Pragmatic Insights on Selection of Indictors to Assess Community Resilience to Disasters

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Climate change induced disasters around the world keep increasing, making building resilience of community who live in risk- prone areas a prominent task of urban engineers, spatial planners and policy makers. Assessing either resilience or vulnerability is an essential step in resilience planning process which demand assessment methods. Among a range of assessment methods, indicator-based approaches/frameworks to measure community resilience to climatic disasters are mostly well taken by many practitioners. In order to contribute to a sound assessment method, this study attempted to stress upon the challenges confronted by practitioners in customizing and consolidating the indices. In this light, the study aimed to explain the relative importance of individual indicators to overall index emphasizing the fact that some indicators require special considerations in the above process.

Study used resilience level computed by three indicator-based methods for 40 disaster prone geographic units of Sri Lanka. Pearson Correlation coefficient was computed using the data of 40 localities to explain the relationship between individual indicators and aggregated resilience value. As this study aimed to identify the relative importance of each indicator to the overall index value, it was considered as stronger the correlation higher the relative importance of the indicator. Results revealed inferred that some indicators in the mix correlate better with the aggregated value of the index. Therefore, the most important indicators require a higher priority in consolidation and special considerations in customizing. Accordingly, it can be suggested that the relative importance of each indicator to the overall index should also considered as one of the criteria in identifying indicators. The finding of the study has derived one more criteria to be considered in the stage of identifying the indicators in the community resilience assessment process contributing to the enhancement of assessment method.

Key Words: *resilience building, disaster risk reduction, assessment methods, decision-making*

1. INTRODUCTION

Abrupt changes in performance of social systems occur in the case of disastrous events can lead systems to be failed, leading to a major reduction or complete loss in performance with respect to some or all measures [1]. Assessing community resilience in the aftermath of a disaster is an explicit task, which undertakes through recording the observations made throughout the recovery process. It enables a detailed overview of how long it has been taken a system to be re-organized, which changes were irreversible and which could have been done to expedite recovery. However, urban engineers, planners and policy makers are mean to take proactive initiatives though the lessons learnt are important in decision making process. Further, the decision making process cannot completely rely on evidenced risk because expected risk can be far higher. Therefore, this disaster risk reduction measures has to be based on long-term predictions, which anticipates a range of possibilities and uncertainties. At this point, measuring the community resilience to disasters at a given futuristic state becomes hypothetical and assumption-based. Further, "Resilience is an emergent property of systems and can be very context dependent, particularly in spatial-temporal scales and perspectives" [2)-3)]. However, practitioners who work in a range of domains – sustainable development, disaster management, and climate change adaptation– claim for a workable method to assess community resilience. "Measuring the resilience of a system is a complex undertaking, but promoting resilience-oriented adaptation will require the development of tools and metrics that will allow decision makers to assess progress and implement sustainable governance structures to facilitate adaptation" [4].

In response, many scholars [5), 2), 6), 7)] have attempted on developing alternative approaches to assess the resilience [3]. Among this range of resilient assessment approaches, inductive approaches –"whereby one establishes a set of characteristics 'inductive' which are judged to be relevant to resilience, and attempts to measure these" [8] – are well taken by many practitioners due to its simplicity and workability. One of the explicit challenges in employing inductive approaches is that "the choice of combinations of specific characteristics as proxy for resilience tends to be case-specific and cannot easily be generalised" [8]. Many have stressed upon the need of being context-specific [9] and there are several steps have been taken for customizing indicators. This study attempt to stress upon limitations in current practice of consolidating and customizing indicator-based methods employs in measuring community resilience to climatic disasters. Customizing and consolidating indicators is a common practice but there is nor or very limited considerations are given on the relative importance of each indicator to the overall index. Hence, the objective of this paper is to explain the difference of the degree that each indicator contribute to the overall resilience figure, which is computed by three selected community resilience indecies with reference to 40 selected disaster prone localities in Sri Lanka.

Findings of the study are envisaged to bring theoretical insights to the current practice of consolidating and customizing the indicator based approaches/frameworks employs in measuring community resilience to climatic disasters.

