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Developing Indicators of Urban Climate Resilience

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1. Abstract

As urban populations grow and climate exposure increases, more cities are introducing formal planning processes to adapt to climate change. The adoption of a conceptual framework for climate resilience offers the prospect of measuring changes in resilience through the development of indicators at the local level. This paper reviews different methodologies for indicator development and explains in detail the process applied to 8 cities in the Asian Cities Climate Change Resilience Network (ACCCRN) for developing resilience indicators to be used for local planning and monitoring changes in climate resilience. The ACCCRN process relied on transferring a common conceptual framework for climate resilience, together with a locally led participatory, iterative, and collaborative process that engaged local, technical, and planning authorities and vulnerable groups. The process varied between different cities and generated a wide diversity of resilience indicators that were chosen for their contextual fit and availability of data. The main benefit of developing resilience indicators in this way is the capacity that the process has built, in terms of understanding resilience, shared learning and establishment of a common platform for future planning and monitoring of climate adaptation interventions at the city level.

2. Introduction

There is growing global recognition of the need to adapt urban planning, development and management practices to dynamic future climate conditions. While local conditions vary, many cities around the world are facing dramatic increases in climate risks in the coming century from the combination of rapid urbanization together with increased likelihood of flooding, drought and water supply pressures, higher temperatures, sea level rise, and more intense storms (World Bank, 2010; Rosenzweig et al., 2011; United

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Nations Human Settlements Programme, 2011). Social groups in these cities who are particularly vulnerable to climate hazards due, for example, to poverty, gender, or localized exposure, will carry a disproportionate burden of the costs of these disruptions, complicating local economic inequities and poverty reduction efforts (Sattherthwaite et al., 2009; Moser and Sattherthwaite, 2010). The need to build climate resilience in cities around the world has attracted increasing local and national attention, but there have been few tools to define and measure resilience in ways that will support practical local planning and interventions.

This paper presents a methodology for the development of local indicators of climate resilience and describes the experience of developing resilience indicators for cities within the Asian Cities Climate Change Resilience Network (ACCCRN). ACCCRN is an 8-year initiative sponsored by the Rockefeller Foundation that set out to support climate resilience in 10 medium sized cities in India, Indonesia, Thailand, and Vietnam (see www.acccrn.org). This initiative supported the local development of climate resilience strategies, and then the implementation of high priority resilience building interventions (Moench et al., 2011). The authors were engaged with regional or local partners in the ACCCRN program to support this resilience planning and implementation effort.

3. A Conceptual Framework for Climate Resilience

Resilience has been defined by the IPCC as “the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change” (2007).

As part of the ACCCRN program, a conceptual framework was developed by the Institute for Social and Environmental Transition (ISET), in collaboration with local partners, to enable the notion of urban climate resilience to be operationalized into planning and intervention measures (Tyler and Moench, 2012). The framework was derived through the synthesis and application of a large literature from multiple disciplines describing and applying the concept of resilience. The purpose of the conceptual framework is to break down the broad and intuitive notion of resilience into simplified component elements that can be characterized with a few descriptors. The key elements of this conceptual framework are ecosystems, physical infrastructure systems, human agents (individuals and social organizations), and institutions (rules and practices) that link agents and systems. For each of these component elements, key characteristics are described generically. The conceptual framework is summarized in Table 1, and described in greater detail in Tyler and Moench (2012).

Within this conceptual framework, building urban climate resilience means:

- strengthening infrastructure and ecosystems to reduce their fragility in the face of climate impacts and to reduce the risk of cascading failures;
- building the capacities of social agents to anticipate and develop adaptive responses, and to access and maintain supportive urban systems; and

- addressing the institutional factors that constrain effective responses to system fragility or undermine the ability of agents to take action.

Table 1: Urban Climate Resilience Framework – based on Tyler and Moench (2012)

Resilience Elements	**Characteristics**	**Performance description**
"What" Physical Infrastructure Ecosystems	***Flexibility and Diversity***	The system can deliver required services under a wide range of climate conditions. Key components are spatially distributed and functionally linked but can be restructured.
	Redundancy and Modularity	Spare capacity to accommodate unexpected service demand or extreme climate events. System components and pathways provide multiple options or substitutable components for service delivery.
	Safe Failure	Failure in one part of the system will not lead to cascading failures of other elements or related systems. Loss of service is minimized even under failures.
"Who" Agents – Individuals, households, and organizations	***Responsiveness***	Ability to organize or reorganize in a timely fashion; ability to identify, anticipate, plan, and prepare for a threat, disruptive event, or organizational failure; and to respond quickly in its aftermath.
	Resourcefulness	Capacity to mobilize assets and resources for action. This includes the ability to access financial and other assets, including those of other agents and systems, through collaboration.
	Capacity to learn	Ability to internalize past experiences, avoid repeated failures, and innovate to improve performance. This includes the capacity to build and retain knowledge over time.
"How" Institutions	***Rights and Entitlements***	Formal and informal rights and entitlements foster equitable access to critical systems, services or capacities, and enable collaborative groups to self-organize and act.
	Decision-Making	Decision-making processes related to urban systems are transparent, representative and accountable. Diverse stakeholders have ways to provide input to decisions. Dispute resolution processes are accessible and fair.
	Information	Agents have access to relevant information in order to determine effective actions and to make strategic choices for adaptation.
	Application of new knowledge	Institutions encourage inquiry, application of evidence, critical assessment, and application of new knowledge.

This framework was applied by cities within ACCCRN in order to develop their own strategies to build resilience, and to identify priority interventions for funding (Tyler and

Reed, 2011). A key advantage of the framework is that it defines normative characteristics of resilience elements that are, in principle, measurable. This feature enables the framework to also serve as the conceptual foundation for the development of resilience indicators. The resilience framework was novel, as the new operational framing of the concept, terminology, and approach were unfamiliar to all of the local ACCCRN partners. The application of this framework to the practical task of developing indicators that could be used in local level planning and monitoring for climate resilience was, therefore, in many respects a test of the conceptual framework itself.

