Determination of Adaptive Capacity for Flash Floods in Sri Lankan Context: Colombo City

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Abstract: Sri Lanka has witnessed many natural and anthropogenic disasters that have had a devastating impact on community and the economic welfare of the country. Disaster management actions are required to be taken to reduce disaster risk. Adaptive capacity is one of such measurements that can predict the resilience of the community. Climate changes directly effects on occurrences of disasters, especially on flash floods, which is one of the frequent disasters in Sri Lanka. The present research explained about developing an adaptive index for flash flood occurrences in the Colombo City, Sri Lanka. Secondary data were used to identify indicators of the index as well as to quantify the frequency and severity of the flash flood. Five determinants and 16 indicators were developed for the index by considering all 47 wards of Colombo city. All measurements were weighted by using a questionnaire survey and the results were normalized. Five determinants were mapped based on analyzed data and the highest vulnerability wards were identified. Mahawatte ward has the highest vulnerability followed by Wanathamulla and Bluemendhal. On the other hand, Kotehena East was observed as the lowest vulnerability ward followed by Wellawatte South and Wellawatte North.

Key words; Adaptive capacity, Vulnerability, Flash floods, Climate change, Colombo City

I. INTRODUCTION

In Sri Lanka, natural disasters frequently occur that cause damage to socio-economic standards of the people [1]. Flooding incidences have increased in recent years, with large scale flooding reported in 2006 and 2018[2]. Deaths caused by floods are relatively low, but property damage and economic losses are very high [1]. In recent years flood in urban areas, which is generally called flash flood, has become a noticeable hazard in Sri Lanka. Flash floods occur as a result of the heavy rainfall and rapid accumulation runoff waters and most flash flooding is caused by slow-moving thunderstorms [3,4,5]. During the last few years some parts in Eastern and Northern provinces and most of the urban areas such as Colombo, Kaluthara, Gampaha, Anuradhapura and were heavily affected [1,6]. As per the information of Disaster Management Center floods have affected nearly 126,000 people from 20 districts in 2018 [7]. Blockages of drainage and silted drainage system due to the rapid development and improper garbage disposal induce the flash flood occurrence [4, 8, 9]. This situation greatly effects to the regions of Asia, specially the countries like Sri Lanka, India, Myanmar and so on [1]. Climate change is making weather unpredictable, uncertain and heavy storm rainfalls are occurring more [3, 10].

The impacts of disasters on development, poverty and vulnerability lead to disaster management and resilience processes [11, 12]. There is an emerging need to understand the current disaster management practices to reflect future adaptations and improvements [13]. The vulnerability of a system depends on three aspects such as sensitivity to climate change effects, system's exposure and its adaptive capacity to deal with those effects [14]. Adaptive capacity is unequal across and within the societies. Assessment of adaptive capacity depends crucially on the time and geographical scale [15, 16]. Adaptive capacity varies partly on the available economic, institutional social, human, and natural resources [17]. It should be measured through a unique view of different indicators for the determinants as well as different analytical approaches in various situations [16, 18].

This research is mainly focused to investigate ability of adjusting to moderate potential damages or to cope with consequences of flash flooding in Sri Lanka. Further, it is expected to identify determinants of adaptive capacity for flash floods and quantitatively analyze the adaptive capacity through those determinants.

II. METHODOLOGY

Colombo city was selected as the study area for this research. It is regarded as the commercial capital of Sri Lanka with the population around 647,000. Colombo has 2,400 mm average rainfall throughout the year. Most of the city area with 47 wards is covered by Colombo Municipal Council (CMC). Presently, Colombo city comprises of the highest abundance of infrastructure facilities, industrial activities, vital government institutions, commercial activities and residential activities. Recent flash flood occurrences and the severity of flash floods have been considered as criterion in selecting the study area. Disaster Management center statistics were used as secondary data to identify flash flood occurrences. The severity of flash floods occurrences was quantified by assessing the damages. Direct damages caused were classified in terms of property losses and life losses. Increase of traffic congestions, delays of trains, disturbances to the school activities, interruptions to the electricity and other services are some of the indirect impacts of flash floods.