"Sri Lanka being an island nation is highly vulnerable to the negative consequences of hydro-meteorological disasters. In response, there is a strong need of urban communities to be coped-up, adopted and bounced back after a disaster" [10]. Therefore, the study will positively contribute to resilience current resilience building needs of Sri Lanka as well.

2. INDICATORS TO MEASURE COMMUNITY RESILIENCE TO DISASTERS

Many scholars and practitioners have utilized indicator-based approaches to define the attributes of community resilience and measure the resilience with proxies. In some studies, "Social resilience is measured through proxies of institutional change and economic structure, property rights, access to resources and demographic change" [11)- 12)]. Many researchers who works on the domains of psychology and sociology emphasized these proxies should include attitudinal and behavioural aspects of community resilience. "Factors such as beliefs, intentions, confidence and trust are often studied as influences on individuals' disaster-related behaviour, but it is harder to assess these at a community or institutional level" [13]. Therefore, decision makers who work on Disaster Risk Reduction (DRR) domains are mainly focused on quantifiable socio-economic indicators.

Socio-economic indicators are mainly represents the individual's internal ability to be resistant to a catastrophe but when refers to a human settlement a governance structure also plays a vital role in improving the overall resilience of the social system. "Any consideration of resilience must begin with a focus on services and functional activities that constitute the backbone of a resilient community. The continued operation and rapid restoration of these services are a necessary condition for overall community resilience" [1]. According Bruneau et al, the critical facilities - water and power lifelines, acute-care hospitals, and organizations- have the responsibility for emergency management at the local community level, therefore should be considered as the indicators of community resilience.

The characteristics approach presented by Hyogo framework convention has provided an integrated measure covering broader areas. "The Hyogo Framework is generally accepted by international agencies, governments and many NGOs Non-Governmental Organizations) – it is the only DRR framework agreed internationally – so it makes sense to align the Characteristics with its five Priorities for Action in order to draw relevant comparisons and present analysis to policy makers and other practitioners" [13]. As the above approach, all aspects of community resilience to disasters have been attributed to five thematic areas such as Governance, Risk Assessment, Knowledge and Education, Risk Management and Vulnerability Reduction, Disaster Preparedness and Response. As the thematic areas are very broad, each thematic are has sub divided into three as Components of Resilience, Characteristics of a Disaster-Resilient Community, and Characteristics of an Enabling Environment [13]. Capital based approach to measure community resilience introduced a five-fold classification based on social capital, economic capital, physical capital, human capital and natural capital [14] and Climate Disaster Resilience Index (CDRI) also presented another five-fold classification of resilience indicators based on physical, social, economic, institutional, and natural dimensions [15]. In 2010, Sherrieb et al [16] explained community resilience to disasters as a function of economic development and social capital where economic capital was attributed to resource level, resource equity and resource diversity and social capital was attributed to social support, participation and community bond [17]. The notion of Resilience within the BRIC framework is understood as a multifaceted concept that includes the social, economic, institutional, infrastructural, ecological, and community-based elements of the DROP model [17].

(1) Consolidating indicators

In a milieu where alternative approaches to measure community resilience to natural disasters were emerging, some authors [17] have developed consolidated matrices after reviewing existing literature comprehensively. In this process, some consolidated matrices were mere combinations whereas some matrices were formed with special reference to the once which has been frequently used by many. In this respect, Meyer et al categorized resilience community measures into two groups as commonly measured aspects and less measured aspects [18]. Many of the commonly referred variables were the once which represents socio-economic status of people whereas other less referred variables were related to institutional, cultural and ecological aspects.

The fact that being referred the most does not necessarily prove such indicators are mostly attributed to community resilience. Even a less referred indicator can be very important in assessing the resilience in a given context. Hence, identifying the most suitable mix of indicator to which represents the community resilience in the particular context is vital. "This should be a thoughtful process of decision making, in which, first, the Characteristics are reviewed to identify and select potentially relevant indicators, and then those selected are amended where necessary to provide the precise indicators required by the project. Often this requires extensive discussion by project stakeholders" [13]. In this process, it is vital to have an undestanding on the reletive importnce of indicators as how much each indicator contributes to the aggregate resilient level computed by a given index.