4. Indicators of Climate Adaptation and Resilience

Several different kinds of indicators have been developed to address different issues related to climate adaptation. The differences between them provide insights into key issues of indicator development, including their scope, content, purpose, and processes through which they can be elaborated. This discussion will review some of these differences to show how they relate to the indicator development process pursued in the ACCCRN program.

Although it would be helpful to have local indicators of climate adaptation, there are a number of difficulties. While it is easy to report on adaptation activity, outcomes are not easy to determine. Typically, it might not be possible to assess whether adaptation measures have been effective until after an extreme climate event. For example, in response to a projected increase in the intensity of extreme rainfall, a city might undertake a program of improving drainage infrastructure or of setting aside green space for flood retention, storage, and infiltration. But if the objective is to adapt to a projected intense rainfall event, effectiveness can only be evaluated when that kind of infrequent event actually happens. Future conditions will probably also include surprises, and indirect or cascading effects from remote impacts (Wardekker et al., 2010; Tyler and Moench, 2012). In addition, given the likely trajectory of climate change, adaptation measures may never be complete. One set of investments will need to be followed by another, as climate continues to shift and likelihoods of extreme conditions change. Trying to measure changes in the extent to which adaptation measures have been effective, therefore, poses both conceptual and practical challenges.

A further problem is that neither adaptation nor resilience can be measured directly. They are the result of complex systemic changes. The systems that are changing cannot be accurately represented in a few simple measures, so indicators are always proxies. They may measure observable change in specific parameters, but they are representations of more complex processes. This means that the indicators may not themselves measure directly those phenomena that are the objects of intervention (Brooks et al., 2011; Spearman and McGray, 2011).

Adaptation measures vary with local context and are difficult to generalize. There are no simple or common indicators that can be applied consistently across all sectors and locations. Adaptation should be incorporated as a standard consideration across many relevant organizations and sectors. But this very integration means that it is harder to identify specific results from adaptation measures because they will be integrated with other decision making, if successful (Department of Environment Food and Rural Affairs (DEFRA), 2010). Furthermore, interventions which are adaptive in one context may be maladaptive in another, complicating the choice of indicators that might measure such activity (Brooks et al., 2011).

We can identify three generic approaches to climate adaptation indicators. One category is national level indicators to draw comparisons of climate vulnerability. These are typically aggregated into a summary or composite indicator, often referred to as an index (Freudenberg, 2003). There is a great deal of interest in national indices of vulnerability for purposes of prioritizing and allocating international funding for climate adaptation according to some comparative rationale, despite the recognition by analysts that processes of vulnerability and adaptation are invariably local (Yohe and Tol, 2002; Eriksen and Kelly, 2007). These indices are intended for use in ways similar to measures such as the UNDP's Human Development Index, indices of national competitiveness, or of quality of life and environment (Prescott-Allen, 2001). They serve as aggregate proxies to reflect complex and dynamic phenomena, and are typically used to generate coarse comparative rankings between countries.

A variant of this approach uses composite indices based on component indicators to compare local measures of disaster resilience (Shaw et al., 2009; Cutter et al., 2010). The composite indices are typically constructed from several thematic components, which themselves represent composites of component indicators. This approach is highly relevant to the task of measuring local climate resilience, but it relies on data that is either generated from very detailed census results (in the case of Cutter's work in the U.S.) or on data reported in a general format from questionnaire surveys (in the case of Shaw's work in Asia). These results are useful in comparing across a number of different local jurisdictions, although challenges of data reliability and availability may limit the application of these approaches in low-income countries. Another problem with using such indices for local planning is that some of the component capacity indicators derived from secondary data, such as migration rates or incomes, are themselves the result of complex factors that are not easily influenced by local action, so the policy measures needed to drive changes in the indicators are not obvious.

There are many methodological challenges in the development of composite indicators, including such issues as missing data, and approaches to standardization or weighting of data. The key methodological conclusions from such efforts are that composite indices should be constructed on the basis of an explicit theoretical framework, recognizing wide variation in data availability, and that weightings and aggregation calculations should be transparent, and sensitivity tested to determine what influence these methodologies have on rankings and results (Freudenberg, 2003; Cutter et al., 2010).

A second generic approach to adaptation indicators is a result of increased attention by donor agencies and governments to climate adaptation issues, and the creation of special purpose international funding structures like the Adaptation Fund. These international funding efforts all rely on measurement of program results, and hence, there is increased attention to indicators of changes in vulnerability, adaptive capacity, or other outcomes over time, and how these can be linked specifically to incremental project or program investments (Brooks et al., 2011; Spearman and McGray, 2011; Brooks et al., 2013). These kinds of indicators may be tied to an explicit monitoring and evaluation framework, or to national policy frameworks. They are typically implemented by project managers, governments or donors, and are intended to compare progress in a program or project to desired outcomes.[11] Given the challenges of measuring adaptation, as described above, project-based monitoring frameworks typically track changes in the capacity of key organizations, such as the ability to understand and integrate climate factors into decision making and planning; and the minimization of disruptive influence of extreme climate events on climate-sensitive socio-economic development (Department of Environment Food and Rural Affairs (DEFRA), 2010).

Indicators can also be distinguished as being derived through methodologies that are either deductive or inductive (Eriksen and Kelly, 2007). Indicators derived deductively are based on an explanatory theory or conceptual framework that is relevant to the phenomena being measured. Indicators derived inductively are based on statistical comparison of observed outcomes with potential indicator measures, in order to match outcomes with those indicators that most closely predict them.

