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A critical review of selected tools for assessing community resilience

Ayyoob Sharifi

Global Carbon Project—Tsukuba International Office, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki Prefecture 305-8506, Japan

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ABSTRACT

The concept of resilience is increasingly used in academic and policy circles. To operationalize this concept and reduce the ambiguities surrounding it, since the turn of the century, various resilience assessment methodologies have been introduced. This paper provides a critical review of 36 selected community resilience assessment tools. These tools have been developed by a variety of entities, including national and local organizations, international donor organizations, and academic researchers. First, an overview of the selected tools is presented. This overview analysis shows that while some commonalities exist, there are also considerable differences between the tools. Next, based on literature review, an analytical framework is developed that identifies six criteria for evaluating performance of resilience assessment tools. These are, namely, addressing multiple dimensions of resilience, accounting for cross-scale relationships, capturing temporal dynamism, addressing uncertainties, employing participatory approaches, and developing action plans. Results show that limited success has been achieved in addressing these criteria. In terms of comprehensiveness, the environmental dimension has received relatively less attention in spite of its significance for building community resilience. Further improvements are needed to account for dynamics over time and across space. More attention to employing iterative processes that involve scenario-based planning is needed to better address challenges associated with uncertainties. Results also show that more attention needs to be paid to stakeholder participation in developing assessment tools. The paper concludes by highlighting several other areas of weakness that need to be addressed and discussing major challenges that still remain.

1. Introduction

Since 1980, the world has seen an increasing trend in the annual number of climatological, hydrological, and meteorological loss events (MunichRe, 2015). There is now a reasonable consensus that climate change has increased the frequency and intensity of loss events and this trend is expected to continue in the future (Field et al., 2014). Given the increasing concentration of people, activities, and resources in urban areas, this can have severe consequences for management of cities in the long term (Field et al., 2014). In response to concerns about the consequences of increase in frequency and severity of disaster events, over the past four decades, the concept of community resilience has gained increasing prominence in science and policy circles. Diffusion of the concept of community resilience also signifies the recognition of the fact that not all threats can be avoided and there should be mechanisms in place to ensure that disturbances are kept to a minimum (Renschler et al., 2010a). Furthermore, resilience implies learning lessons from the disruptive event and adopting adaptive and transformative approaches that lead to long-term incremental evolution of the system (Elmqvist, 2014; Matyas and Pelling, 2015; Sharifi and Yamagata, 2016).

As the concept of community resilience has continued to evolve, there has also been increased recognition of the importance of developing methods and instruments for its assessment (Cohen et al., 2016; Cutter, 2016). Community Resilience Assessment (CRA) can be regarded as a recent development in the field of resilience assessment and the last decade has seen a proliferation of works focused on this topic. In addition to growing recognition of the potential adverse impacts of climate change, surge of interest in CRA initiatives can be attributed to rise in the funds available for enhancing resilience, increasing reliance of donor organizations on resilience assessment results for allocating funds (Cutter, 2016; Tyler et al., 2014), and the need to measure progress against the risk reduction targets outlined in international frameworks and protocols (Schipper and Langston, 2015).

Since this study is focused on CRA tools, it is essential to first explain what is meant by the term "community". Community is a contested notion that has been defined in a variety of ways

E-mail addresses: sharifi.ayyoob@nies.go.jp, sharifigeomatic@gmail.com

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and there is still no single, universally accepted definition for it in the literature (Mulligan et al., 2016). An often used definition is a diverse group of individuals in a shared geographical area, who have common interests, are linked by dynamic socio-economic interactions, and engage in collective action (Alshehri et al., 2014; Frankenberger et al., 2013; MacQueen et al., 2001; Miles, 2015; Twigg, 2009). Defining community boundaries remains an issue of debate. Boundaries can be defined using functional measures such as catchment area of services (Chandra et al., 2011), psychological measures such as residents' perceptions (UNDP, 2014a), and political measures such as administrative boundaries (Frankenberger et al., 2013). Community boundaries can also be blurred. Mulligan et al. (2016) argue that it is difficult to draw community boundaries with certainty and, given the constant changes in the mobility and communication technologies, the community boundaries are likely to change over time. A community can be nested within larger communities (Mulligan et al., 2016). It is also possible that overlaps exists between communities and people belong to more than one community (Mulligan et al., 2016). Elaborating on the meaning of community resilience, Mulligan et al. (2016, 9) continue that community is a "multi-layered" notion. Dynamic interactions occur between communities and they "can operate simultaneously across multiple scales". For the purpose of this study, community is defined as a location-based entity that can be as small as a neighborhood or as large as a county. It is acknowledged that community is not a static entity and dynamic interactions exists across different scales. Assessing resilience of "imagined" and "virtual" communities (Mulligan et al., 2016) is beyond the scope of this paper. It is argued that community should be defined on a "case-by-case basis" (Sherrieb et al., 2010) and different scales (ranging from neighborhood to county) can be used as a suitable units of analysis for resilience assessment (Sherrieb et al., 2010). Adopting such a broad and flexible definition makes it possible to include various relevant tools in this critical review. It should be noted that tools and frameworks examined in this study are mainly focused on communities in the context of urban environments. However, some tools refer to communities beyond the city scale which may be located in rural settings. Therefore, it is decided to use the term community in general and avoid drawing distinction between urban and rural communities. It is also worth noting that tools and frameworks specifically designed for only assessing rural community resilience are not analyzed here and should be analyzed in the future.

Measuring community resilience is recognized as an essential step toward reducing disaster risk and being better prepared to withstand and adapt to a broad array of natural and human-induced disasters (Burton, 2014). Various other benefits can be realized by developing and implementing CRA tools. These tools transform resilience into a more tangible and measurable concept, and help understand what constitutes community resilience by, among other things, investigating different environmental, social, economic, physical, and institutional elements of a community that are related to resilience (see Section 3 for more details on how tools are related to communities). They encourage thinking about future uncertainties, and provide a lens through which complexities of communities as socio-ecological systems can be better understood (Levine, 2014; Sellberg et al., 2015). Conceiving communities as socio-ecological systems implies that ecological factors are coupled with socio-economic factors and multiple feedbacks, across different spatial and temporal scales, link these different factors together (Evans, 2011). Resilience assessment tools can also be used for benchmarking performance (resilience status) of communities against peers and best-practice standards. This can instigate competition among communities and provide a platform for them to share knowledge and learn lessons from one another (Barkham et al., 2014; Arbon et al., 2012).

As ex-ante decision support systems, assessment tools can help planners and decision makers identify vulnerable areas that need to be strengthened and suggest potential leverage points for intervention (Frankenberger et al., 2013). They can also help identifying areas that are lagging behind and need to be prioritized when allocating limited resources (Khazai et al., 2015; Sellberg et al., 2015; Sempier et al., 2010). As ex-post decision support systems, assessment tools can be utilized by organizations/local authorities that have undertaken resilience and disaster risk reduction activities and need to monitor effectiveness and efficiency of their plans and find out whether they have worked and the community is making progress toward becoming more resilient (Khazai et al., 2015; Renschler et al., 2010b).

Conducting assessment and effectively disseminating the results is important for enhancing transparency of the planning process and improving accountability of authorities (Pringle, 2011; Tyler et al., 2014). If developed and implemented in collaboration with different stakeholders, the assessment process can also empower citizens and enhance their role in decision-making process (Cox and Hamlen, 2014). In addition, stakeholder involvement can enhance risk communication to community members and help them understand what resilience means to them and where their community stands in terms of resilience (Khazai et al., 2015; White et al., 2014). Collaboration in the process can also lead to establishment of social networks that are deemed to be essential for enhancing resilience (Frankenberger et al., 2013).

Despite the existence of many CRA tools, few researchers have studied them and they have only focused on providing an overview of the existing tools and their structure. Irajifar et al. (2013) investigated eight selected assessment frameworks and found that they lack specific variables and attributes suitable for measurement purpose at the community level. Monaghan et al. (2014) provided a list of six CRA toolkits and explained the main features of them. Pfefferbaum et al. (2014) studied six different CRA tools and outlined their similarities and differences. Their work shows that existing tools have achieved considerable success in promoting resilience assessment and further research is needed to provide communities with more resilient development pathways. Larkin et al. (2015) provide an overview of resilience assessment efforts undertaken by various agencies across the United States. Their study highlights major characteristics of seven assessment frameworks. The study argues that the frameworks can help communities in identifying their weaknesses. However, more work is needed in terms of specifying guiding standards for use at the local scale (Larkin et al., 2015). To date, the most detailed investigation has been made by Cutter (2016) who provides an overview of 27 assessment tools. She discusses commonalities and differences between these tools in terms of their spatial orientation, main dimensions addressed in each tool, and the approaches they have adopted towards assessment. She argues that existence of multiple solutions to the assessment issue can be explained by the fact that the concept of resilience is interpreted differently depending on the context and assessment proponents have different motivations. She also emphasizes the need for assessment tools that are co-designed and acknowledge social dynamism of communities.

The issue of CRA deserves further consideration. This study aims to broaden the understanding of CRA tools by critically reviewing 36 selected CRA tools. The specific objectives are: (a) to provide a detailed overview of CRA tools; (b) to develop a framework for evaluating the validity of CRA tools in terms of content, construct, and development/implementation process; (c) to examine the selected CRA tools using the evaluation framework; and (d) to discuss various challenges and opportunities for improving performance of CRA tools.

This study is important because CRA is a relatively new and still developing field. CRA can provide a platform for involvement of

different agencies and stakeholders, within and beyond the community, in the planning and preparation processes. This in turn makes it possible to better address different socio-economic and environmental challenges faced by communities. CRA can also contribute to making resilience a "governable strategy" through developing iterative and quantifiable frameworks for resilience implementation (Larkin et al., 2015). CRA tools merit further investigation to identify their weaknesses and limitations and shed light on potential improvements needed in order to make them more effective for planning towards disaster-resilient communities.

This paper is divided into four main sections. The following section explains materials and methods and proposes a framework for evaluating performance of CRA tools. In the third section an overview of the selected tools is provided and results of analyzing them using the evaluation framework are presented and discussed. Conclusions of the study are drawn in the fourth section.