(2) Customizing indicators

Many of the indicator-based frameworks guide practitioners to customize the indicators by removing indicators, adding new indicators and modifying existing ones referring to the characteristics of the resilient community in the given context. "Such 'customizing' is to be encouraged, because it makes the characteristics more relevant to the particular needs and capacities of communities, the hazard threats those communities face, the type of DRR work implementing organizations are expert in and their capacities to deliver, and the wider operational and policy environment. It is important not to adopt individual characteristics without questioning their accuracy and relevance to a given situation" [13]. Therefore, it is cear that undestanding the difference of the degree that each indicator contribute to the overall resilience figure, which computed by an index, can better guide the decision makers in customizing indicators.

3. METHOD OF STUDY

This study aimed to identify the indicators, which significantly correlate with the aggregate value of the index and thereby explain the rletive importance of each indicator to the overall index. First, the study reviewed literature on resilient assessment methods to climate change-induced disasters and then selected three inductive assessment methods to compute resilience. Then, a set of 40 geographically defined administrative units in Sri Lanka, which had affected by climatic disaster at different degree were selected (Refer **Fig.1, Fig.2** and **Fig.3**).

Secondary data, which requires in computing resilience under each of the assessment method, were collected for all selected geographic units. Next, the community resilience levels of each geographic unit were computed employing three assessment methods respectively and the results were described through correlation between each indicator and the aggregated value to explain which indicators better represents the aggregate resilient value.

(2) Selection of Indicator-based approaches

Three methods out of the reviewed indicator-based assessment methods have been intended to select considering the (a) definition of resilience (b) ability to assess the resilience with secondary data sources (c) availability of practical, validated tool and materials.

(a) Definition of resilience: resilience of community has been defined in several ways but two common reflections which considered in screening were the capacity to bounce back after a shock and the capacity to adapt to a changing environment.

(b) Ability to assess the resilience with secondary data: "assessment becomes highly operational when data required are readily available from quantitative secondary and reliable sources" [19]. "The specific combination of measures chosen tends to be based on available data rather than a normative approach" [20]. Specially, this was considered as essential in making decisions at regional scale due to the need of overcoming difficulties in collecting a large set of primary data for communities of wide-spread geographic boundaries.

(c) Availability of practical, validated tools and materials: The approach requires going beyond the theoretical frameworks in order to support decision makers. Specially, it needs to be incorporated with a comprehensive set of supportive materials on how to compute, compare, prioritise and evaluate decisions.

Three selected assessment methods for the study consist of three indices; (i) Community Resilience Index (CRI) developed by Australian Government Bureau of Rural Sciences to assess the dependence on water for agriculture and social resilience, (ii) Resilience Index Measurement and Analysis (RIMA) model developed by Food & Agricultural Organization (FAO), and (iii) Resilience Capacity Index (RCI) developed by MacArthur Foundation Research Network on Building Resilient Regions with assistants from State University of New York.

All of the indices are consist of a set of criteria and measurable indicators. **Table 1, 2 and 3** show these criteria and indicators. Some indicators were subjected to slight modifications as per data availability but in such circumstances, the concept of original index was carefully considered.

The data pertaining to the selected indicators were based on various sources: Population and Housing Census 2011 and Provisional Census 2014, MDG (Millennium Development Goals) indicators of Sri Lanka 2014, Poverty Indicators 2012/2013, Sri Lanka Labour Force Survey 2013, and District Statistical Hand books 2014 published by the Department of Census and Statistics; Central Bank annual report 2014 published by the Central Bank of Sri Lanka; District Topological Maps (1:10000 scale) published by the Survey Department of Sri Lanka; and General Election Results 2010 published by Election Department of Sri Lanka.

Method of computing the resilience value is different from one index to another. Accordingly, In CRI method, each indicator score is converted to a score between 0 and 1 by dividing each DS division's score by the highest value for all DS divisions. Average of each dimensions were given an equal weight and the average of all dimensions were considered as the resilience value [19]. In RIMA method, "In the first stage, an index for each component is estimated separately using an iterated principal factor analysis over a set of observed variables. In the second stage, the resilience index is derived using a factor analysis on the interacting components estimated in the first stage in which the resilience index is a weighted sum of the factors generated using Bartlett's scoring method and the weights are the proportions of variance explained by each factor" [21)-22]. In RCI method, "to accommodate different indicator scales and metrics, indicator values are reported as Z-scores, which quantify how many standard deviations—in a positive or negative direction—a region's performance on an indicator deviates from the all metropolitan DS Division) average. The RCI for any metropolitan region DS Division) is the simple average of its Z-scores for each of the underlying RCI indicators" [23]. Resilience levels were computed according to the original methods specified in each approach without any modification.