Finally, a different approach to indicators emphasizes the measurement of changes and progress towards long-term policy objectives. Sustainability indicators are a typical example of this type of approach, and have been widely applied at national and sub-national levels to monitor progress towards sustainable development policy objectives (Bell and Morse, 2008). Sustainability indicators cover a much broader field than climate adaptation, and they are understandably more complex and involve a wider number of parameters and procedural issues as a result. However, this type of indicator seems to be a good analogue for the task of measuring progress in resilience. They have been applied at many different scales, from the community level to the city, watershed, sub-national, and national levels (Hardi and Zdan, 1997). Sustainability indicators measure multiple factors that influence future well-being across social capital, natural capital, and economic capital (National Sustainability Council, 2013). In addition, sustainability indicators measure phenomena that are emergent characteristics of the interaction of complex systems, such as water quality, land use, community engagement, or economic productivity. In all these ways, they are similar to resilience indicators.

This approach is different than monitoring the results of programs and policy implementation, because (as with composite indicators) it may be difficult to identify cause-effect relations between specific policy measures and indicator values. Nevertheless, these approaches overlap because the point of sustainability indicators is to monitor changes and trends directly relevant to the achievement of the broad social goal of improved well-being (National Sustainability Council, 2013). Over time, one should expect that adaptation policy and programming decisions should align with

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[11] Examples of results indicators for international donor programs can be found here: multilateral donors Climate Investment Funds – Pilot Program on Climate Resilience https://www.climateinvestmentfunds.org/cif/measuring-results/ppcr-measuring-results

sustainable development objectives. However, sustainability indicators are sometimes designed to precede policy commitments, and may be deliberately intended to stimulate policy debates (Pinter, 2013).

There is a large amount of literature and considerable experience with sustainability indicators, which can help inform our approach to indicators of climate resilience. The International Institute for Sustainable Development (IISD) convened a broad international exchange in 1996, updated in 2008 with the OECD, on general principles for developing such indicators (see Box 1 below). It was felt to be more useful to have a set of principles to guide indicator development, rather than propose specific indicators, because they should be developed in context, and fit to scale and purpose (Hardi and Zdan, 1997; Bakkes, 2012).

Approaches to developing sustainability indicators can be categorized generally as mainly expert-driven (“top-down”) or community-driven (“bottom-up”). Reflecting the complexity of the systems and processes that influence sustainability, it is expected that the derivation of indicators will require a high level of scientific expertise. On the other hand, the effort required for data collection and interpretation will only be undertaken on a recurring basis if it delivers high local value. Therefore, not only must indicators be relevant to local users, but the methods for collecting, interpreting, and sharing them need to be simple enough that they can be replicated at low cost and implemented by non-specialist user groups, or else the exercise is unlikely to be repeated. In addition, indicators may be expected to change over time as community circumstances evolve. Expert driven indicators are more likely to follow theory and models, to integrate large volumes of data, and reveal unexpected analytical insights. Community or user-driven indicators are more likely to build capacity, support local interests, and to be sustainable, but may lack rigour (Reed et al., 2006).

> *Consequently, sustainability indicators can go far beyond simply measuring progress. They can stimulate a process to enhance the overall understanding of environmental and social problems, facilitate community capacity building, and help guide policy and development projects.* (Reed et. al., 2006, p. 407)

Both top-down and bottom-up approaches have advantages. Indicators of sustainable development should reflect the priorities and development goals of the geographical and administrative unit to which they are applied, from the community to the global level, to provide feedback to relevant decision-making processes and citizens. Particularly as the scale of application becomes more local, and the context for their use more diverse, the need to engage users in defining, measuring, and interpreting the indicators grows. When local planning and management choices are the main target, shared learning processes based on credible monitoring and research can strongly influence decision-making (Tyler, 2006; Tyler and Mallee, 2006). The challenge is, therefore, not to choose one or the other approach exclusively, but to design a process that will integrate elements of both.

Box 1: Bellagio Sustainability Assessment and Measurement Principles (STAMP)

1. Guiding Vision

Assessing progress towards sustainable development is guided by the goal to deliver well-being within the capacity of the biosphere to sustain it for future generations.

2. Essential Considerations

- The underlying social, economic, and environmental system as a whole and the interactions among its components
- The adequacy of governance mechanisms
- Dynamics of current trends and drivers of change and their interactions
- Risks, uncertainties, and activities that can have an impact across boundaries
- Implications for decision making, including trade-offs and synergies

3. Adequate Scope

- Appropriate time horizon to capture both short and long-term effects of current policy decisions and human activities
- Appropriate geographical scope ranging from local to global

4. Framework and Indicators

- A conceptual framework identifies the domains that core indicators have to cover
- The most recent and reliable data, projections, and models are used to infer trends and build scenarios
- Standardized measurement methods, wherever possible, in the interest of comparability
- Comparison of indicator values with targets and benchmarks, where possible

5. Transparency

- Data, indicators, and results of the assessment are accessible to the public
- Choices, assumptions, and uncertainties determining the results of the assessment are explained
- Data sources and methods are disclosed
- Sources of funding and potential conflicts of interest are disclosed

6. Effective Communication

- Use clear and plain language
- Present information in a fair and objective way to help build trust
- Use innovative visual tools and graphics to aid interpretation and tell a story
- Make data available in as much detail as reliable and practical

7. Broad Participation

- Find appropriate ways to reflect the views of the public, while providing active leadership
- Engage early on with users of the assessment so that it best fits their needs

8. Continuity and Capacity

- Repeated measurement
- Responsiveness to change
- Investment to develop and maintain adequate capacity

Source: modified from **http://www.iisd.org/measure/principles/progress/bellagiostamp/**

The experience of the UK government in designing indicators for adaptation also points to the need for measures of both process and outcomes (e.g. incorporation of adaptation explicitly into plans, mortality from heat-related illnesses). The UK Department for Environment, Food and Rural Affairs notes the difficulties, even within the UK alone, of collecting standardized data on a range of sectors at the local level, making aggregation or comparison of indicators a major challenge. In addition, DEFRA specifically identifies the importance of using existing data for indicators, rather than adding further data collection requirements to local authorities (Department of Environment Food and Rural Affairs (DEFRA), 2010).