2. Materials and methods

2.1. Tools selected for analysis

In the previous section it was discussed that community size can range from a neighborhood to a county. Given this wide variation, a broad-based search strategy was used to retrieve tools and assessment frameworks related to various scales (i.e. block, neighborhood, district, and city). The search strings also accounted for the fact that different developers may use different terms to refer to their assessment schemes (i.e. tool, toolkit, model, framework, guidebook, and index). More details about the search strings can be found in the Appendix. The Web of Science Core Collection under the Online Search dropdown menu of EndNote software (title/keywords/abstract) was used to search for relevant studies. Also, since not all assessment schemes may be indexed in scientific databases, the strings were also searched for in Google (the first 20 hits).

Initial searches were conducted in June 2015 and yielded 510 matches, excluding duplicates. The titles and abstracts of these documents were examined to determine if they are reporting on tools developed for assessing resilience. It was found that many assessment tools have been developed by governmental and non-governmental organizations and academic researchers. To keep the scope of the study within manageable proportions, here attention will be restricted to those tools that are aimed at assessing resilience of community as a whole system. Accordingly, the study excludes tools designed to assess resilience of only a single component of the system (such as tools for assessing resilience of critical infrastructure (Fisher et al., 2010) or urban water system (CREAT, 2015)).

A complete list of the 36 selected tools can be found in Table 1. A brief overview of these tools and their approach towards assessing resilience is provided in Section 3.1. Content analysis of documents such as guidelines, policy papers, manuals, and peer-reviewed articles related to the selected tools was the main method used for evaluating them using the analytical framework introduced in the following section.

2.2. Framework for analysis

To critically analyze resilience assessment tools, it is necessary to first clarify what is meant by resilience. Resilience is a polysemic concept and its definition varies from one field of study to another, or even within a given field of study (Meerow et al., 2016; Norris et al., 2008; Sharifi and Yamagata, 2014, 2016). Issues related to the definition of urban and community resilience have been extensively discussed elsewhere (Meerow et al., 2016; Norris et al., 2008) and will not be repeated here. The definition provided by the National Academies is adopted for the purpose of this study: "resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (TNA, 2012, 14). These four abilities are interconnected and mutually reinforcing. However, interventions designed to enhance planning, absorption, recovery, and adaptation abilities may involve trade-offs that should be carefully considered (see Chelleri et al. (2015) and Matyas and Pelling (2015) for more information on resilience trade-offs). It should also be noted that community resilience building is not a linear process. Rather, it is a dynamic and iterative process influenced by forces across spatial and temporal scales. Acknowledging the dynamic interplay between preparation, absorption, recovery, and adaptation is needed to avoid being overwhelmed by constantly changing conditions brought about by uncertainties inherent in the future of communities as social-ecological systems (Sharifi and Yamagata, 2016).

The framework for analysis is developed based on literature review and includes criteria for assessing whether the above mentioned abilities and the dynamic interactions between them are accounted for in the development and implementation of a given CRA tool. An effective assessment tool should: comprehensively address multiple dimensions of community resilience, take into account the connections between different spatial scales, be able to measure changes across temporal scales, develop suitable measures for capturing uncertainties, be developed and implemented in collaboration with stakeholders, and lead to development of action plans for enhancing resilience. The methods used for assessing compliance with these characteristics are briefly explained below:

- *Being comprehensive*: multiple dimensions of community resilience should be addressed in the resilience assessment process (Cimellaro et al., 2016). To examine the extent of compliance with this characteristic, the methodology used in Sharifi and Murayama (2015) was adopted. First an extensive literature review was conducted to extract important criteria related to community resilience. An initial list of criteria was developed. This list was then compared with the criteria used by the selected CRA tools. This was done to ensure that all related criteria are included in the list. Following this, the selected criteria were grouped into five categories. Next, matrices, with criteria in the rows and tools in the columns, were developed and content analyses of documents related to the selected tools were conducted to determine whether the selected criteria are included in the selected assessment tools. It should be noted that, unless otherwise stated, content analysis is the method used for all critical analyses mentioned in this paper.
- *Acknowledging cross-scale relationships*: since resilience is a multi-scalar concept and changes at one scale may affect the others, it would not be realistic to assess resilience of a community in isolation from the upper and lower scales in the hierarchy. Each community is an open system, nested within a hierarchy of spatial scales, and its resilience is influenced by dynamic relationships and dependencies that may exist between different scales (Chelleri et al., 2015; Constas et al., 2014; Frankenberger et al., 2013; Quinlan et al., 2015). The selected tools were analyzed to see if they have accounted for interrelationships between the community level and other levels in the system.
- *Capturing temporal dynamism*: comparing baseline conditions with those recorded before a disruptive event provides information on the extent to which intervention measures have been effective in absorbing the shocks and also the extent of recovery following the event. Changing climatic conditions make it difficult to create resilient communities by only making reference to past and existing conditions. It is necessary to also understand system dynamics and develop strategies for anticipating future

Table 1
Basic information related to the selected CRA tools.

Tool	Year	Primary developer (s)	Focus	Risk	Target audience	Ref
CRC	2015	Bushfire and Natural Hazards CRC	AU	Natural	Local authorities and councils	Morley and Parsons (2015)
CRDSA	2015	Academia, Alshehri et al.	Saudi Arabia	Multiple	Local authorities	Alshehri et al., 2014 (2015)
DRI	2015	Earthquakes and Megacities Initiative (EMI)	Global	Multiple	Local, regional and national government agencies	Khazai et al. (2015)
CDR	2015	Academia, Yoon et al.	Korea	Multiple	Local authorities and public	Yoon et al. (2015)
NIST	2015	National Institute of Standards and Technology	US	Multiple	Local authorities	NIST (2015a,b)
RELi	2015	American National Standards Institute (ANSI)	US	Multiple	Developers	C3LD (2015)
TCRI	2015	Australia Netherlands Water Challenge	AU	Multiple	Local, state and national government, international organizations	Perfrement and Lloyd (2015)
CoBRA	2014	UNDP|Drylands Development Centre	Horn of Africa	Drought	Community leaders/governmental and non-governmental organizations	UNDP (2014a,b)
CRF	2014	The Rockefeller Foundation, Arup	Global	Multiple	Local authorities	TRF (2014)
FCR	2014	International Federation of Red Cross and Red Crescent Societies (IFRC)	Global	Multiple	IFRC programs and national societies (of IFRC)	IFRC (2014)
Grosvenor	2014	Grosvenor, real estate investor (industry)	Global	Multiple	Company officials, city authorities, aid agencies	Barkham et al. (2014)
ICLEI	2014	ACCCRN, Rockefeller Foundation, ICLEI	Global	Natural	Local authorities	Gawler and Tiwari (2014)
UNISDR	2014	IBM and AECOM	Global	Natural	Local authorities, insurance companies, private industry	UNISDR (2014)
CRS	2013	Community and Regional Resilience Institute (CARRI); Meridian Institute; Oak Ridge National Laboratory	US	Multiple	Community leaders	CARRI (2013) and White et al. (2014)
LDRI	2013	Academia, Orencio and Fujii	The Philippines	Multiple	Local authorities	Orencio and Fujii (2013)
USAID	2013	USAID	Global	Poverty	Government and non-governmental organizations, donors	Frankenberger et al. (2013)
CDRST	2012	Torrens Resilience Institute	AU	Multiple	Planners, local authorities, community members	Arbon et al. (2012, 2016)
BCRD	2011	RAND corporation	US	Health	Community leaders/governmental/non-governmental organization	Chandra et al. (2011)
CART	2011	TDC/University of Oklahoma	US	Health	Community-based organizations	Pfefferbaum et al. (2011)
ResilUS	2011	US, Resilience Institute is part of Western Washington University's Huxley College of the Environment	US, Japan	Mainly Earthquake	Local authorities	Miles and Chang (2011), based on a prototype developed in 2006
ICBRR	2012	Palang Merah Indonesia (PMI) and Canadian Red Cross (CRC)	Indonesia	Multiple	Local authorities and public	Kafle (2010, 2012)

Table 1 (*Continued*)

Tool	Year	Primary developer (s)	Focus	Risk	Target audience	Ref
	Kafle (2010, 2012)					
BRIC	2010	Academia, Cutter et al.	US	Multiple	Local authorities	Cutter et al. (2014) and Cutter et al. (2010)
CDRI2	2010	Academia, Shaw et al.	South/South East Asia	Multiple	Community leaders/local authorities	Shaw et al. (2010)
CERI	2010	AWM (Advantage West Midlands) Strategy Team	UK	Recession	Local authorities	Team (2010)
CDRI	2010	Coastal Services Center And The National Oceanic and Atmospheric Administration	US	Multiple	Community leaders	Peacock et al. (2010)
CRI2	2010	Academia, Sherrieb et al.	US	Multiple	Local authorities	Sherrieb et al. (2010)
CRI	2010	MS-AL Sea Grant/National Oceanic and Atmospheric Administration (NOAA)	US	Coastal (natural)	Planners, policy makers, emergency service providers	Sempier et al. (2010)
PEOPLES	2010	National Institute of Standards and Technology (NIST)	US	Multiple	Planners and local authorities	Renschler et al. (2010b)
CRT	2009	Bay Localize project of the Earth Island Institute	US	Recession; natural	Planners, community organizations, individuals, training centers	Schwind (2009)
SPUR	2009	San Francisco Planning + Urban Research Association	US	Earthquake	Local authorities, builders and developers	Poland (2009)
DFID	2009	Department for International Development and other agencies	UK	Natural	Academia, government and civil society organizations	Twigg (2009)
CARRI	2008	Community and Regional Resilience Institute	US	Multiple	Community-based organizations	Cutter et al. (2008)
Hyogo	2008	UN/OCHA and UN/ISDR	Global	Natural	Local and national authorities, community-based organizations, non-governmental organizations	UN/ISDR (2008)
USIOTWT	2007	U.S. Indian Ocean Tsunami Warning System Program and other institutes	South/South East Asia	Coastal (natural)	Governmental and non-governmental organizations; International aid agencies, banks, and donors.	USIOTWSP (2007)
THRIVE	2004	Prevention Institute	US	Racial health disparity	Local government, NGOs	THRIVE (2004)
CRM	2000	Canadian center for Community renewal	Canada	Recession	Local authorities, community members	Rowcliffe et al. (2000)

changes (Walker and Salt, 2012). The extent of attention to past, current, and future conditions was examined across the selected tools.