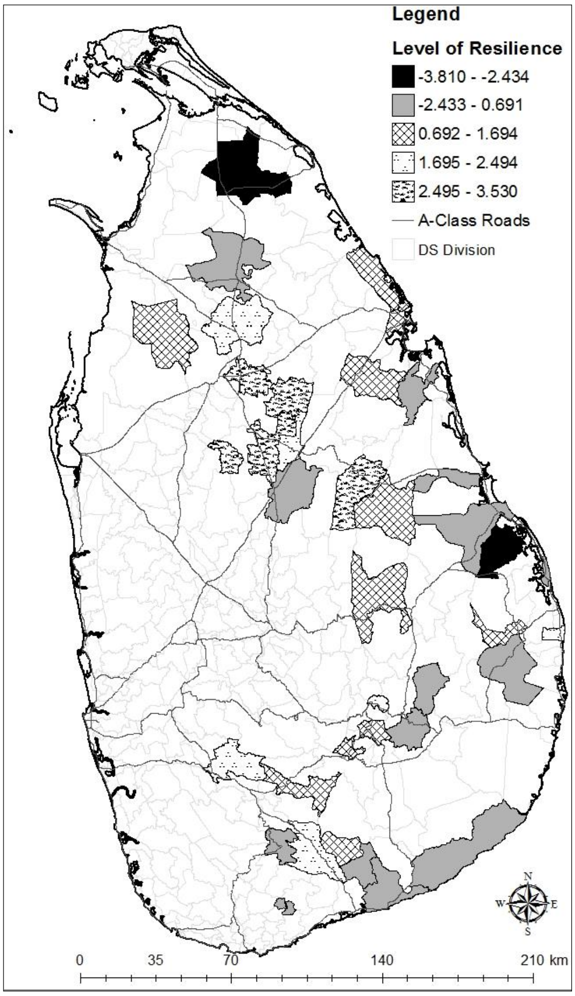

Fig.1 Spatial depiction of the resilient values derived from CRI method.

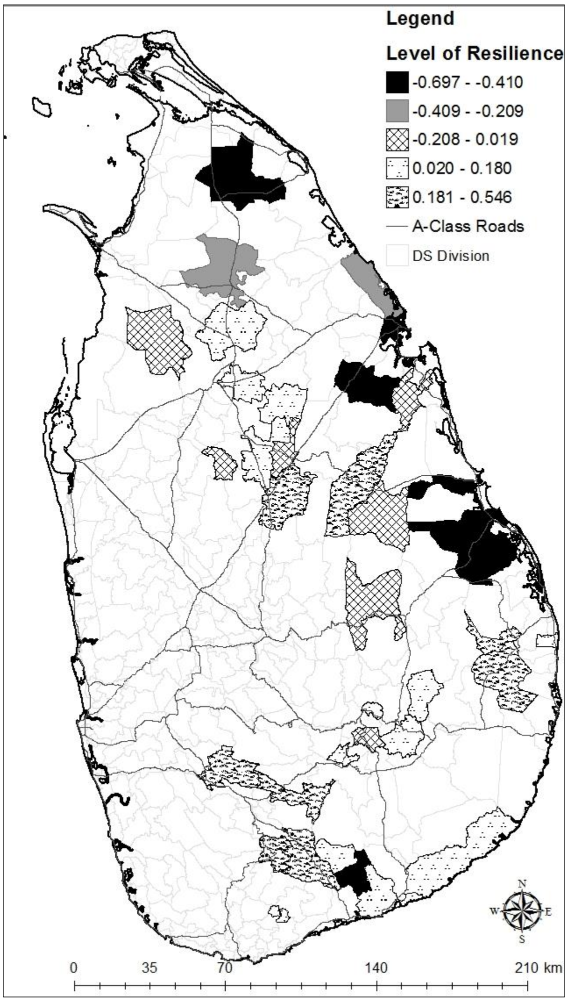

Fig.2 Spatial depiction of the resilient values derived from RCI method.

