, Wekkawatta, Ranala and Nawagamuwa) in Kaduwela MC Limits and Experts from the area. 60 households were chosen from above mentioned flood affected areas based on systematic random sampling method to conduct questionnaire survey. 10 flood-causing were included in the questionnaire, which were based on Likert scale questions (1 for strongly disagree and 5 for strongly agree). Those were under two categorization as natural and man-made factors, identified through literature. In addition, five experts such as Grama Niladari (the administrative officer at village level), a member from Municipal Council (Disaster management section), President of the Trade Union in the Kaduwela city area and two leaders from village level societies who are having more than 30 years living experience in this area were selected for in-depth interviews. The data obtained from residents via the questionnaire was evaluated using descriptive statistics. The expert impressions gleaned from interviews were evaluated using a qualitative method of the content analysis.

4. RESULTS AND DISCUSSIONS

4.1 Analyzed the Residents' Perception about Natural and Man-made Factors

The descriptive statistics of the 10 variables are shown in Table 1. Accordingly, the most significant flood-causing cause is a lack of proper drainage system, followed by violation of existing rules and regulations, Heavy rainfall, difficulties with the physical characteristics of the lands, and waste disposal in the area. The other parameters have little impact on the flood risk in the study area. Man-made causes are the most influential variables that enhance the flood risk in the Kelani River basin, compared to all other natural flood causing factors.

Table 1: Descriptive Statistics of Natural and Man-made Flood Causing Factors

Factor	Category	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Heavy rainfall	**Natural factors**	60	1	5	214	3.57	.927
Wind		60	1.0	3.25	113.50	1.8917	.39959
Land characteristics		60	1.00	4.00	151.50	2.5250	.73747
River characteristics		60	1.00	5.80	96.20	1.6033	.67647
Soil condition		60	1.00	3.00	104.50	1.7417	.53076

Population increment	**Man-made factors**	60	1.00	3.00	94.00	1.5667	.51845
Land use changes		60	1.00	3.25	101.75	1.6958	.50019
Improper waste disposal		60	1.00	3.50	146.75	2.4458	.54674
Lack of drainage system		60	3.25	5.00	271.50	4.5250	.63729
Violation of regulations		60	1.75	5.00	231.25	3.8542	.78017
Valid N (list wise)		60					

Source: Survey data, 2020

Out of all the natural flood causing factors, heavy rain especially first quarter of the year and the issues related to physical characteristics of land are the only two significant factors that create an influence to flood risk in the area (See Table 1). This is due to the fact that precipitation flowing down the river congeals in low-lying regions, and once the water retention limit is reached, river water floods the low-lying areas. The majority of the lands in the research region are low and undulated, and therefore are very vulnerable to flooding.
Accordingly, the man-made factors that affected for flooding; lack of proper drainage system is the most significant factor that increases the flood risk in the area. There is no adequate system in place to reduce water congestion in low-lying areas and divert it to waterways or floodplains. Due to the filling up of floodplains, wetlands, and forests, water retention capacity and drainage are also constrained and drainage system also interrupted. Further, violation of prevailing rules and regulations also malpractices of waste disposal have also become considerable flood causing factors in the area. The people dispose waste in to the surrounding areas, abundant lands and floodplains etc. As a result, waste becomes trapped in drainage systems, reducing flood retention and water flow.

4.2 Analysis of Expert Opinions on Flood Causing Factors

After a deep observation on all four views, the author identified that there were nine major flood causing factors in Kelani River Area. The summary of the analysis is represented in table 2.

Table 2: Summary of the Findings

Respondent / Factor	**#1**	**#2**	**#3**	**#4**
Lack of proper drainage system	✓	✓	✓	✓
Encroachment	✓		✓	✓
Increasing Population		✓		✓
Heavy rain			✓	
Informal Land filling	✓			✓
Soil erosion			✓	
Sand mining		✓		
Damages to water gates	✓			

Unauthorized developments	✓	✓		

Source: Survey data, 2020

As per the comments of all four experts, "lack of proper drainage system" and "encroachment" were the most addressed flood causing factors in the area. All of the respondents agreed that there is no appropriate drainage infrastructure in the Kaduwela city area to deal with water logging. As a result, collected water flows naturally to low-lying regions near the city borders. Encroachments have already harmed the area's natural drainage system. Encroachments may be plainly visible on both sides of the riverbanks, according to experts, breaking the requirement of a minimum distance from the river. Constructing human settlements in riverbanks destroy the plantation along the river boundaries loosening the soil condition, hence, increases the flood risk.

Further, they have highlighted the adverse effect of increasing population, informal land filling and unauthorized development in the area. It is noted that many people like to move to Kaduwela town center because of proximity to Colombo city (Central Business District) with affordable land prices. When population increases the demand for land and buildings also increase. As a result, when land supply is restricted, individuals aim to build unlawful constructions. Many commercial, industrial, and residential structures have been built closer to the river by filling marshy, paddy, and natural flood-prone regions, which is important. Unauthorized filling of these marshy regions and construction on those lands extends the time it takes for water to be retained in the surrounding areas. Other than that, some of them mentioned about the impact of sand mining, soil erosions, damages to water gates and heavy rain on flood risk in the area. As per the respondent #2 "sand mining is one major factor that increases flood risk in the area". Also, informal sand mining has already damaged the riverbanks in this area". According to respondent #3, the damages to the riverbanks are also caused by heavy soil erosion. Further, respondent #1 commented on "ineffectiveness of Watergates fixed in several strategic locations in the area". However, these Watergates are currently damaged and are not functioning. As a result, water flows with no control and flocked in the area for a longer period. Other than these direct and indirect man-made causes respondent #3 stated heavy rain to up country is a reason for outflow of Kelani River. However, as the respondent stated, "the real problem is that it takes a long time period to direct outflowed water to the water ways due to lack of proper drainage system".

5. CONCLUSION

The study explores to identify the significantly contributing factors on flood in Kaduwela MC Limits. The findings obtained from both analysis methods concluded that man-made factors are the most influenced factors for flooding in this area. Findings from residents' perceptions emphasize that non-availability of proper drainage system, violating rules and regulations, ineffective waste disposal are the major man-made flood causing factors in the area. Also, heavy rainfall is a significant natural factor for the flooding in the area. The most causative factors for flooding are blockage of drainage system (Cirella et al., 2019), improper waste dumping (Eran & Worku, 2018; Ijaz et al., 2021) as well as the natural factors like heavy rainfall (Cirella et al., 2019), were tally with the findings of the study.

Results of the content analysis that contained the views of the experts, further justified that the same above results such as the non-availability of proper drainage system as well as encroachments, increasing population, informal land filling, unauthorized developments, soil erosion along with sand mining and no attentions on the maintenance of broken Watergates are some other direct and indirect man-made flood causing factors. Therefore, this study encourages the immediate attention to construction and maintenance of proper drainage

system as an inevitable factor though it takes time. The relevant institutions and the leaders of the societies in the region are also working together to improve people's good attitudes in order to restrict unlawful acts. In order to reduce flood danger, improper trash disposal, unlawful developments, and sand mining in the region should be strictly monitored. Finally, it will benefit for planners and decision makers to create adaptive measures and policies to mitigate flood risk in the area to ensure the sustainability of the area.

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