Given these general approaches, the question is how to select local indicators. While measures of adaptive capacity are generally agreed across a wide range of applications (Smit and Pilifosova, 2001; Yohe and Tol, 2002; Shaw et al., 2009; Cutter et al., 2010), these measures are not easily compared with each other or aggregated, and they can be represented by data types that may not be comparable between jurisdictions. Selection of indicators always involves subjective decisions (Eriksen and Kelly, 2007; Huang et al., 2012). This suggests the importance of two methodological considerations. First, to ensure that indicator selection decisions are sensible, even if subjective, it would be important to have a clear and relevant theoretical framework (Freudenberg, 2003; Cutter et al., 2010). Second, subjective decisions in indicator selection should involve the judgment of both experts familiar with the theoretical framework, but also practitioners who understand local context.

Successful adaptation measures will require local planning and action, probably across a broad range of sectors. As a result of this local specificity, it is frequently local governments, especially in major cities, who are taking up this challenge and developing adaptation plans, although such efforts are generally at an early stage (Hounsome and Iyer, 2006; Birkmann et al., 2010; World Bank, 2010; Bassett and Shandas, 2011; Carmin et al., 2011; City of Copenhagen, 2011; Ecologic Institute, 2011; Preston et al., 2011; Carmin et al., 2012; City of Vancouver, 2012; Columbia Basin Trust, 2012).

There are several reasons why local authorities should be interested in monitoring changes driven by these early adaptation efforts. Firstly, adaptation is a new and inexact practice. Uncertainty about future climate conditions and linked social and economic drivers is high, and there is limited experience anywhere with implementing city-level climate adaptation measures. Therefore, a key element of long-term adaptation will be mechanisms for learning from experience and improving performance. These will require identification of baseline conditions, and monitoring of changes. In addition, a basic principle of governance is accountability, and public agencies should be expected to monitor and report on progress in achieving long-term policy objectives such as climate resilience. Any such monitoring effort will require the development of practical and meaningful indicators for measurement and reporting of how the need for adaptation is changing, both in response to changing context (which may increase or decrease risks) and to implementation of specific interventions. The remainder of this paper discusses how indicators of climate resilience were developed in ACCCRN cities in order to meet this challenge of informing local adaptation planning and action.

5. Developing Indicators of Urban Climate Resilience

In the ACCCRN program, local city-level partners in each of the participating cities collaborate with national level program coordinators to propose and implement interventions that will build climate resilience, with funding from the Rockefeller Foundation. As part of its regional-level responsibilities for program support, ISET worked with country coordinators in Thailand and Indonesia, and with city level partners in Vietnam and Gorakhpur, India, to help them develop city-level resilience indicators. The authors of this paper were involved in the different stages of this indicator development process, from conceptual development and guidance to local indicator definition and data collection.

The focus of this effort was on the active engagement of city level partners in leading indicator development. This approach, of combining expert advisory input with local leadership and capacity development, was selected for the reasons outlined in the literature review above: it has been suggested to be most effective at ensuring local capacity both to develop and use the indicators. However, at the city level, ACCCRN partners were still grappling with the concepts of climate change, adaptation, and resilience, and how those issues translated into planning and operational decisions for local authorities and communities when the idea of indicators was first introduced. In most cases, the cities already faced climate hazards that could be expected to worsen with an increase in the frequency and intensity of extreme events. They had undertaken a formal vulnerability assessment to determine areas of high vulnerability, and a resilience strategy to identify priorities for local action to build resilience (Moench et al., 2011). Each city was also developing proposals for funding from Rockefeller Foundation and other donors, and then managing implementation of resilience interventions. While the organization and structure of this effort varied from city to city, a great deal of it was undertaken by local government staff, typically as an additional task on top of other job responsibilities.

Normally, the logic of indicator development is that indicators can only be defined once goals and objectives (targets) are clearly specified. However, for policy areas that are new or poorly defined, such as climate resilience in the case of ACCCRN cities, the exercise of developing indicators may constructively proceed in parallel with clarification of goals and targets. Indicator development can help to clarify policy development and to reveal challenges in planning and objective setting (for example, if plans are not specific enough to be monitored), as reflected in the experience of Sustainable Development Indicators in the Rio+20 process (Pinter, 2013). When communities do not have a clear goal or target for the value of different measurable parameters, but can easily reach consensus on a preferred direction of change, indicators can provide a way to assess qualitative improvement (Reed et al., 2006).

To simplify the process and guide local partners in the development of indicators, ISET worked with IISD to develop a “guidance tool” in the form of a spreadsheet providing direction for indicator development. We also developed a scoring tool—a separate spreadsheet that would help users to convert indicator data to normative scores and then summarize these in a visual dashboard display. These tools were used in training workshops to introduce the resilience indicator concept and indicator development task to partners at the national level in Thailand and Indonesia (TEI and MercyCorps, respectively) and with city level partners in Vietnam and in Gorakhpur. In Thailand, Indonesia, and Vietnam, national partners needed to translate the tools into local languages before they could be used at the city level.

In relation to the indicator typologies described above, these indicators combine aspects of deductive approaches (based on a conceptual or theoretical framework) with the inductive element of responding to empirically assessed local vulnerabilities. The selection of indicators, which is described below, was in all cases the result of both guidance from external experts (national program coordinators and ISET) and local practitioners (technical departments of local and senior governments, utility companies, civil society, and vulnerable groups). In these respects, the methodology used can be described as hybrid, but with an emphasis on local ownership and leadership, to build capacity and help ensure relevance and sustainability of results.

A portion of the guidance tool, with hypothetical contents included by way of illustration, is shown in Table 2. The tool helps users to start from the general elements of the Climate Resilience Framework (CRF), described above, and then proceed to more specific local context and definitions. The elements of resilience—systems (infrastructure and ecosystems), agents, and institutions—are listed in the left hand column of the spreadsheet tool, then the characteristics of these elements are described in the next column. Next, working from left to right, the tool has a column in which users can summarize the relevant results from prior vulnerability assessment for this particular element of the framework (in this example, for water supply). Users frame assessment questions that would help them determine, in their own context, whether vulnerable aspects of the system were resilient or not, and then identify indicators that could be used to measure and track this resilience.