A suitable framework of adaptive capacity was identified through a literature survey.

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Several indicators and measures for the framework were identified from census data sources and other inventories were weighted. Comparison of adaptive capacity across wards was required. Aggregated determinant value was calculated by using respective indicators for each determinant. Finally overall index of adaptive capacity was calculated by using the determinant values. Since normalizing disparate units is an essential step of analyzing adaptive capacity index, the normalization procedure was used. All the indicators under each determinant have been weighted from 1 to 4 scales according to relative importance of each indicator. Required data for the indicators were collected through secondary data sources of respective authorities during the period of 2015 to 2019. Average of the normalized indicator values were calculated based on the assumed weighting and later a single aggregated value for the determinant was calculated. Each determinant was equivalent significance in calculating the overall adaptive capacity index for each ward. Based on this assumption a final adaptive capacity index was calculated as the average of combined value of determinants for each ward and the values were mapped.

III. RESULTS AND DISCUSSION

A. Development of index

Five determinants and 16 indicators were used to develop the index. The spatial analysis of the adaptive capacity index and its determinants for the 47 wards within the CMC has given a unique view of the ability of city to potentially deal with flash floods which will occur in the future. Economic resource, technology resource, infrastructure, human resources, institutions and networks were identified as determinates. Identified determinants and indicators are shown in Table 1.

Table- I: Indicators and determinants of the index

Determinant	Indicators	Measurement
Economic resources	Income sources	Percentage of people having permanent income source
	Employment rates	Percentage of people employed out economically active population
	Income level	Percentage of families below poverty line
	Home ownership	Percentage of free hold ownerships
Infrastructure resources	Access to water	Percentage of safe drinking water source
	Accessibility	Road density
	Availability of health facilities	No of health facilities
	Availability Natural infrastructure	Percentage of water retention areas (channels, paddy, marsh, rivers etc)
Technology	Access to information	Percentage of television Percentage of radio
	Technology used for building construction	Percentage of buildings using non-permanent materials for wall, floor and roof Percentage shanty houses
Human resources	Education level	Literacy rate Percentage of population of school attainment over o/l
	Dependency ratio	Percentage of dependent population
	Good health condition	Percentage of people good mental and physical health
Institutions and network	Elected representation	No of political members elected for CMC 2010
	Reaction to past flash floods situations by institutions	No of emergency programs No of relief camps established by institutions
	No of social institutions	No of social institutions related to flash floods

The results of the individual determinants help to understand the contributors of adaptive capacity. Mapping the results of the adaptive capacity for wards is the one of the best way to analyze the data since it reveals the spatial relationship between area and respective adaptive capacity as represented by each determinant.

B. Economical Resources

Normalized results for indicators representing economic resource determinant are presented in Figure 1. Three clusters of areas were identified. The most extensive grouping of wards exhibits relatively high values for the economic resources determinant in the southern and western boundary of CMC. There is a grouping of wards revealing comparatively low values for the economic resources determinant straddling at the center of CMC area close to Pettah area. The bottom five wards for economic determinant are shown in Table 2. Fort and Milagiriya have the highest relative values respectively for the employment rates and income level where as Ginthupitiya and Mahawatte have the least for them.