– *Addressing uncertainties*: due to uncertainties inherent in climate models, adaptation thresholds are constantly shifting and this makes setting long-term resilience goals a very challenging task. It should be acknowledged that resilience is an emergent feature of complex, adaptive social-ecological systems and assessment indicators and targets should be set through evolutionary processes (Collier et al., 2013; Folke et al., 2010; Levine, 2014; Schipper and Langston, 2015; Watson et al., 2014). Adopting an iterative process that involves monitoring performance and regular update of baseline conditions and targets is necessary for dealing with uncertainties (Pringle, 2011). Furthermore, as part of an ongoing resilience assessment, it is needed to develop different future scenarios in order to ensure being prepared for even the most extreme conditions (Frankenberger et al., 2013; McLeod et al., 2015). To examine compliance with this criterion, the selected tools were examined to find out if they have employed iterative processes that involve scenario-based planning and adaptive management.
– *Employing participatory approaches*: importance of participation for enhancing community resilience is emphasized in the literature (Norris et al., 2008). Multiple benefits can be obtained from open, participatory approaches that engage a broad array of stakeholders in the decision making process. Adopting participatory approaches throughout the assessment process (both development and implementation) improves local understanding of risk and resilience, provides capacity-building benefits and creates a platform for knowledge and experience sharing

(Frankenberger et al., 2013; Pfefferbaum et al., 2014; Tyler et al., 2014). Through improving social communication networks and enhancing social capital, co-design and co-implementation of assessment tools leads to better performance in terms of the four resilience abilities discussed at the beginning of this section (Pfefferbaum et al., 2012a; Pringle, 2011; Renschler et al., 2010b). Collaborative development and implementation of tools also improves accuracy and context-specificity of the process. It furthermore, helps ensure that selected criteria reflect the priorities of a larger group of stakeholders, can be used to inform decisions regarding trade-offs, and enhances local ownership and legitimacy that can lead to better implementation (Gibson, 2006; Pasteur, 2011). The selected tools were analyzed to see if they have been developed and implemented through participatory approaches.

– *Developing action plans*: results of the resilience assessment process should be disseminated to the community. They should also be used to identify and prioritize intervention strategies and develop action plans and road maps for transition to a more resilient community (Pfefferbaum et al., 2012b; Schwind, 2009).

Results of the study are presented in the next section.

3. Results and discussion

3.1. Overview of the selected tools and their approach towards assessment

The CRA tools selected for the purpose of this study are listed in Table 1. As can be seen from the table, all these tools have been developed since the turn of the century and most of them have been released since 2010. This indicates a surge of interest in CRA (Fig. 1 in the Supplementary Appendix). In terms of the "resilience of what?" question, Table 2 shows that framing of community can be different depending on the tool, and it can encompass a wide variety of spatial scales including neighborhood, city, and county. As explained in the Introduction, assuming that the term 'community' has a broad definition and can be defined on a "case-by-case" basis, it has been used for discussions in the rest of this paper.

Fifteen out of the 36 selected tools are developed for assessing resilience of American communities. Eight tools have been used for assessing resilience of different communities across the globe. These have mainly been developed by international donor organizations. The rest of the tools have been developed for use in Australia, Canada, Japan, Horn of Africa, and South/South East Asia, Korea, and Saudi Arabia. Important point to be mentioned here is that there is still a lack of tools developed by local authorities and organizations in the developing countries. Tools developed by non-local experts may not be able to appropriately reflect local needs and conditions.

Regarding the "resilience to what?" question, a large proportion of the selected tools (about 50%) are designed to address multiple hazards. Eight tools are focused on natural hazards only. There are also tools for addressing health-related risks, recession issues, earthquake hazards, and poverty issues (Fig. 3 of the Appendix in Supplementary material). Communities need to be prepared to address risks posed by multiple hazards occurring in multiple domains. This should be accounted for when developing CRA tools. As can be seen from Table 1, CRA tools are designed to attract attention and inform a wide range of target audience(s) including, in decreasing order of frequency, local authorities, non-governmental organizations and community members, aid agencies and international donor organizations, planners, developers, insurance companies, and academia (Fig. 4 of the Appendix in Supplementary material).

3.1.1. Types of assessment

Based on overall aims of the assessment and the timeframe over which it has been conducted, assessment tools can be categorized into two broad types: "formative" and "summative" (Pringle, 2011; Turner et al., 2014). Formative assessment involves ex-ante evaluation and continuous monitoring of the conditions from the early stages of the planning process. It is based on process-based methodologies aimed at enhancing adaptive capacity through incremental improvement of the conditions (Pringle, 2011; Turner et al., 2014). This type of assessment provides opportunities for learning and given its iterative nature would be suitable for addressing dynamism issues and accounting for future uncertainties. In contrast, summative assessment is conducted as an ex-post measure of the effectiveness of interventions. It is, therefore, outcome-based, helps communities understand where they stand in terms of resilience, and provides evidence needed for making decision about the necessity of modifying intervention strategies (Pringle, 2011; Turner et al., 2014). About 60% of the tools have used summative approach.

3.1.2. Methods and approaches to assessment

Selected tools have adopted one or a combination of the following methods to determine the extent of compliance with the resilience criteria (the first three have already been mentioned by Pringle (2011)): assessment against baseline conditions, assessment against thresholds that reflect program objectives, assessment against principles of good resilience, assessment against peers (benchmarking), and assessment based on the speed of recovery. Assessment against baseline conditions aims to determine changes in the community status over time, particularly in terms of vulnerability to hazards (longitudinal assessment). Assessment can also be against threshold values assigned to each individual resilience criterion. These threshold values reflect program objectives pursued by the community. Principles of good resilience can be identified, and continuously updated, based on the evolutionary understanding of what constitutes community resilience (Pringle, 2011). Benchmarking is used to compare status of communities against their peers. It can help communities learn lessons from one another. Finally, assessment based on recovery speed is used to find out whether the community has been able to return to the equilibrium state in a timely manner. This method would only be applicable in case disaster strikes the community. For instance, an acceptable recovery time range can be specified with upper and lower bounds corresponding to "best potential performance" and "minimal acceptable performance", respectively. The better the performance of the community, the closer the equilibrium point will be to the upper bound of acceptable recovery time (Fox-Lent et al., 2015, 213). Table 2 shows that assessment against baseline conditions, assessment against principles of good resilience, and benchmarking are the most common methods adopted by the selected CRA tools (Fig. 5 of the Appendix in Supplementary material).

Selected tools rely on both existing secondary data and primary data collection for assessing resilience. Secondary data include, but are not limited to, census data, historical records, and statistics provided by national/local departments and non-profit organizations. Primary data is collected by methods such as surveys and key informant interviews. As shown in Table 2 and Fig. 19 of the Appendix in Supplementary material, for 44% of the tools both primary and secondary data is needed. Twenty eight percent of the tools mainly rely on secondary data only. For primary data only, this share is six percent. Due to lack of information, it is not clear what kind of data would be needed for assessment using the rest of the tools. However, based on the indicators and variables proposed by them, it can be stated that they will also rely on both primary and secondary data.

Table 2
Basic characteristics of the selected CRA tools.

Tool	Scale	Formative, Summative	Format	Data source	Quan or qual	Baseline	Thresholds	Principles of good resilience	Benchmarking	Recovery speed	Equal weighting	Ongoing communi-cation	Strengths/ weaknesses	Changes over time	Illustration techniques
CRC	Community	**S**	Index	NA	Both	×	×	×	√	×	√	×	√	×	√
CRDSA	Community	**S**	Index	NA	Both	√	×	×	×	×	×	×	×	×	√
DRI	City	S	Index	Prim	Qualitative	×	×	√	√	×	√	×	×	√	√
CDR	City (local municipalities)	S	Index	Seco	Quantitative	√	×	×	√	×	√	×	√	×	√
NIST	Community	F	Toolkit	Both	Both	√	√	√	×	√	√	×	√	√	×
RELi	Community, building, infrastructure	S	Index	NA	Both	√	√	√	×	×	√	×	√	×	×
TCRI	Community	**S**	Model	Seco	Quantitative	√	×	×	√	×	×	×	√	×	√
CoBRA	Community, household	F	Toolkit	Both	Both	√	√	√	√	×	√	√	√	√	√
CRF	City	**F**	Toolkit	NA	Qualitative	√	×	×	×	√	√	×	√	×	×
FCR	Community	F	Toolkit	NA	Quantitative	×	√	×	×	×	×	×	√	√	×
Grosvenor	City	**S**	Index	Seco	Qualitative	×	×	×	√	×	√	×	×	×	√
ICLEI	City	**F**	Toolkit	Both	Qualitative	√	×	√	√	×	×	√	√	×	√
UNISDR	City	S	Scorecard	Both	Both	×	×	√	×	×	√	×	×	×	×
CRS	Neighborhood	**F**	Toolkit	Both	Qualitative	×	×	×	×	×	×	√	√	×	√
LDRI	Community	**F**	Index	NA	Both	×	×	√	×	×	×	×	×	×	×
USAID	Community	S	Toolkit	Both	Both	√	×	×	×	×	√	×	×	×	×
CDRST	Community	S	Toolkit	Both	Both	√	×	√	×	√	×	×	√	×	×
BCRD	Community	**F**	Toolkit	Both	Both	×	×	×	×	×	√	×	×	×	×
CART	City, neighborhood	**F**	Toolkit	Both	Qualitative	√	×	×	×	×	√	√	√	×	×
ResilUS	Household, neighborhood, Community	**S**	Model	Seco	Qualitative	√	×	×	√	√	√	×	√	×	√
ICBRR	Community	**F**	Index	NA	Both	√	×	√	×	×	×	×	×	×	×
BRIC	County	**S**	Index	Seco	Quantitative	√	×	×	√	×	√	×	√	×	√
CDRI2	City	**S**	Toolkit	Both	Both	√	√	×	√	×	×	√	√	√	√
CERI	Local Authority District	S	Index	Seco	Quantitative	×	×	×	√	×	×	×	√	×	√
CDRI	County	**S**	Index	Seco	Both	√	×	×	√	×	×	×	√	×	√
CRI2	County	**S**	Index	Seco	Both	√	×	×	√	×	√	×	√	×	√
CRI	Coastal Community	**S**	Index	Seco	Qualitative	√	×	×	×	√	√	×	√	×	×
PEOPLES	Community	**S**	Toolkit	Both	Both	√	×	×	×	√	×	×	×	√	√
CRT	Neighborhood, city, or county	**F**	Toolkit	Both	Qualitative	×	×	×	×	×	√	√	√	×	×
SPUR	Community, city	F	Scorecard	Prim	Quantitative	√	×	×	×	√	√	×	×	×	×
DFID	Community	**F**	Toolkit	Both	Qualitative	√	×	√	×	√	×	√	√	×	×
CARRI	Community to regional	**S**	Index	Seco	Both	×	×	×	√	×	√	×	×	×	√
Hyogo	City and state levels	F	Toolkit	Both	Both	√	×	√	×	√	√	×	×	√	×
USIOTWSP	Community	F	Toolkit	Both	Qualitative	√	×	√	×	√	√	×	√	√	√
THRIVE	Neighborhood	**F**	Toolkit	Both	Qualitative	×	×	√	×	×	×	×	√	×	×
CRM	Community	F	Toolkit	NA	Both	√	×	×	×	×	×	×	√	×	×

√: addressed.
×: not addressed or not enough information provided.
Prim: primary data source.
Sec: secondary data source.
Both: both primary and secondary data source.
NA: not enough information provided.