The result is a list of potential indicator measures in the right hand column, based on the CRF and the contextual vulnerability assessment for each city. These are organized as indicators of system resilience, agent capacity, and of enabling institutions. Due to simplicity and space constraints, Table 2 shows only the first two characteristics of systems. Based on the ten rows of the resilience framework in Table 1, a full matrix here would have ten rows as well, with potential indicators identified in each.

Table 2: Guidance Tool for Indicator Development (example only)

Direction of Work → *User input italicized*

	Urban Climate Resilience Desired Outcomes		Vulnerability	Key Assessment Questions	Examples of Resilience Indicators
SYSTEMS: Water Supply	**Flexibility and Diversity**	The system can meet service needs under a wide range of climate conditions. Key elements are spatially distributed but functionally linked.	*One of several water intakes must be shut down periodically due to high salinity levels, which are expected to intensify with SLR and drought. Another intake is already at risk due to silt deposition by floods and low stream flows during dry seasons. Pump stations and treatment plants have no backup power supply.* *City is committed to expanding distribution system to reach 90% of residents. Per capita consumption is also expected to increase with income levels, which will require investment in new sources of supply from surface water sources further upstream.* *Water quality is mainly threatened by salinity in lower reaches and by excessive turbidity during flood season. Both problems will get worse.*	*1. Does the system meet the basic service needs of subscribers now?* *2. Are alternative sources of supply in place to meet household demand if primary sources are disrupted?* *3. Is water being conserved through demand-side management programs and limiting system leakage?*	*Reliability of water supply (e.g. % time water service available)* *Proportion of water supply from single source* *Number of treatment / pumping stations* *Total annual water conserved through demand-side management and leakage repair, relative to demand.*
	Redundancy and Modularity	There is spare capacity to accommodate unexpected service demands or extreme climate events. System components and pathways provide multiple options or substitutable components for service delivery.		*1. Does the system have sufficient storage for extended droughts (longer than historical)?* *2. Are alternative delivery modes in place to meet demand if primary delivery modes are disrupted?* *3. Do users have independent sources of safe water (i.e. rainwater harvesting, independent groundwater wells, access to bottled water)?* *4. Is supply system expandable / substitutable (e.g. tankers, access to private wells)?*	*Total surface storage capacity relative to projected annual demand in 5 years / 10 years / 20 years (pick one).* *Total groundwater yield potential relative to projected annual demand.* *Treatment capacity relative to demand.* *% of households with rainwater harvesting system.* *% of households or water user groups using private wells* *Quality of well water (coliforms, heavy metals, salinity)* *Size of water tanker fleet*

Each matrix was structured around a key vulnerability issue in each city. Normally the cities found this most sensible to structure in relation to infrastructure systems or to departmental responsibilities. That way, it was easier to identify sources of data and understand who would most likely use the resulting indicators. For example, water supply was a key vulnerability in several cities, and they could identify infrastructure issues related to sources, quality, distribution network, etc.; as well as capacity issues on the part of both water users and the water suppliers (whether private such as tankers, or public distribution utilities). The institutional issues typically related to planning mechanisms, incentives for water demand management, information on water quality, tariffs for water use, etc. The toolkit prepared by ISET included hypothetical examples of indicator development for water supply (an example of a major infrastructure vulnerability); for watershed management (an ecosystem vulnerability); and for housing (with features of infrastructure and institutional factors).

ISET suggested that the cities develop three sets of indicators for the top three priority issues, as revealed in vulnerability assessments. Some cities focused only on one key issue, while others developed indicators across more than three issues. Table 3 shows the issues selected in each participating city for indicator development. The idea in each case was that indicators would provide a baseline picture that could be used to characterize resilience at the local level and could be tracked relatively simply by local authorities to monitor changes over time.

Table 3: Key Issues Selected for Resilience Indicators in Each City

City	Thematic Focus for Indicators	Leadership
Gorakhpur, India	Drainage, water supply, solid waste management, public health, peri-urban agriculture	Gorakhpur Environmental Action Group (GEAG) – NGO
Bandar Lampung, Indonesia	Flood protection, water supply, solid waste management	City Environment Agency and BAPPEDA (planning agency)
Semarang, Indonesia	Flood protection, water supply, public health	University of Diponegoro and BAPPEDA
Chiang Rai, Thailand	Water resource management	Multi-stakeholder resilience working group sub-committee
Hat Yai, Thailand	Flood management	Multi-stakeholder resilience working group sub-committee
Can Tho, Vietnam	Water supply, public health, Resettlement	Climate Change Coordination Office (local government)
Da Nang, Vietnam	Water supply, flood protection, tourism sector	Climate Change Coordination Office (local government)
Quy Nhon, Vietnam	Mangrove protection, fisheries sector, tourism sector	Climate Change Coordination Office (local government)

Because the indicators were expected to be integrated into city level resilience planning and intervention efforts over the long term, it was important that they be developed by local partners. This was not only more likely to result in identification of meaningful indicators for the local context, but also greater understanding and commitment to their application. After training workshops that explained the conceptual framework and included exploratory development of indicators relevant to their own needs, the timing and evolution of indicator development was generally left to local partners to determine.

Selection of indicators in each of the cities was to be guided by similar criteria. Indicators were to be observable and verifiable. They could be quantitative or qualitative. They were to be relevant to local decision-making. They were to be simple and specific, measurable, actionable (meaning that decisions by local authorities should lead to changes in the indicator value), relevant to resilience characteristics, and dynamic (change over relatively short time periods). Possibly most constraining, they were to rely primarily on available data, in order to avoid high data collection costs and assure that they could be sustainable.