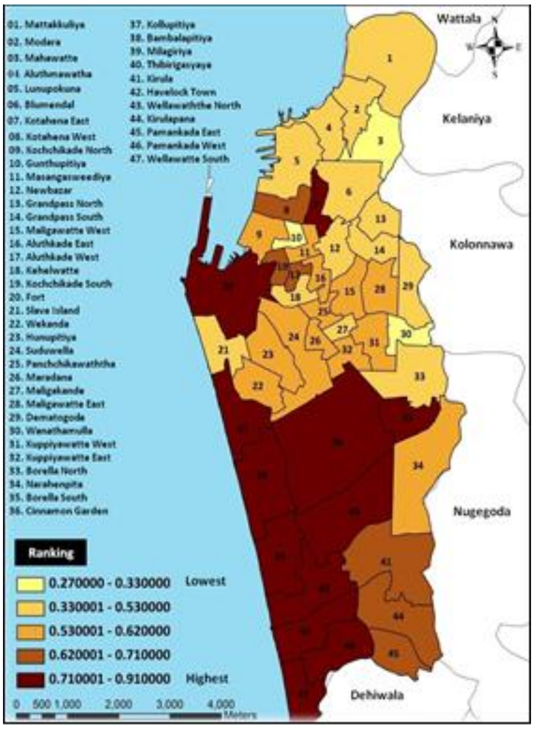

Fig. 1 Results of Relative Rankings for the Economic Determinant

Table- II: Wards that obtained highest and lowest values for economic determinant

Rankings	Ward Name	Index of Employment Rate	Index of income level	Index of source of income	Index of home ownership	Final economic determinant
1	Milagiriya	0.94	1.00	0.92	0.59	0.91
2	Fort	1.00	0.80	0.94	0.31	0.87
3	Havelock Town	0.92	0.95	0.80	0.69	0.87
4	Bambalapitiya	0.96	0.93	0.80	0.45	0.85
5	Thibirigasyaya	0.77	0.82	0.86	0.45	0.77
43	Grandpas North	0.28	0.27	0.59	0.57	0.40
44	Blumendhal	0.39	0.29	0.29	0.67	0.37
45	Wanathamulla	0.52	0.13	0.09	0.70	0.33
46	Mahawatte	0.58	0.07	0.00	0.78	0.32
47	Ginthupitiya	0.00	0.32	0.28	0.51	0.20

C. Technological Resources

Figure 2 illustrates that wards with the relative values of Technological Resources from high to low be disperse throughout the CMC, cluster pattern as such in economic determinant cannot be noticeable. First five wards having the highest values of the determinant scored high for both the indicators while Mahawatte has scored the lowest for both. Rest of the wards having lowest values, scored moderately for the indicator "access to information" but scored low for the indicator "technology used for building construction". Top and bottom five wards for Technological determinant are shown in Table 3.