Tools have used both quantitative methods based on numerical data and qualitative methods based on public perceptions and expert judgement for evaluating performance using the above-mentioned methods. Several reasons have been mentioned for the importance of employing qualitative methods based on normative judgements. These methods are useful for circumstances where data availability is a problem. Furthermore, resilience is a value-laden concept, influenced by factors such as preferences, attitudes, and perceptions. Community members have a better knowledge of needs, vulnerabilities, and coping capacities of their own community and qualitative assessment is needed to understand the opinions of people (Jones and Tanner, 2015; Olazabal and Pascual, 2016). Quantitative methods are also needed to address concerns about subjectivity of the assessment process.

Depending on how the above mentioned methods have been utilized for conducting resilience assessment, four major approaches (overall format) to resilience assessment can be distinguished: scorecards, indices, models, and toolkits (Cutter, 2016). Scorecards are used to obtain values for performance against each criterion in the resilience assessment tools. These values could be in a variety of forms such as answers to dichotomous or multiple-choice questions (Rowcliffe et al., 2000), calculated statistical values (e.g. counts, percentages, medians, means, rates) (Peacock et al., 2010; Rowcliffe et al., 2000), or judgements and/or perceptions (Rowcliffe et al., 2000). When using judgements for assessment purpose, scaled questions are often used to quantify the qualitative feedback. For instance, using questionnaire surveys, degree of meeting the resilience criteria can be assessed on a 1–5 level scale, with 5 being the complete compliance (Pfefferbaum et al., 2011; Twigg, 2009).

Indices often use (weighted) average or (weighted) sum of scores obtained for all criteria in the assessment tool. Therefore, indices are mainly relying on quantitative data for generating an aggregate index value (Cutter, 2016). Obtaining an index may require standardization for comparison purposes (Peacock et al., 2010). Also, since the relative importance of the assessment criteria may vary depending on contextual and temporal factors, some tool developers assign weights to the selected criteria (Table 2). This is often done based on methods such as Analytical Hierarchy Process (AHP) that is used to determine weights using expert opinions (Alshehri et al., 2015; Orencio and Fujii, 2013). Therefore, it involves a certain degree of subjectivity. As Table 2 indicates, majority of the selected tools have treated the criteria as being equally important (Fig. 6 of the Appendix in Supplementary material). Obtaining an index value can be useful for assigning an overall rating to the performance of the community (e.g. outstanding, excellent, etc.).

Models are used to simplify complex relationships between various risk and resilience related factors, and overcome uncertainties and limitations associated with predicting future events and their consequences. Data obtained using other methods discussed above (e.g. the past and current data on disaster impact, historical trends, community vulnerability, etc.) are utilized as input to mathematical algorithms and scenario analyses. The outputs can be used to approximate future conditions (Cutter, 2016). Probabilistic risk models and models for estimating losses and recovery time are three examples to be mentioned here (Miles and Chang, 2011; Winderl, 2014).

Lastly, toolkits have a broader scope and establish procedures for assessing resilience using one, or a combination, of the three approaches mentioned above (Cutter, 2016). In addition to providing guidance on how to conduct assessments, toolkits can also outline mechanisms for identifying assessment criteria, collecting required data (Cutter, 2016), assigning weights (if deemed necessary), conducting assessment and suggesting interventions based on the assessment results, and monitoring implementation of action plans. Frequency distribution of the approaches taken by the selected assessment tools is displayed in Fig. 7 of the Appendix in Supplementary material. It can be seen that most of the assessment processes have been structured in the format of toolkits and indices.

3.1.3. Presentation of results

As mentioned earlier, assessment results are expected to be communicated with multiple target audiences. Effective dissemination of findings is an important component of any assessment process and should be considered as an essential effort that lays the groundwork for a better informed decision-making process. Findings should be presented in a way that provides a concise overview of the performance of communities in terms of resilience. Only presenting a composite index would not be sufficient for informing the potential target audience(s).

Several issues should be considered for effective communication of the findings. Since resilience is an emergent property of communities, communication should be an ongoing, two-way process and not just a one-time, isolated activity that happens as the last step of the CRA (Pringle, 2011). Strengths and weaknesses of the community should be communicated in a manner that facilitates further improvement. Those features of the community that have helped it achieve desirable performance should be identified and highlighted for guiding development of other communities (Pfefferbaum et al., 2012a). Tools and techniques such as spider diagrams (Fig. 1a) can be used to identify the criteria on which the community performs poorly and prioritize them when developing interventions to be promoted by action plans.

Communication should be done in a way that Positive assessment results do not lead to a false sense of security and complacency. On the other hand, inappropriate communication of vulnerabilities and weaknesses can have significant socio-economic ramifications and create a sense of panic.

When CRA tools are used for assessing several communities, visualization techniques such as color-coded maps can be used to highlight communities that are lagging behind and need to be prioritized for improvement. In order to enhance transparency of the planning process and accountability of the decision makers, illustration techniques such as “bull’s eye representation” can be used and regularly updated to indicate not only current status, but also progress or decline in meeting the benchmarks over time (Fig. 1b) (Khazai et al., 2015).

As can be seen from Table 2 (and Fig. 8 of the Appendix in Supplementary material), these issues are not appropriately addressed in the selected CRA tools. In particular, selected tools need to pay more attention to ongoing communication of findings with stakeholders and providing information on how resilience status has changed over time.

3.2. Evaluation against the framework

3.2.1. Scope of assessment and comprehensiveness

As explained in Section 2.2, tools should, ideally, provide a unifying framework for incorporating multiple dimensions and aspects of resilience into the assessment process. Table 3 shows different resilience dimensions addressed by each of the selected CRA tools. Following a thorough review of the criteria used by these tools and criteria extracted from the literature, five common dimensions were identified. These are namely, environmental, social, economic, built environment and infrastructure, and institutional. Each dimension is divided into several sub-dimensions which are further divided into several resilience criteria (Table 5). Similar approaches have been taken by other scholars for categorizing resilience criteria (Alshehri et al., 2014; Cutter, 2016).

Regarding the scope of assessment, it can be seen from Table 4 and Fig. 2 that majority of the CRA tools include criteria related to

Table 3
Main assessment themes, method of development, and implementation selected assessment tools.

Tool	Themes	Method of development	Implementation
CRC	"Emergency services, self-reliance, mitigation, economic capital, risk awareness and access to information, social cohesion/connectedness, recovery potential, natural capital.	Lit. review	To be implemented in several Australian Communities
CRDSA	Social, economic, physical and environmental, governance, health and well-being, and information and communication	Lit. review, Expert opinions (AHP, Delphi)	To be implemented in Saudi Arabia
DRI	Legal and institutional processes, Awareness and capacity building, Critical services and infrastructure resiliency, Emergency preparedness, response and recovery planning, and Developmental planning, regulation and risk mitigation	Stakeholder input	Mumbai, Aqaba (Jordan), and different provinces and municipalities in the Philippines
CDR	Human, social, economic, institutional, physical, environmental	Lit. review	229 municipalities in Korea
NIST	Social, financial, natural, infrastructure, political, cultural, human capital	Expert opinions	Examples such as Riverbend, USA are provided
RELi	Panoramic approach to planning, design, maintenance + operations; Hazard preparedness; Hazard adaptation + mitigation; Community cohesion, social + economic vitality; productivity, health + diversity; energy, water + food; materials + artifacts; Applied Creativity, Innovation + Exploration	Stakeholder input (market, public, etc.)	Several pilots, including the District of Columbia,
TCRI	Social, Built, Natural, and economic environments	Lit. review	10 communities in the Greater Brisbane Area
CoBRA	financial, human, natural, physical (resources and infrastructure), and social	Lit. review, stakeholder input, field testing	Kenya (Marsabit, Turkana and Kajiado); Uganda (Karamoja); Ethiopia (Yabello), etc.
CRF	Infrastructure and environment, leadership and strategy, health and wellbeing, economy and society	Lit. review, stakeholder input, field testing	Pilot surveys in six cities: Cali, Colombia; Concepción, Chile; New Orleans, USA; Cape Town, South Africa; Surat, India; and Semarang, Indonesia.
FCR	Knowledge and health; social cohesion and connectedness; infrastructure; economy; natural assets	Lit. review, Stakeholder input	Not enough information reported
Grosvenor	Climate, Environment Capacity, Resource Capacity, Infrastructure, Community, governance, institutions, technical and learning, planning systems, funding structure	Developed by experts	50 cities internationally
ICLEI	Strategies, Policies, Plans and Procedures, Information, Data, Tools and Processes, Budget Allocation and Financing Processes, Staff Participation, Existing Initiatives, Community Engagement	Draws on the experience from the ten core ACCCRN cities	Applied to three Indian cities – Shimla, Bhubaneswar and Mysore – and a range of other cities in Indonesia, Bangladesh, the Philippines and India"
UNISDR	10 sections, corresponding to the UNISDR's "Ten Essentials of disaster risk reduction and management"	Lit. review	Not enough information reported
CRS	Economic, Environmental, and Social	Stakeholder input (about 150 individuals)	Annapolis/Anne Arundel County; Anaheim; Charleston Tri-Counties Region; Gadsden; Greenwich; Gulfport; Mt. Juliet, and St. Louis/St. Louis County.
LDRI	Environmental and Natural Resource Management, Human Health and Well Being, Sustainable Livelihoods, Social Protection, Financial Instruments, Physical Protection and Structural and Technical Measures, and Planning Regimes	Expert opinions, stakeholder input (AHP, Delphi)	Not enough information reported,
USAID	Disaster risk reduction, conflict management, social protection, natural resource management, and public goods management	Lit. review	Not enough information reported
CDRST	Community connectedness; Risk and vulnerability levels; Planning, response, and recovery procedures; emergency planning, response and recovery resources	Lit. review, expert opinions	Several Australian communities
BCRD	Physical and psychological health; Social and economic well-being; Effective risk communication information; Integration and involvement of organizations in all stages; Social connectedness	Lit. review; stakeholder input, expert opinions	Not enough information reported
CART	Connection and Caring; Resources; Transformative Potential; Disaster Management; Information and Communication	Field testing, expert opinions	Yes, including five neighborhoods as mentioned in Pfefferbaum et al. (2012a)
ResilUS	social, economic, physical capital	Expert opinions	Kobe earthquake; southwest Louisiana; Western Washington; 1994 Northridge earthquake, LA