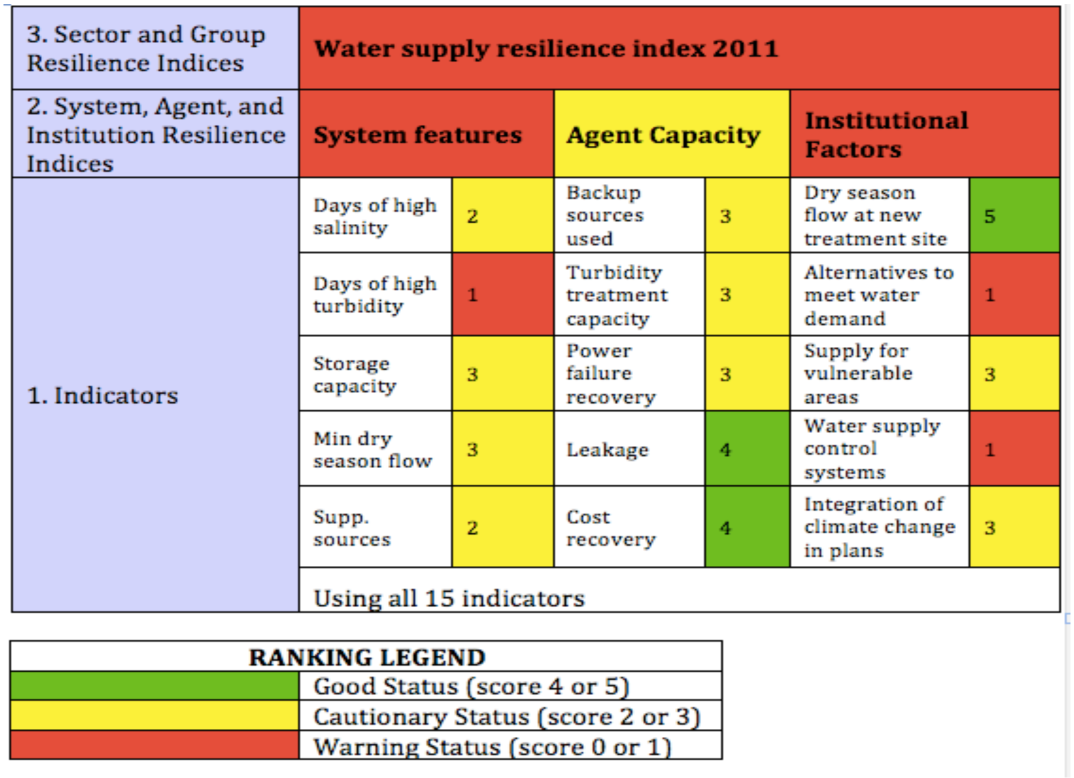
In most cases, the concept of collecting and using data for monitoring progress on policy goals was familiar, but indicators were a new approach. Typical monitoring approaches used already in these cities were based on simple monitoring of quantitative planning targets, often activity-based rather than results-oriented. Some partners were still struggling with the notion of climate resilience as a planning goal, and so the guiding vision for indicator development remained unclear. It was difficult to distinguish measurements of activity from outcomes, to decide when each might be relevant and to determine what kind of indicator would be most appropriate to measure different aspects of resilience. ISET worked with local partners to explain concepts, review draft indicator sets, provide procedural suggestions, and encourage progress.

Leadership of the indicator development task varied from city to city (see Table 3). Typically, leadership lay in a single planning agency, or in an external research group providing advice to local decision-makers. However, in all cases, it took some time for the leading group to sort out the concepts and gain confidence. These leading groups in each city began to develop indicators based on their understanding of the conceptual framework and the city's vulnerabilities. However, they quickly discovered that they lacked sufficient technical understanding of the different sectors relevant for indicator development. Therefore, they had to seek additional expertise from the agencies responsible for managing these sectors in order to develop meaningful indicators, assess data availability, and interpret data. This was generally done through a series of small sectoral workshops with key partners: introducing concepts, developing indicators, and validating data. In some cases, these discussions were broad and led to a substantial role by other agencies in contributing to indicator development. In other cases, the interaction was limited mainly to providing data requested by the leadership group.

An important final step in developing the indicators was to compare current levels of indicators with desired targets. Indicators by themselves were just observed values, which would change over time. But in order to give them normative meaning, their current values had to be compared with desirable levels and preferred direction of change. Sometimes the data also had to be scaled or normalized. For example, a relevant indicator might be the extent of damage or losses from flooding in the city. However, this indicator obviously varied randomly with the level of flooding from year to year. The principle behind the indicator was that for a given level of precipitation or streamflow, the area of the city flooded should decline over time. Where local data existed, flooded areas could be normalized to stream flow or 24-hr precipitation. Alternatively, in the absence of reliable data to match with flooded area, this indicator could be averaged over a longer historical time period, to generate a rolling average in each year. This step also required discussion and deliberation between the resilience leadership group and sector technical specialists who were better able to judge not only the parameters that could sensibly be measured, but also the normative values, scaling and adjustment factors that should be applied to annual data.

The data collection process included, for the Indonesian and Vietnamese cities, preparation of nominal scores on a consistent 6-point ranking scale (0–5) for each indicator. This process allows the various different indicators to be compared and aggregated to derive summary index scores in a simple "dashboard" visual display (see Fig 1 below). Aggregation algorithms weighted the lowest scores more highly in order to reflect the fact that vulnerability, generally, results from the weakest parts of the system, not from mean values.