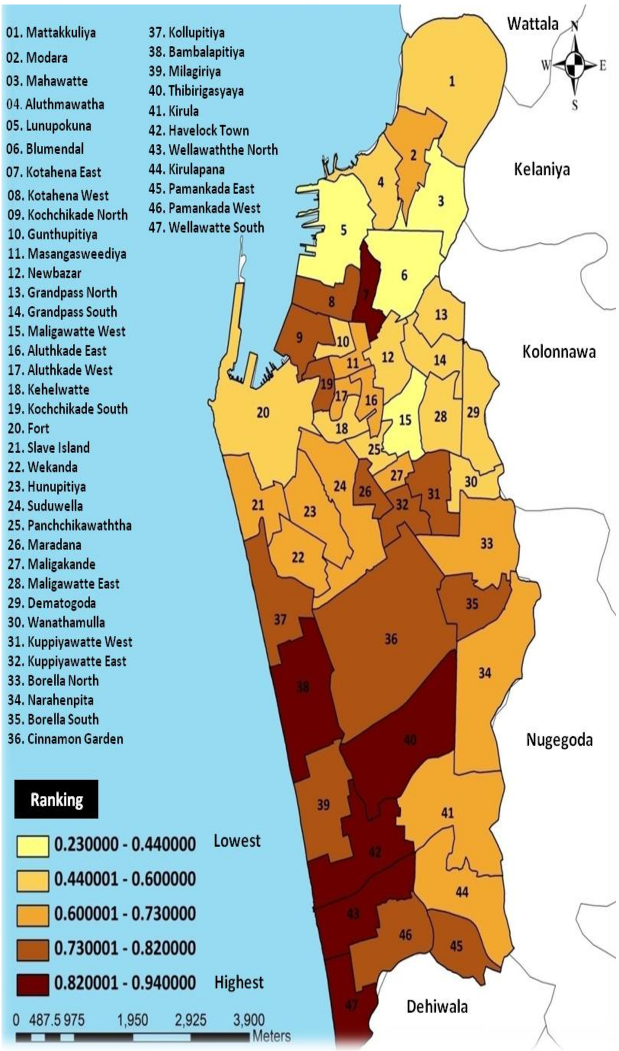

Fig. 2 Results of Relative Rankings for the Technological Determinant

D. Human Resource

Mapping of Human Resource shows four clusters of wards, one relatively high cluster, two moderate clusters and one cluster with the lowest values (Figure.3). Fort area is standing as lone leader of values of determinant as it scored the highest value for all the three indicators. High ranked areas are reported in the southern and western part of the CMC. Wards in this area showed high values for the indicator "education level" and low values for the indicator "dependency ratio". Results show that scores for indicators "education level" and "dependency ratio" are low and scores for the indicator "physical condition" are moderate and high.

Table- III: Wards that obtained highest and lowest values for Technological determinant

Rankings	Ward Name	Index of technology used for building construction	Index of access to information	Final technologic determinant
1	Havelock Town	0.94	0.88	0.94
2	Kotahena East	0.90	0.79	0.90
3	Wellawatte North	0.89	0.90	0.89
4	Thibirigasyaya	0.88	0.83	0.86
5	Bambalapitiya	0.85	0.87	0.86
43	Fort	0.23	1.01	0.49
44	Lunupokuna	0.38	0.57	0.44
45	Maligawatte West	0.39	0.47	0.42
46	Blumendhal	0.32	0.45	0.37
47	Mahawatte	0.23	0.29	0.20

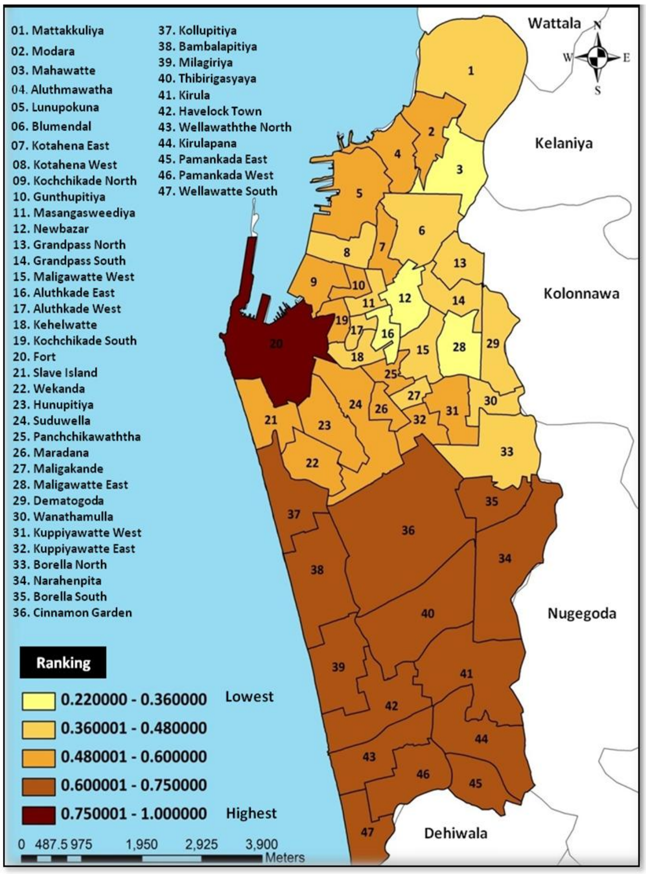

Fig. 3 Results of Relative Rankings for the Human Resource Determinant

E. Infrastructure

High ranked wards on the Infrastructure Determinant were scattered throughout the CMC area (Figure 4). The high ranked wards were Narahenpita, Kotahena East and Wellawatte South. Wellawatte south and Kotahena East scored high values for the access to water, whereas Narahenpita scored moderate values for it.
The results for the low-ranking wards were ambiguous and acquired very low scores on all aspects.