Table 3 (*Continued*)

Tool	Themes	Method of development	Implementation
ICBRR	Governance; risk assessment; knowledge and education; risk management and vulnerability reduction; disaster preparedness and response	Lit. review	Targets coastal communities in Indonesia
BRIC	Social, Housing/infrastructure, Community capital, Economic, Institutional, Environmental	Lit. review	US counties
CDRI2	Social, physical, economic, institutional, natural	Expert opinions	Several South and Southeast Asian cities, including, Chennai, Colombo, Dhaka, Hue, Kuala Lumpur, Makati, Sukabumi, and Suwon
CERI	Economic, Labor market, social	Expert opinions	Applied to 30 districts in The West Midlands, UK
CDRI	Social capital, economic capital, human capital, physical capital	Lit. review and expert opinions	Yes for several communities along the U.S. Gulf coast
CRI2	Economic Development, Social Capital	Lit. review	Counties in the state of Mississippi
CRI	Critical infrastructure and facilities; Transportation; Community plans and arrangements; Mitigation measures; Business plans; Social systems	Expert opinions	Widely deployed in Gulf Coast and Southeast coastal communities
PEOPLES	Population and Demographics, Environmental/Ecosystem, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social-Cultural Capital	Lit. review	A site in Western New York
CRT	six key sectors: food, water, energy, transportation and housing, jobs and economy, and Social Services and Civic Preparedness (governance)	Expert opinions	Yes, in the San Francisco Bay Area
SPUR	Safety during the earthquake, and usability during the response and recovery periods	Lit. review	San Francisco
DFID	Governance, Risk Assessment, Knowledge and Education, Risk Management and Vulnerability Reduction, Disaster Preparedness and Response	Lit. review, expert opinions, field testing	Communities in Bangladesh, Pakistan, Afghanistan, Malawi, the Philippines, Nepal. And by organizations such as Plan International, and Christian Aid.
CARRI	Social vulnerability; built environment and infrastructure; natural systems and exposure; hazards mitigation and planning	Expert opinions	Not enough information reported, several US communities mentioned
Hyogo	Institutional priority of disaster risk reduction; Assessing & monitoring risk; knowledge, innovation, and education; risk reduction; Strengthening preparedness for response	Stakeholder input, Expert opinions	Yes, several case studies are mentioned in the documents. Costa Rica, Mozambique, Indonesia,
USIOTWT	Governance, society and Economy, Coastal Resource Management, Land use and Structural Design, Risk Knowledge, Warning and Evacuation, Emergency response, Disaster Recovery	Stakeholder input	Used to guide developments along Asian coasts. Cases related to Sri Lanka, Indonesia, and Thailand are mentioned in the report
THRIVE	Built environment; social capital; services and institutions, and structural factors(overall 20 factors)	Lit. review, expert opinions	Hidalgo County, New Mexico; Del Paso Heights, Sacramento, CA; New York City District Public Health Offices
CRM	People, organization, resources, community process	Expert opinions	Some test communities in Canada: Revelstoke

all the five dimensions in their assessment framework. On average, more attention has been given to the institutional dimension, followed by social, built environment, economic, and environmental dimensions. Emphasis on the institutional dimension indicates the existence of a multiplicity of agents and forces that can influence any efforts to enhance community resilience. A mixture of top-down and bottom-up approaches should be employed to regulate and coordinate the interactions between these agents and forces. Physical (built environment), social, and economic dimensions have been addressed in a relatively balanced way. The environmental dimension, however, has received relatively less attention in spite of its significance for building resilience. As there is evidence to indicate that resource management, ecosystem protection, and presence of natural assets is essential for shock absorption and speedy recovery (Burton, 2014; Cutter et al., 2008; Hughes et al., 2013), minimal integration of environmental dimension can significantly undermine resilience of communities.

More detailed analyses were conducted to also understand distribution pattern of resilience criteria across resilience sub-dimensions. Results of these analyses are shown in Tables 2 through 5 and Figs. 10–13 of the Appendix in Supplementary material. It can be seen that commonalities exist across the selected tools, in terms of criteria used for assessing resilience. There are also dissimilarities between the tools that can be explained by contextual differences and variety of conceptual and methodological approaches underpinning the development of assessment criteria (Schipper and Langston, 2015).

Criteria related to 'community bonds' and 'safety and well-being' are dominant under the social dimension. Economic criteria are almost evenly distributed among 'structure', 'security and stability', and 'dynamism' sub-dimensions. Under the 'built envi-

Table 4
Percentage distribution of the frequency of criteria falling under each main theme.

Dimension	CRC	CRDSA	DRI (EMI)	MCDR	NIST	RELi	TCRI	CoBRA	CRF	FCR	Grosvenor	ICLEI	UNISDR	CRS	LDRI	USAID	CDRST	BCRD	CART	ResilUS	ICBRR	BRIC	CDRI2	CERI	CDRI	**CRI2**	CRI	PEOPLES	CRT	SPUR	DFID	CARRI	Hyogo	USIOTWT	THRIVE	CRM	Average
Environmental	4	5	6	6	9	13	8	22	4	6	6	12	5	6	9	14	0	3	5	0	4	2	16	0	5	6	4	7	16	9	8	8	6	3	6	0	6.8
Social	29	29	10	19	18	16	46	28	17	26	17	12	14	16	26	31	33	30	36	11	26	32	20	0	24	50	17	24	26	18	23	25	13	20	36	32	23.5
Economic	25	10	6	13	16	16	15	22	17	15	11	12	11	22	19	10	5	8	10	33	9	15	14	100	27	22	8	20	32	9	15	18	13	15	15	50	18.8
Built environment	21	21	26	31	31	36	31	16	28	21	17	27	22	28	23	19	19	14	17	22	9	27	20	0	19	11	29	24	19	64	21	20	13	15	27	0	21.8
Institutional	21	36	52	31	25	19	0	13	34	32	50	37	49	28	23	26	43	46	33	33	52	24	31	0	24	11	42	26	6	0	34	30	55	48	15	18	29.1

ronment and infrastructure' dimension, more attention has been paid to criteria related to 'robustness and redundancy' and 'land use and urban design'. Finally, the institutional dimension is characterized by the dominance of criteria related to 'emergency and recovery planning' and 'leadership and participation'.

More detailed analysis of the scope of assessment of each selected tool is required in order to understand what specific criteria have received minimal attention and need to be further addressed. The extent of uptake of each criterion is shown in Table 5. The darker the cell color, the more the respective criterion has been taken account of in the selected tools. It can be seen that only few criteria have been used in most of the tools. Those criteria receiving less attention might be relevant and important for enhancing community resilience. In particular, some important criteria such as 'collective ownership of community assets', 'multi-functionality of spaces and facilities', 'availability of shared assets', 'public-private partnership', 'passive design', 'mixed-use development', 'political stability', 'behavioral issues and demand management', etc. have been considered in less than 25% of the selected tools. Community resilience is a multifaceted construct and cannot be achieved by only focusing on single aspects of resilience. CRA tools should adopt a broader understanding of resilience that pays attention to all potentially relevant aspects.

3.2.2. Cross-scale relationships

CRA tools were analyzed to find out if they have accounted for cross-scale dynamics in the nested hierarchy of scales. Community as the focal level of analysis in the CRA tools is linked to lower levels such as households and individuals and higher levels such as cities, and regions. CRA tools should examine how interventions designed to enhance community resilience affect/are affected by events, practices, processes, dynamics, and interventions related to other scales (Alliance, 2007; Davis et al., 2013; Frankenberger et al., 2013). As shown in Table 6 (and Fig. 14 of the Appendix in Supplementary material) the issues of cross-scale relationships and dynamic hierarchical system of scales have been largely overlooked in the assessment process and only six tools have considered them in their framework.

The framework developed by Frankenberger et al. (2013) articulates that coordination between different scales is needed to, among other things, strengthen socio-economic networks, and develop mechanisms for better utilization of resources that are distributed across different scales. The Hyogo indicators have also recognized the significance of this criterion and emphasize addressing horizontal and vertical institutional relationships and collaborations across different scales (ISDR and OCHA, 2008). The USIOTWSP tool recommends that exploring the cross-scale relationships should be done in collaboration with community members (USIOTWSP, 2007). This can improve the knowledge base for decision making.