Fig. 1: Sample Dashboard – Water Sector Indicators, Da Nang, Vietnam (Climate Change Coordination Office, 2013)



3. Sector and Group Resilience Indices	**Water supply resilience index 2011**					
2. System, Agent, and Institution Resilience Indices	**System features**		**Agent Capacity**		**Institutional Factors**	
1. Indicators	Days of high salinity	2	Backup sources used	3	Dry season flow at new treatment site	5
	Days of high turbidity	1	Turbidity treatment capacity	3	Alternatives to meet water demand	1
	Storage capacity	3	Power failure recovery	3	Supply for vulnerable areas	3
	Min dry season flow	3	Leakage	4	Water supply control systems	1
	Supp. sources	2	Cost recovery	4	Integration of climate change in plans	3
	Using all 15 indicators					

RANKING LEGEND	
🟩	Good Status (score 4 or 5)
🟨	Cautionary Status (score 2 or 3)
🟥	Warning Status (score 0 or 1)

The ranking process requires achieving a subjective consensus on what the desirable levels of each indicator should be, for both qualitative and quantitative indicators, and then scoring the actual values relative to those desired levels. In some cases, the desired levels are set by policy (e.g. Da Nang's policy objective of ensuring 90% of the population is served by treated municipal water supply by 2020). Most often, however, they are set by professional and expert judgment, as negotiated through interaction between the climate working groups and technical experts at the local level. These scores could change: in Bandar Lampung, after initially scoring flood management indicators relatively highly, the city experienced serious flooding and the indicators team was forced to reconsider their choice of indicators and scoring levels.

ISET convened two workshops to discuss and compare progress between the city level partners, in October 2011 and in March 2013. The co-authors contributed to this paper through their documentation of the city level indicator development process, through reporting at these workshops, and through subsequent interviews with the lead author.

6. Results of Indicator Development

The eight ACCCRN cities that engaged in the process of developing indicators came up with a total of some 152 different indicators across 10 different sectors. These are listed in Appendix A, although indicator labels have been generalized for summary purposes. Individual cities may have used slightly different labels. Each city chose its own priorities for indicator development, so there was substantial variation between them. At the same time, there are a number of indicators that are similar or identical across multiple cities in each sector. The most popular sector for which to develop indicators was water supply: 6 of the 8 cities chose water as one of the sectors most vulnerable to climate change impact, and therefore the focus of resilience building and monitoring. Five cities chose flood prevention and drainage as a key sector for monitoring, and three chose public health. Other sectors for indicator development included tourism, solid waste management, ecosystem management (mangroves, peri-urban agriculture), and housing/resettlement.

A review of Appendix A shows that cities identified indicators related to all the elements of the climate resilience framework: ecosystems, infrastructure systems, agent capacities, and institutional factors. The greatest number of indicators was identified for infrastructure systems, in part because in most cases, a greater range of data already exist from the responsible organizations. Institutional factors were more difficult to identify, and these were especially constrained by data availability. Two important factors that are frequently identified for monitoring (often qualitative) are the degree of community participation in planning and decision-making for key infrastructure and disaster risk reduction, and the extent to which information on climate related risks is easily available to the public.

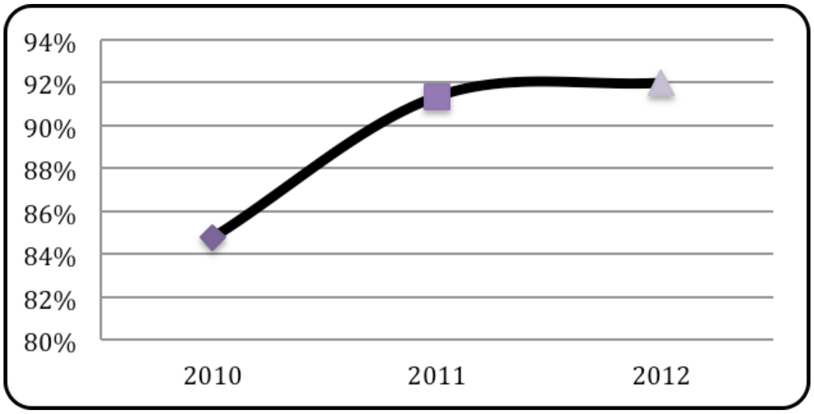
Commonly used indicators for water supply, for example, include:

- Leakage rate
- System coverage (% of households served)

- Measures of system capacity
- Diversity of sources
- Measures of water quality
- System cost recovery
- Existence of formal adaptation plans
- Measures of accessibility of the poor to water distribution

In all cases, by late 2013 the cities had collected (or were in the final stages of collecting) data on the indicators identified. For Bandar Lampung, Semarang, and Can Tho, they collected historical as well as current data, and typically have 3 years of indicators available (see Fig 2 for example). Gorakhpur has 2 years of data, representing baseline situation (prior to project implementation) and the result of 18 months of project activity. Da Nang and Quy Nhon collected only 1 year of data.

Fig. 2 Example of multi-year data: Percentage of inspected homes free of mosquito larvae (public health indicator) – Semarang, Indonesia ("City Level Resilience Indicators and Data Collection for Semarang," 2013)



A crucial result is that in all 8 cities, resilience indicators corresponding to priority local vulnerabilities and available local data could actually be identified and locally generated. The exception was in Gorakhpur, where there was essentially no available data at the ward level, where GEAG was focusing their interventions. Some data was available at a city-wide level, but it was fragmentary and could not be disaggregated to the ward level. Therefore, for their purposes all the data had to be collected as part of the resilience intervention projects undertaken by GEAG.

All of the local partners used ISET's Climate Resilience Framework and the related resilience indicator tool (Table 2 above) to guide their analysis and their selection of indicators. In the cases of the Thai cities and of Gorakhpur, the resilience framework and the related indicator development tool were used by process leaders and facilitators, but proved to be inappropriate as starting points for the community partners involved in the work, who were much more focused on the thematic issues and problems than on the conceptual framework. However, in Vietnam and Indonesia, the framework and the indicator development tool were used to guide initial sectoral indicator development and to explain resilience concepts to a wider group of local government technical agencies outside the limited climate adaptation working groups (or Coordination Offices in Vietnam). The Indonesian teams found it helpful to explain resilience by using the conceptual framework to prompt discussion of what resilience might look like more concretely in each sector.

In Vietnam, Climate Change Coordination Offices in each city, which had been established under Rockefeller Foundation funding, led the process of indicator development and provided most of the staff resources for indicator development and data collection. They first worked from the principles of the CRF, and from the results of their own vulnerability assessments, to identify priority sectors and to propose suitable indicators for each. A similar process was followed in Indonesia, where accountability and leadership lay with a specially appointed multi-stakeholder Climate Change Coordination Team (City Team) but the work was undertaken by the city Environment Department in Bandar Lampung, and by contracted researchers from the University of Diponegoro in Semarang. In these cases, the teams started with the framework and proposed indicators based on climate vulnerabilities.