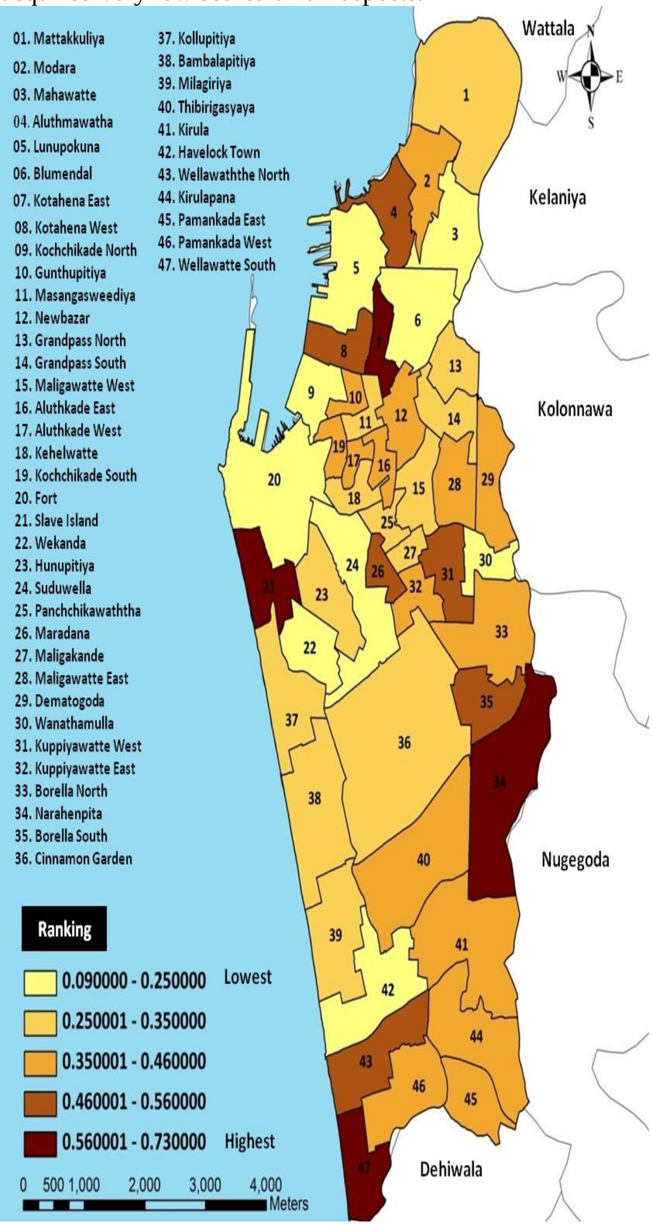

Fig. 4 Results of Relative Rankings for Infrastructure Determinant

F. Institution and networks

High ranked wards were clustered to the northern part of the CMC area and patches of moderate ranked wards dispersed throughout the other parts of CMC (Figure 5). High ranked wards scored high for the indicators "reaction of institutions for past flash floods" and "social institutions and networks". Political representation contributed unevenly for values of these wards. A band of low ranks existed on the western boundary of the CMC area. Those wards scored very low values for both reaction of institutions for past flash floods and social institutions and networks as there were limited attention paid by institutions for those areas.