3.2.3. Temporal dynamism

Temporal scale is an essential component of resilience (Norris et al., 2008), and community resilience should be assessed within the context of a temporal continuum, where each stage is inextricably linked to what precedes and succeeds it. Findings show that about one fourth of the CRA tools have taken all phases of the temporal continuum into account (Table 6 and Fig. 15 of the Appendix in Supplementary material). A similar proportion of the tools have made reference to only past and existing conditions, and about 6% have considered only present and future conditions. About 42% of the tools have only focused on the present conditions and their output can be described as "a snapshot in time" that is not sufficient to reflect the evolutionary and emergent nature of resilience (Schipper and Langston, 2015). Ability to track changes along the temporal continuum is what makes resilience assessment

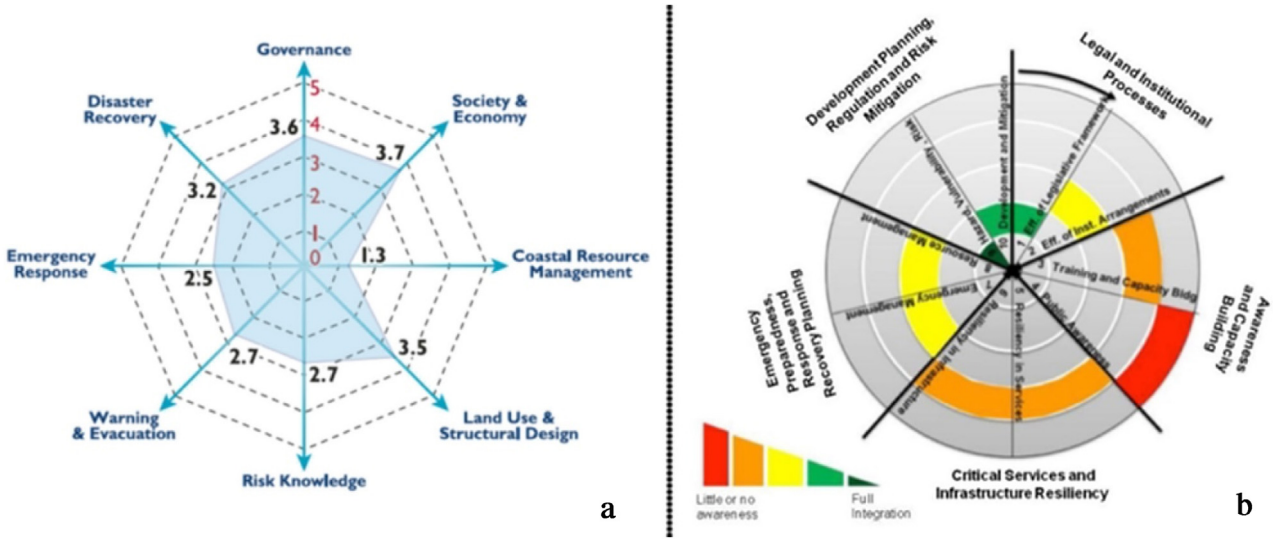

Fig. 1. Use of illustration techniques for presenting assessment findings, (a) adapted from USIOTWSP (2007), (b) Copyright © 2015 EMI, adapted from Khazai et al. (2015). Permission to reproduce (a) and (b) for educational,informational, and non-commercial use is granted in USIOTWSP (2007) and Khazai et al. (2015), respectively.

distinct from vulnerability assessment which is more focused on the present conditions (Wolf, 2011).

Evaluating the community's ability to recover from past disasters is the main method used by the tools for taking the past conditions into account. In particular, they have focused on time needed for recovery and lessons learned from the event (Frankenberger and Nelson, 2013; Sempier et al., 2010; Watson et al., 2014). Also, longitudinal analyses have been conducted to monitor performance against resilience criteria in subsequent time periods (Engle, 2011; UNDP, 2014a,b). Longitudinal variations have

Table 5
List of criteria evaluated by the CRA tools and proportion of tools including each criterion.

	Sub-Dimension	Criteria	%		Sub-dimension	criteria	%
Environmental	Natural Assets (environment and resources)	Ecosystem monitoring and protection	56	Economic		Insurance (domestic and non-domestic) and social welfare	58
		Using local knowledge and native species	11			Financial instruments (Contingency funds, operating funds, capital funds etc.)	53
		Erosion protection	19			Stability of prices and incomes , property value	17
		Protection of wetlands and watersheds	25		Dynamism	Inward investment	19
		Availability and accessibility of resources (air, energy, water, food, soil, etc.)	19			Investment in green jobs and green economy (self-sufficiency, urban farming, etc.)	17
		Reduction of environmental impacts (various types of pollution)	11			Connections with regional economy	8
		Quality of resources	56			Business cooperation (inter and intra)	8
		Biodiversity and wildlife conservation	25			Diverse economic structure and livelihood strategies	64
		Resource management (production, consumption, conservation, recycling, etc.)	28			Openness to micro enterprises and micro-finance services, entrepreneurialism	31
Social	Social structure	Population composition	39			Public-private partnership	28
		Language abilities	17			Private investment	8
		Car ownership, mobility	17			Locally owned businesses and employers	17
		Land and home ownership	25			Balance of local labor market supply and demand	8
		Diverse skills (to pool skills at the time of disaster	17		Robustness & redundancy	Redundancy of critical infrastructure, facilities, and stocks	72
	Community bonds, social support, and social institutions	Degree of connectedness across community groups	39			Robustness and Fortification (of critical infrastructure, vital assets, ecosystems, etc.)	61
		Volunteerism and civic engagement in Social networks	89			Spatial distribution of critical infrastructure (measure against cascading effects)	8
		Collective memories, knowledge, and experience	22			Location of critical infrastructure and facilities	17
		Trust, norms of reciprocity	44			Consolidation of critical utilities and collaboration between utility providers	11
		Shared assets	11			Multi-functionality of spaces and facilities	11
		Strong international civic organizations	17			Shelter and relief facilities and services	72
		Place attachment and sense of community and pride	33		Efficiency	Regular monitoring, maintenance, and upgrade of critical infrastructure	39
		Existence of conflict resolution mechanisms	6			Retrofit, renewal, and refurbishment of the built environment	22
		Empowerment and engagement of vulnerable groups, social safety-net mechanisms	25			Promotion of efficient infrastructure	17
	Safety and wellbeing	Crime prevention and reduction	25		ICT	Diverse and reliable information and communication technology (ICT) networks	58
		Security services such as police	6			Emergency communication infrastructure (before, during, after disaster)	44
		Physical and psychological health	64		Transport	Capacity, safety, reliability, integratedness (connectivity), and efficiency of transportation	64
		Preventive health measures	36				
		Responsive health measures	47			Inclusive and multi-modal transport networks and facilities	39
	Equity and diversity	Gender norms and equality	33		Land use & urban design	Accessibility of basic needs and services over time (food, water, shelter, energy, health, education)	61
		Ethnic equality and involvement of minorities and population with special needs	22			Site selection and avoiding risk and habitat areas (floodplain, flood prone; exposed coastal zone)	50
		Diverse workforce in culturally diverse places	6				
		Decency, affordability, and fair access to basic needs, infrastructure and services	72			Urban form (compact, dispersed, etc., SVF, aspect ratio)	11
	Local culture	Past experience with disaster recovery; learning from the past	28				
		Cultural and historical preservation; indigenous knowledge and traditions	31			Mixed-use development	3
		Considering and respecting local culture and specificities in the process	11			Street connectivity	8
		Positive social, cultural, and behavioral norms	17			Density of development	14
Economic	structure	Employment rate and opportunities	64			Public spaces and communal facilities (for recreation, physical activity, etc.)	25
		Income (equality, multiple sources, ..), poverty	50			Green and blue infrastructure	19
		Age structure of working population	11			Amount (percent) of impervious surfaces	6
		Qualifications of working age population	11			Aesthetics , visual qualities	8
		Individuals with high and multiple skills ; literacy (education)	42			Landscape-based passive cooling	14
		Job density (housing-work proximity; extent of out commuting)	17			Passive lighting	3
	security	Individual and community savings	28			Passive heating	3
		Collective ownership of community resources	8			Passive cooling	3
		Business mitigation, response and redevelopment plan	11				
Codes	≥ 0 <25%		≥ 25% <50%		≥ 50% <75%		≥ 75% ≤100%

Table 5 (*Continued*)

Sub-dimension	Criteria	%
Leadership and participation	Strong Leadership	44
	Stability of leadership and political stability	3
	Shared, updated, and integrated planning vision (long term)	36
	Transparency, accountability, corruption etc.	36
	Multi-stakeholder planning and decision making	64
	Decentralized responsibilities & resources	6
Management of resources	Efficient management of resources (funds, staff, etc.)	19
	Skilled personnel and emergency practitioners	39
	Population with emergency response and recovery skills (first aid, etc.)	14
	Redundant capacity in terms of personnel	8
Contingency, emergency, and recovery planning	Integration of risk reduction and resilience into development plans and policies	28
	Existence of climate change and environmental policy and plans	8
	Understanding risk patterns and trends	14
	Continuous and updated risk assessment; scenario making for different kind of infrastructure and services (costs, losses, etc.)	42
	Emergency planning and existence of emergency operation center that integrates different agencies and organizations	25
	Availability and update of contingency plans (e.g. post-storm traffic management)	61
	Availability of mitigation plan	53
	Early warning, evacuation plan, and access to evacuation information	61
	Inclusion of transient population (tourists, etc.) in emergency planning	3
	Inclusion of disaster resilience and lessons learned in the recovery plan	14
	Speed of recovery and restoration	19
	Ongoing process of revising and monitoring plans and assessments	39
	Standardized, updated, and integrated databases for action planning, monitoring and evaluation purposes	19
Collaboration	Cross-sector collaboration (alignment of aims) and partnership among organizations	39
	MOUs and MOAs with neighboring communities and agencies within the broader region	39
	Knowledge and information transfer and best practice sharing (inter and intra city)	28
R&D	Innovation and technology update	36
	Research (funds, facilities) on risks and academy-society collaborations	25
Regulations/enforcement	Availability and enforcement of legislations (policing, crime, building code, environmental law, business law, etc.)	64
	Management of informal settlements	11
Education and training	Behavioral issues and demand management	3
	Education (from elementary or secondary school), training, and communication	75
	Drills and exercises	22
	Education and training for all linguistic groups; and all groups generally	8
	Capacity building and enhancing awareness; dissemination of statistical data and assessment results	44
	Incentives for encouraging mitigation and adaptation (including self-mobilization, self-organization, etc.)	19