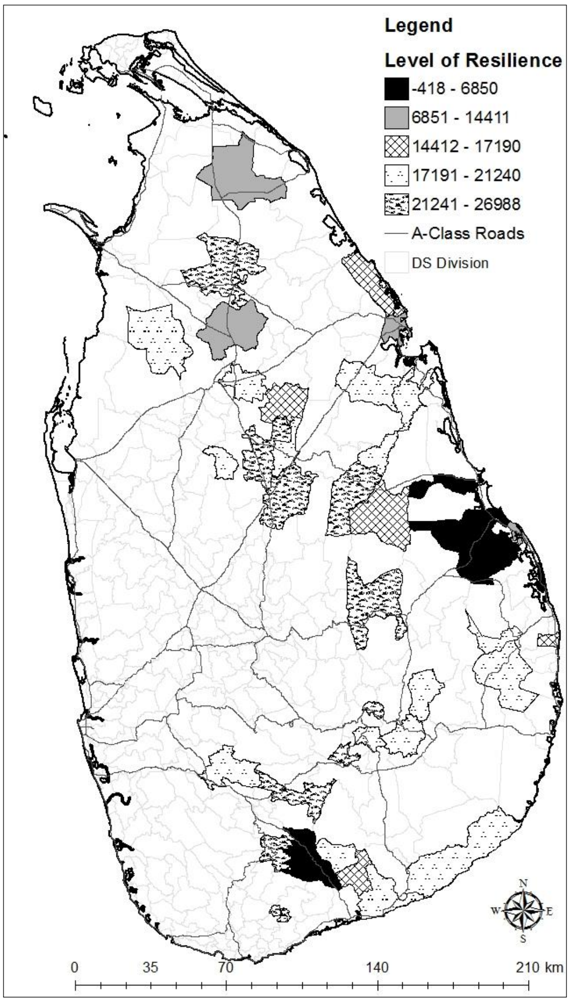

Fig.2 Spatial depiction of the resilient values derived from RIMA method.

4. RESULTS AND DISCUSSION

Once the community resilience values are computed, the aggregated value of each index for a given locality was correlated with the individual indicator values of the same locality. Pearson Correlation was coefficient using the data of 40 localities to explain the relationship between individual indicators and aggregated resilience value. As this study aimed to identify the relative importance of each indicator to the overall index value, it was considered as stronger the correlation higher the relative importance of the indicator.

In RCI, the indicators that represent the business environment including Number of small & medium business, access to electricity, banking density, road accessibility (r=.628, p<.001); annual average percentage over a five-year period of a local area population that lived within the same local area a year prior (r=.693, sig= p<.001); number of voters participating in the 2008 general election as a percentage of population age above 18 (r=.652, sig.= p<.001); and access to health service (r=.576 sig.= p<.001) were indicated a moderate relationship with the aggregate resilience level (refer **table 1**).

Table 1 Correlation Coefficient values derived for the indicators of RCI method.

Criteria		Indicator	r*
Income Equality	1.	Gini coefficient for income inequality	-.017
Economic Diversity	2.	Degree to which a local economy differs from the national economy by the proportion of its jobs in service, industrial and agricultural sectors	.043
Regional Affordability	3.	Percentage of households in the local area spending less than 35 percent of their income on food	.425
Business environment	4.	Number of small & medium business, access to electricity, banking density, road accessibility	.628
Educational Attainment	5.	Literacy rate	.282
Without disabled	6.	Prevalence of chronic illnesses and disabilities	-.002
Out of Poverty	7.	Poverty Head Count Index	-.231
Health Insured	8.	Access to health service	.576
Metropolitan stability	9.	Annual average percentage over a five-year period of a local area population that lived within the same local area a year prior.	.693
Home Ownership	10.	Number of owner-occupied housing units as a percentage of total occupied housing units	.149
Voter Participation	11.	Number of voters participating in the 2008 general election as a percentage of population age above 18	.652

Note : * r; correlation coefficient value with p <0.001

In RIMA, the indicator that represent the number of evacuated, dead, affected and relocated people during climatic disasters occurred in last 50 years revealed strong relationship (r= -.787, sig.= p<.001) relationship with the aggregate resilience level. Average monthly income also indicated a moderate relationship (r= -.653, sig.= p<.001) (refer **table 2**).