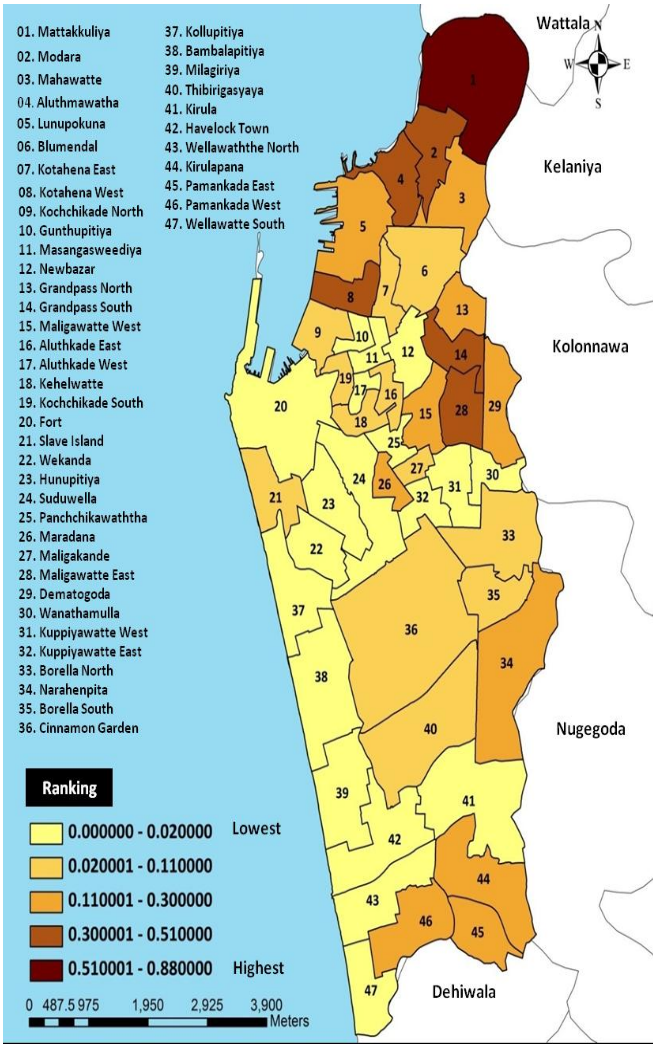

Fig. 5 Results of Relative Rankings for Institution and Network Determinant

G. Overall Rankings

Determinant values of each are aggregated to an average value to produce overall adaptive capacity index and used for spatial analysis. Identification of areas of groups of very high and very low ranking wards is very important for the policy planning. In additionally, demonstrations of the determinants that contribute mainly to these ranking are vital to accurately implement strategies. Such assessment will lead to better understanding of potentials and ways and means of planning and policy intervention. Figure 6 exhibits all the adaptive capacity values by summarizing them in to five groups. They are Kotehena East, Wellawatte South, Wellawatte North, Thibirigasyaya and Narahenpita. There is a second highest group of 11 wards and majority of them are located at the western boundary of CMC. Determinants rankings and overall ranking of first 5 wards are classified in Table 4.