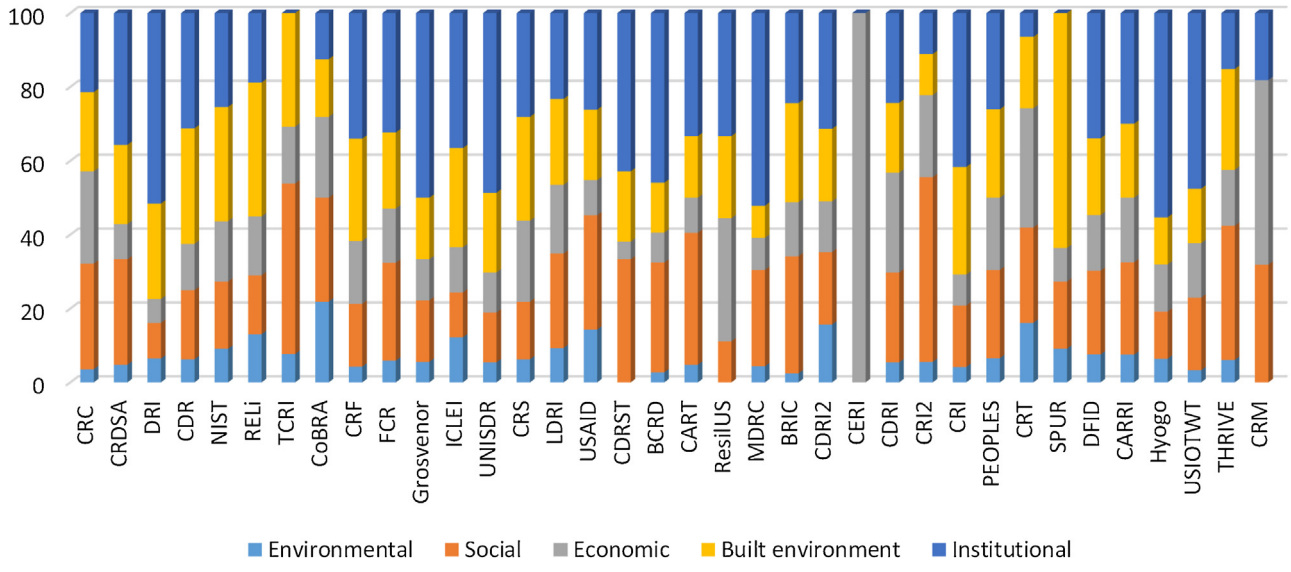

Fig. 2. Percentage distribution of the frequency of criteria falling under each main theme.

been investigated either through conducting surveys asking stakeholders how the conditions have changed over a certain time period (UNDP, 2014a), or by comparing baseline conditions at different time intervals (Rowcliffe et al., 2000; Team, 2010; Twigg, 2009). Results of such comparisons can help examine whether transition to resilience has occurred. It also shows how strengths and weaknesses of the community have changed over time. The way community has reacted to previous disasters can also be useful for estimating how it will respond to future risks. When using baseline assessment for longitudinal analyses, regular update of assessment thresholds is needed to ensure addressing the dynamic and evolutionary nature of resilience (Rowcliffe et al., 2000; UNDP, 2014a).

Three major approaches have been used for taking the future time horizon into consideration. First is through modelling future trajectories of the community and/or capacity of the community to absorb and recover from potential adverse events (Miles and Chang, 2011; NIST, 2015b). Second is by developing different future scenarios using various forecasting and back-casting methods (Gawler and Tiwari, 2014; Poland, 2009; UNISDR, 2014). Finally, future time horizon has also been considered by asking stakeholders and community members to rate future resilience of their community against several selected criteria (Schwind, 2009).

3.2.4. Uncertainties

Adopting an iterative approach and planning for extreme scenarios are two criteria used to investigate whether the CRA tools have made efforts to address uncertainties. Resilience is not a fixed quality and is likely to change over time, during the transition of the system to different states (Frankenberger et al., 2013). Assessing resilience through a continuous and iterative process helps minimize the influence of uncertainties on the decision making process. The uncertainty regarding future conditions is a fundamental challenge for achieving community resilience. This challenge can be, to some extent, addressed by planning for the most severe scenarios (UNISDR, 2014). In the absence of disturbance, scenario making provides a platform to simulate performance of the community in the event of disaster. Scenario making and elaboration on alternate states also helps gain a better understanding of strengths and weaknesses of communities (Monaghan et al., 2014).

About half of the CRA tools have paid attention to conducting assessment at regular intervals (Table 6 and Fig. 16 of the Appendix in Supplementary material). This has been done through measures such as regular monitoring and continuous update of baselines and threshold values (Schipper and Langston, 2015; Sempier et al., 2010; UNDP, 2014a; USIOTWSP, 2007). If iterative assessment involves receiving feedback from the stakeholders, it will also lead to a more inclusive decision making process (USIOTWSP, 2007).

Across the selected tools, only five have paid attention to scenario making and modelling alternate states that the community can shift into when the critical thresholds are crossed (Gawler and Tiwari, 2014; Poland, 2009; Schwind, 2009). UNISDR (2014) takes a forward-looking approach and estimates losses (economic as a result of service disruption, etc.) and restoration time needed under different severe scenarios to evaluate resilience. The RELi assessment tool provides guidance on how to "raise the bar on resiliency" by transitioning from basic to advanced, to revolutionary levels. Obtaining higher levels of resiliency leads to better performance of communities under more severe scenarios. To better address challenges associated with uncertainty, further development and utilization of scenario making techniques is recommended.

3.2.5. Participatory approaches

In Section 2.2 it was discussed that adopting a bottom-up, participatory approach to development and implementation (including priority setting and action planning) of assessment tools provides multiple benefits to communities.

Development of assessment tools includes various steps such as defining community, identifying and standardizing indicators, and assigning weights to selected indicators (Peacock et al., 2010). As shown in Table 6 and Fig. 17 of the Appendix in Supplementary material, only about 36% of the selected tools have been developed through participatory processes. Tools have mainly been developed based on literature review and expert input (Table 3). There are, however, several examples of inclusive engagement of stakeholders that can be mentioned here. In the CoBRA assessment framework "community" is defined in a bottom up process that occurs during focus group discussions. Participants would reach consensus on what they perceive as community and on indicators that need to be included in the assessment framework (UNDP, 2014a). The FCR tool has been developed using a mixed methods approach. An initial list of indicators is identified through literature review and expert input. This list is later confirmed with citizens in order to ensure reliability and context validity of the indicators and assign weights to them according to the long-term vision of the community (IFRC, 2014).

Participatory approaches should also be adopted for evaluating community resilience using assessment tools, identifying priorities, and developing action plans using assessment results. This issue has been better addressed across the tools (about 45% of the tools comply with this criterion). Participatory mapping using interviews, questionnaire surveys, and focus group discussions is a method recommended by several tools (Pfefferbaum et al., 2011; Schwind, 2009; UNDP, 2014a; USIOTWSP, 2007). The CART system has taken a bottom-up approach to use the assessment framework for creating a baseline community profile in collaborations with community members (using methods such as surveys, interviews with key informants, and community conversations). This baseline profile would be used in follow-up meetings to identify strengths (SWOT analysis) and gaps and undertake actions for enhancing resilience (Pfefferbaum et al., 2011). The assessment survey is suggested to be conducted twice: once, early in the process and once, after undertaking programs to enhance resilience (Pfefferbaum et al., 2011). A similar approach has been adopted by the CoBRA assessment tool. Stakeholders participate in focus group discussions designed to examine if community's performance against selected resilience criteria has improved over time (UNDP, 2014a). Pasteur (2011, pp. 70–71) explains several other tools and methods such as storytelling and "Transect walk/observation" that can be used to encourage stakeholder participation.

Advocating for bottom-up approaches does not mean that top-down methods should be dismissed. Cutter (2016) argues that while bottom-up methods are better capable of reflecting community needs and priorities, data variability and contextual differences make top-down approaches more suitable for standardization of data and comparison across scales. Therefore, choice of the optimal approach depends on the purpose of assessment and whenever deemed necessary, a combination of bottom-up and top-down approaches is recommended.

It should also be noted that, due to high dependence of bottom-up approaches on community input and given the fact that an iterative process may be needed to reach consensus, a substantial amount of time and resources would be required (Tyler et al., 2014; USIOTWSP, 2007). The short-term horizon of investors and funding agencies makes it challenging to allocate sufficient time for broad engagement of all stakeholders. Therefore, long-term investment strategies should also be implemented (Glandon, 2015).

3.2.6. Action plans

Assessment process should enable communities to highlight gaps, prioritize concerns, and identify leverage points for intervention and corrective action. In about 42% of the tools attention has been paid to developing action plans for enhancing resilience

Table 6
The extent of compliance with the criteria outline in the framework for analysis.

Tool	Time horizon			Panarchy			Alternate states	Interlinkages	Iterative process	Participatory development	Participatory assessment	Action plan
	Past	Current	Future	Large	Focal	Small						
CRC	×	√	×	×	√	×	×	×	√	×	×	×
CRDSA	×	√	×	×	√	×	×	×	×	√	×	×
DRI	×	√	×	×	√	×	×	×	√	√	√	×
CDR	×	√	×	×	√	×	×	×	×	×	×	×
NIST	√	√	×	√	√	√	×	√	√	×	×	√
RELi	√	√	×	×	√	√	√	√	×	√	×	×
TCRI	√	√	×	×	√	×	×	×	√	×	×	×
CoBRA	√	√	×	×	√	×	×	×	√	√	√	√
CRF	√	√	×	×	√	×	×	×	×	×	√	×
FCR	×	√	×	×	√	×	×	×	×	√	×	×
Grosvenor	×	√	×	×	√	×	×	×	×	×	×	×
ICLEI	√	√	√	√	√	√	√	×	×	√	√	√
UNISDR	×	√	√	×	√	×	√	×	×	×	√	×
CRS	×	√	×	×	√	×	×	×	√	√	√	√
LDRI	×	√	×	×	√	×	×	×	×	√	×	×
USAID	√	√	√	√	√	√	×	×	√	×	√	×
CDRST	√	√	×	×	√	×	×	×	√	×	√	√
BCRD	×	√	×	×	√	×	×	×	√	×	×	×
CART	√	√	×	×	√	×	×	×	√	√	√	√
ResilUS	√	√	√	×	√	×	×	×	×	×	×	×
ICBRR	×	√	×	×	√	×	×	×	×	×	×	×
BRIC	×	√	×	×	√	×	×	×	×	×	×	×
CDRI2	√	√	×	×	√	×	×	×	√	×	√	√
CERI	×	√	×	×	√	×	×	×	√	×	×	×
CDRI	√	√	×	×	√	×	×	×	×	×	×	×
CRI2	×	√	×	×	√	×	×	√	×	×	×	×
CRI	√	√	√	×	√	×	√	×	√	×	√	×
PEOPLES	√	√	√	√	√	√	×	√	√	×	×	√
CRT	×	√	√	√	√	×	×	×	×	√	√	√
SPUR	√	√	√	×	√	×	√	×	×	√	×	√
DFID	√	√	×	√	√	√	×	×	√	√	√	√
CARRI	×	√	×	×	√	√	×	×	×	×	×	×
Hyogo	√	√	√	√	√	√	×	×	√	×	×	√
USIOTWSP	√	√	√	×	√	×	×	√	√	√	√	√
THRIVE	×	√	×	×	√	×	×	√	×	×	√	√
CRM	√	√	√	×	√	×	×	√	√	×	√	√

√: addressed.
×: not addressed or not enough information provided.