Table 2 Correlation Coefficient values derived for the indicators of RIMA method.

Criteria		Indicator	r*
Productive Assets	1.	Percentage of people live in own-house	.030
	2.	Percentage of families own Television, Radio, Laptop, Personal Computer	.210
		Data not available	
	3.	Percentage of population above 2030 Kcal level of dietary energy consumption	.268
Access to basic services	4.	Access to safe drinking water	.251
	5.	Access to electricity	.465
	6.	Access to sanitation	.489
	7.	Distance to primary school, public transport, market, health centre	.178
Social safety nests	8.	Percentage of people live in the DS Division since birth	.303
	9.	Bank density	.139
Adaptive capacity	10.	Average monthly income	.653
	11.	Employment to population force ratio	.422
	12.	Literacy rate	.502
Sensitivity	13.	Number of evacuated, dead, affected and relocated people during climatic disasters occurred in last 50 years Data not available	-.787

Note : * r; correlation coefficient value with p <0.001

In RCI, the indicators that represent percentage of households in houses with non-permanent wall materials (r= -.747, sig.= p<.001) and percentage of households in houses with non-permanent roof materials (r= -.747, sig.= p<.001) were indicated strong and moderate relationships respectively with the aggregate resilience level.

Accordingly, household level socio-economic indicators such as duration of residence, income and housing condition revealed a relatively high importance as well as local level amenities such as access to critical infrastructure - electricity, road health and sanitation- and business opportunities has been denoted high importance among other indicators (refer **table 3**).

Table 3 Correlation Coefficient values derived for the indicators of CRI method.

Criteria	Indicator	r*
Social Vitality	1. Percentage of people live in the DS since birth	.376
	2. Percentage of people in-migrated during last 5 years compare to previous 5 years	-.316
	3. Change of the Labour force participation (age 15-60) during last three years (2010-2013)	.531
	4. Access to safe drinking water	.285
Social Stress	5. Poverty Head Count Index	-.213
	6. Unemployment rate	-.014
	7. Percentage of households without housing	-.058
	8. Percentage of households in houses with non-permanent roof materials	-.641
	9. Percentage of households in houses with non-permanent wall materials	-.747
	10. Percentage of households in houses with non-permanent floor materials	-.436
	11. Percentage of people live in own hous	.308
Social Inclusion	12. Labour force participation of females	.502
	13. Share of women in employment in the non-agricultural sector	.356
	14. Change in the Unemployment rate 2010 to 2013	.127

Note : * r; correlation coefficient value with $p < 0.001$

5. CONCLUSION AND WAY FORWARD

In a context where indicator-based approaches/frameworks to measure community resilience to climatic disasters are vital to the decision making in the national efforts on resilience building, this study attempted to bring some light to the challenges confronted by practitioners in customizing and consolidating the indices. The objective of the study was to explain the relative importance of sole indicators to overall index. Study used resilience level computed by three indicator-based methods for 40 disaster prone geographic units of Sri Lanka.

Pearson Correlation coefficient was computed using the data of 40 localities to explain the relationship between individual indicators and aggregated resilience value. As this study aimed to identify the relative importance of each indicator to the overall index value, it was considered as stronger the correlation higher the relative importance of the indicator.

In conclusion, it was clear that some indicators in the mix correlate better with the aggregated value of the index. Therefore, the most important indicators require a higher priority in consolidation and special considerations in customizing. Giving less priority to the indicators has insignificant relationship is useful to manage the number of indicators in consolidation process specially, in circumstances where total number of indicators is reasonably high. Further, the indicators that have strong correlation are more crucial to omit or modify when customizing. This derives one more criteria to be considered in the stage of identifying the indicators in the community resilience assessment process contributing to the enhancement of assessment method.

This study only highlights the fact that relative importance should account in the above process yet to there more case studies are needed to validate the relative importance by indicator to a given context. This can be achieved by focusing future research either to generalize with more case studies for each approach or to modify the existing approaches remaking them more representative to the context.

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