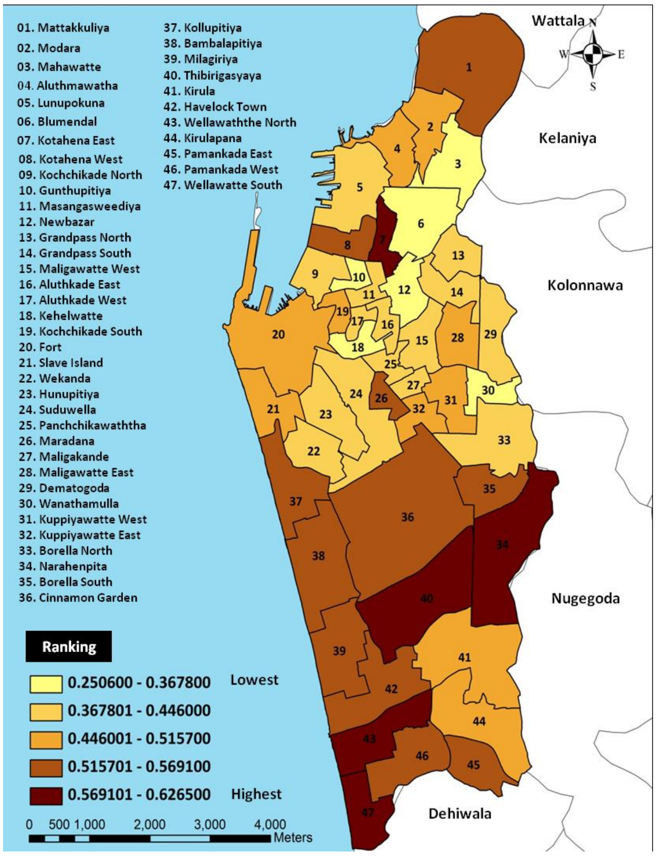

Fig. 6 Overall Adaptive Capacity Index

However, the interesting observation of this research is the wards with the comparatively lowest adaptive capacity are concentrated at the center and the eastern boundary of CMC area. Overall ranking and determinant rankings to understand principal determinants that cause them to be the lowest are shown in Table 5. The importance of researching determinants and indicators of adaptive capacity has lightened many aspects which can influence adaptive capacity for flash floods as well as for other climate change related disasters which may open ways for new domain of researches. Index of adaptive capacity and the spatial analysis has given opportunities for planning and policy designing to find the areas of the highest and lowest adaptive capacity and to facilitate necessary areas through policies and strategies. Moreover, the results can be used to help assess sites for detailed field surveys in order to realize the aspects, which have helped for city to adopt for Flash floods. This investigation will provide useful guidance to officials and legislators who are accountable for addressing the adaptation for the disasters like flash floods. The results can be used to predict future vulnerability for flash floods.

Table- IV: First five wards as per the overall ranking

Ward Name	Overall ranking	Economic resource determinant ranking	Technological resource determinant ranking	Human Resource determinant ranking	Infrastructure determinant ranking	Institution Network Determinant ranking
Kehelwatte	43	40	41	36	37	25
Ginthupitiya	44	47	32	23	28	30
Bluemendhal	45	44	46	32	46	23
Wanathamulla	46	45	37	39	47	38
Mahawatte	47	46	47	47	44	7

Table- V: Last five wards as per the overall ranking

Ward Name	Overall ranking	Economic resource determinant ranking	Technological resource determinant ranking	Human Resource determinant ranking	Infrastructure determinant ranking	Institution Network Determinant ranking
Kotehena East	1	6	2	16	2	17
Wellawatte South	2	11	6	3	3	47
Wellawatte North	3	10	3	6	4	46
Thibirigasyaya	4	5	4	7	13	19
Narahenpita	5	21	22	12	1	12

IV. CONCLUSION

Adaptive capacity should be measured through a unique view of different indicators to investigate ability of adjusting to moderate potential damages or to cope with consequences of flash flood in Sri Lanka. Five determinants and 16 indicators were developed for the index by considering all 47 wards within the CMC. Economic resource, technology resource, infrastructure, human resource and institutions and networks were identified as determinates. All wards were assessed against the determinants. All the top five wards score low value for the institution and network determinants. Both Wellawatte North and South ranked as the last two wards for the determinant "Institution and Network". But the good scores for technological resource, human resource and infrastructure determinants cause them to be second and third of overall ranking. Kotahena East has the first overall index despite the low scores for both Institution and Network and human resource determinant. The results of this study are very crucial in identifying the factors that influence the flash floods and predicting future vulnerable areas for flash floods. Spatial analysis has given opportunities for planning and policy designing to find the areas of highest and lowest adaptive capacity and to facilitate necessary areas through policies and strategies. In addition to that, the results can be used to help evaluate locations for detailed field surveys to better understand the aspects, which have helped for city to adopt for Flash flood.

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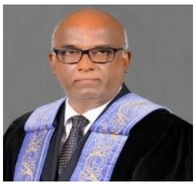

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