(Table 6 and Fig. 18 of the Appendix in Supplementary material). CRS, CRM, ICLEI, and THRIVE provide detailed guidelines for developing action plans. CRS elaborates on how to identify and prioritize factors contributing to community resilience and use them as the basis for developing action plans (CARRI, 2013). It also examines whether external support is needed for implementing the action plans (CARRI, 2013). According to the CRM tool, assessment is conducted as part of a process that leads to action planning. After a portrait of the baseline conditions is illustrated using the selected indicators, priority setting is conducted and an action plan is proposed to encourage transition towards resilience. This can be done through a decision-making workshop that gets a broad group of decision makers and stakeholders engaged and asks them to identify and rate the priorities. The number of priority actions should be limited to make them achievable (Rowcliffe et al., 2000). The process proposed by ICLEI includes developing a risk index that shows major threats and severity of their consequences. This is then used for prioritizing actions. The framework also identifies agents and actors (e.g. residents, vendors, etc.) with low adaptive capacity to prioritize them in action plans (Gawler and Tiwari, 2014). The THRIVE tool offers paths to action by helping communities identify strengths and weaknesses, prioritize needs, and discuss potential actions that could be taken to address them (THRIVE, 2004).

4. Summary and conclusions

The concept of resilience has gained widespread popularity over the past few decades. As climate change advances, there is an increasing need to develop tools that can provide guidance on how to enhance community resilience. In response to this need, a growing number of CRA tools have been developed since the turn of the century. Thirty six selected CRA tools were critically analyzed in this study. In the light of results discussed in the previous section, it is now possible to return to the research questions outlined at the outset of the paper.

The broad aim was to provide an overview of CRA tools. Selected CRA tools have taken diverse and even divergent approaches to fulfill the common aim of providing guidance on building resilient communities. This is a reflection of the diverse origins of the CRA tools, variations in the definition of community across the selected tools, and the diverse and divergent entry points that have guided their development. Tools have mainly been developed in developed countries, raising concerns about their generalizability and applicability to communities in the developing world. Local authorities and community organizations are the main target audiences. There are also tools designed to inform other sectors such as academia, aid agencies, and insurance companies.

Acknowledging that resilience against one type of hazard does not guarantee resilience against others (Frankenberger et al., 2013), there is a growing recognition that communities should be prepared to respond to a wide variety of hazards occurring in multiple

domains. However, further research is needed to find out if there are any trade-offs associated with addressing multiple hazards in a unified assessment framework. Addressing multiple hazards should not result in choosing indicators that are too general and fail to address hazard-specific issues.

Broadly speaking, assessment tools can be categorized as being either "formative" or "summative" (Pringle, 2011; Turner et al., 2014). Unlike summative tools that are mainly outcome-based, formative tools take account of the significance of the assessment process. Since process-based assessment provide opportunities for learning and is better capable of addressing the dynamic nature of resilience, more focus on formative tools is needed.

Five major assessment and scoring methods have been used. These are, in order of their frequency of use, assessment against baselines, assessment against principles of good resilience, benchmarking, assessment based on recovery speed, and assessment against thresholds reflecting program objectives. It is recommended that a combination of all these approaches should be used to gain outputs that would be conducive to more-informed decision making.

Different types of assessment frameworks have been used for evaluating community resilience using one or a combination of the above mentioned methods. They are, in order of their frequency of use, toolkits, indices, models, and scorecards. Scorecards are used to calculate performance values for each of the resilience criteria. Using data related to various resilience criteria, models provide approximate estimates of future resilience trajectories. Indices are developed based on mean or sum of the scores calculated for the resilience criteria. They are capable of providing the audience with a snapshot of the community's status. Toolkits specify mechanisms and procedures to use scorecards, models, and indices for measuring community resilience. In addition, toolkits provide guidance on other issues such as timeline of assessment, stakeholders that need to be involved, and interventions that should be made based on assessment results (Cutter, 2016). Because of these characteristics, it can be argued that toolkits are more appropriate for conducting formative resilience assessment and should be further promoted.

Regarding presentation of results, it was argued that several issues should be considered to effectively communicate assessment findings to the target audience. These are utilization of illustration techniques, highlighting strengths and weaknesses, ongoing communication, and identifying changes that have occurred over time. More improvement, specifically in terms of ongoing communication of findings and presenting temporal changes is needed.

Another aim of this paper was to develop a framework for evaluation, and using it to examine the selected CRA tools. According to the proposed framework, CRA tools should be able to cover multiple dimensions of community resilience, address issues related to interlinkages and connections over time and across space, develop suitable measures for capturing uncertainties, engage stakeholders in the process, and lead to development of action plans for enhancing resilience.

Criteria related to community resilience were identified through literature review and a comparison matrix was constructed to examine the extent of inclusion of resilience criteria across the selected tools. The matrix categorized resilience criteria into five key dimensions, namely, environmental, social, economic, infrastructure and built environment, and institutional. It was found that most of CRA tools are broad in scope and address multiple dimensions of resilience. However, environmental dimension has not been adequately incorporated into the assessment frameworks. Resilience is a multifaceted construct that can only be achieved by addressing all the dimensions. Therefore, further attention to the environmental dimension is required. The comparison matrices (Tables 4 and 2–5 of the Appendix in Supplementary material) can also be used for other purposes. They will help tool developers compare their assessment tools with others to see if there are any missing criteria that need to be addressed. Furthermore, Table 5 can provide those intending to develop new tools with a pool of criteria that could be considered. It will be incumbent upon local decision makers to choose (in collaboration with stakeholders and local organizations) those criteria that are most appropriate and relevant to local conditions.

An important finding of this study is that CRA tools have failed to adequately reflect the dynamic nature of resilience by addressing interactions of forces operating over various geographic and temporal scales. Cross-scale relationships are largely neglected and communities are often being assessed as stand-alone and isolated entities. Also, tools need to better acknowledge the fact that resilience building is a dynamic process. In addition to relying on historical trends and baseline conditions, it is essential to monitor conditions at regular intervals and also use modelling and projection techniques to avoid being overwhelmed by the constantly changing conditions. Developing methodologies to appropriately address dynamics over time and across space is highlighted as an area for further work.

It was discussed that resilience is an evolving target and resilience assessment tools should be able to deal with future uncertainties. Adopting an iterative approach to assessment and accounting for alternative states and extreme scenarios were suggested as strategies to reduce uncertainties associated with resilience assessment. Selected CRA tools have achieved limited success in effectively using these strategies. In particular, there has been minimal integration of scenario making into the resilience assessment process. An important way forward for enhancing adaptive capacity and improving CRA would be to conduct assessment through an iterative process and acknowledge that communities need to be flexible enough to accommodate impacts of different severe scenarios.

Selected tools have mainly been developed using top-down methods. However, about half of the tools have used bottom-up approaches to assess resilience. While more attention is needed to ensure broad engagement of stakeholders in development and implementation of assessment tools, it should not be forgotten that choice of the optimal approach depends on the purpose of assessment. Thus, whenever deemed necessary, a combination of bottom-up and top-down approaches should be used.

Any assessment process is expected to result in development of an action plan that, among other things, highlights weaknesses and prioritize interventions aimed at addressing them. Previous research indicates that assessment tools have achieved limited success in developing guidelines and plans to translate assessment findings into action (Fox-Lent et al., 2015). This issue has only been addressed by less than half of the assessment tools analyzed in this study and should be further considered in the future.

The last objective of this study was to discuss various challenges and opportunities related to CRA. On the one hand, it was argued that resilience is a multi-faceted concept and addressing a large number of criteria (Table 5) is important for comprehensiveness and accuracy of the process. On the other hand, an effective and informative assessment should be concise and doable within a reasonable timeframe (Burton, 2014; Cox and Hamlen, 2014). Caution is needed to ensure that comprehensiveness does not come at the cost of speed and simplicity of the assessment process. Further research is needed to find an optimal balance between these factors. Inclusion of a large number of criteria may also make the process resource- and data-intensive. When data availability is an issue and resources are limited, developing an all-inclusive tool may not be possible. Under such circumstances it would be more appropriate to focus on a representative group of indicators and/or collect data using qualitative techniques such as interviews and questionnaire surveys that were mentioned earlier in the paper.

Another challenge would be to develop assessment tools that are flexible enough to be applicable to various locations. Except for rare cases, no two communities feature identical conditions. Therefore, tools should be developed in a way that allows customization to the specific needs of different communities. In other words, communities should be able to add or remove criteria and indicators according to their needs and priorities. Also, tool developers should be aware of the limitations of using fixed thresholds for assessing resilience. Allowing for flexibility in defining thresholds is essential to reflect the specific needs and conditions of different communities.

It was discussed that the term "community" has been defined loosely in the literature and selected CRA tools are focused on a wide variety of scales, ranging from neighborhood to city and to county. It is worth investigating whether there are commonalities and differences among the tools developed for different scales (in terms of content and structure). This would be useful to, for instance, understand whether a tool developed for assessing resilience at the county level is also suitable for use at the city scale.

Finally it should be reiterated that CRA is still in its formative years. It is hoped that findings of this study will be used to improve the design of assessment tools and to stimulate further research on this topic. There remains much work to be done to provide a more complete account of the issues related to CRA tools. Since a relatively large number of tools have already been developed, it is worth investigating whether there has been any cross-fertilization between the CRA tools. Ideally, tools should not be developed in isolation from each other and cross-fertilization is needed to create more comprehensive and better-informing assessment tools. Another issue to be noted is that various resilience criteria do not function in isolation, but rather interact in a complex network of interrelationships (Sharifi and Yamagata, 2014, 2016). Future research should, therefore, examine whether assessment tools have accounted for potential synergies and trade-offs between various criteria used for assessing community resilience. There is also a lack of research on implementation of CRA tools and their integration into local development plans. More empirical research is needed to investigate applicability and utility of assessment tools and determine whether integration of CRA into planning process can improve its efficacy and enhance the outcomes. Such empirical research would also provide information on possible strategies for better integration of CRA into the planning process (e.g. provision of incentives, regulatory and institutional reforms, etc.). Finally, further work is needed to elaborate on the differences and commonalities between CRA tools and various tools that exist for assessing sustainability of communities (e.g. see Sharifi and Murayama (2013, 2014)). It should be examined if CRA tools and sustainability assessment tools can complement each other. Also, since developing separate tools requires more expenditure in terms of time, money, and human resources, the possibility of integrating sustainability and resilience assessment into unified frameworks merits investigation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2016.05.023.

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