In Thailand, and in Gorakhpur, the teams started with community issues, and followed the interests of the community leadership to define indicators. This meant that in Hat Yai and Chiang Rai, for example, only one sector was chosen as the focus of indicator development: flooding in Hat Yai, and water management in Chiang Rai. In these two cities, discussion of potential planning goals and indicators helped the multi-stakeholder working groups to better understand the problems, the key infrastructure and ecosystem elements involved, the various stakeholder interests and agents, and the institutional framework for decision making. A key finding in developing the indicators was that data was weak in both cases. In Hat Yai, the team used project resources to collect data, and in particular to survey communities. In Chiang Rai, the team hired a consultant to collect data and refine indicators, because of the complexity and multiple jurisdictions involved (local, provincial, and national agencies). The indicator development process contributed substantially to the framing of resilience building actions in both cities, a process driven by the local climate working groups but supported by research consultants and special studies in both cases. In trying to better define the indicators needed and the potential data to be used, based on previous vulnerability assessments, the teams in both Thai cities had to more clearly define the problems, leading to greater clarity about potential interventions.

In Gorakhpur, indicator development was supported through an ACCCRN project grant for the establishment of a community level resilience planning process. The planning process focused on community problem identification and action, and ward-level planning committees worked with GEAG to develop 46 indicators across all 6 of the sectors important for community resilience planning. Of these they could collect data only for 34. Most of the data was collected through community surveys of 2,000 households or from workshops with community leaders, because local government data proved either unavailable or unreliable. In Gorakhpur, the indicators served a valuable role in demonstrating to local government, which had displayed little interest in addressing the drainage problem in the poor peri-urban Mahewa ward, of how successful modest local interventions could be.

In Vietnam and Indonesia, after the initial development of indicators, the team leaders set out to verify indicators and data availability with the relevant technical departments responsible. In some cases, such as water supply, most of the data was available from the water utility. But in other cases, such as public health, flood management, or resettlement, several different agencies needed to be consulted in order to identify whether data was available. The results of these efforts were generally frustrating: many of the proposed indicators had to be revised or redefined because the relevant data were not available and could not be easily calculated or collected. This led to a series of meetings or workshops with these technical agencies, to explain the CRF for understanding and building resilience, in an effort to solicit their support in identifying better indicators. In Quy Nhon, sectoral working groups were formed for each of the three sectors for which indicators were developed, with CCCO staff on each of them. In Da Nang, indicator development was turned over mostly to the sectoral agencies responsible, and the CCCO played a largely supportive role. In each of the Vietnamese and Indonesian cities, ISET was also consulted several times to improve the quality of the initial draft indicators. All of the local partners described this process as iterative and collaborative, but also time-consuming.

The main result, in addition to the set of indicators described in Appendix A, was a much deeper understanding of climate resilience and its practical implications, across a wide range of agencies involved in the key climate vulnerability issues for each city. Iterations of indicator development involved local technical experts, external ISET advisors, and the inputs of the coordination and leadership group in each city.

Overall, the process of indicator development took longer than any of the participants expected, largely due to the time involved in this iterative and collaborative approach. Workplans developed in 2011 by each of the leading partners suggested they would have their first complete set of indicators within 6 months, but only Gorakhpur was able to identify and collect baseline data on indicators within their planned timeframe. In other cities, the process took at least 12–18 months, even in the case of the Vietnamese cities with dedicated staff resources in the CCCO’s. Estimated staff time for preparing the indicators ranged from about 6 to 12 person-months in each city (see summary comparison in Appendix 2), but much of this was spent on understanding and explaining the overall resilience framework and becoming familiar with the purpose of the indicators. Future data collection will be relatively simple and quick in most cases, although it is likely that some of the indicator sets will continue to be revised.

The collaborations established to develop indicators in each of the cities involved a wide range of participants. Depending on the city, these included various city departments, public utilities, expert researchers or consultants, NGOs, community leaders, and other levels of government. All of these partners learned about climate resilience in order to provide feedback on the proposed indicators, their feasibility, and application.

Two of the ACCCRN cities found the exercise of developing indicators in this way to be not relevant for their purposes. Indore and Surat, both in India, were introduced to the concept of indicators but chose not to develop resilience indicators because they participate in several national programs for infrastructure and urban services, which require recipient cities to monitor service benchmarks across a wide range of infrastructure and utilization factors. These benchmarks, which will be required anyway under the national funding programs, were seen as providing comparable information to the ACCCRN resilience indicators for these cities. In general, Indore and Surat concluded that there was a large amount of data already being collected at the city level, either by local, state or national authorities, and that they needed to clarify the policy and planning rationale for resilience interventions prior to focusing more attention on developing new indicators.

7. Summary of Selected Indicator Data

Gorakhpur: In Gorakhpur the resilience indicator data was collected for the period before and after an 18 month effort on community-level interventions. Unlike in the other cities, the indicators in Gorakhpur apply only to Mahewa ward, one of 70 wards in the city. One of the main objectives of the Gorakhpur ward-level resilience strategy designed and led by GEAG was to raise the profile of drainage and poor public services in this low-income peri-urban area, and to use the community's initiative to demonstrate to local government that modest improvements could achieve substantial results. To that end, the ward-level resilience project in Gorakhpur worked closely with community leadership to improve local drainage, water supply, solid waste collection, public health awareness, and introduced a composting and community agriculture program.

Table 4: Selected Gorakhpur Indicators

Indicator	2010	2012
Days of flooding	30–60	4–6
Number of flooded areas	5	1
Households with piped water	331	453
Households with >1 source of water	397	856
Households using solid waste collection	0	953
Plugged drains during monsoon	15	8
Frequency of drain cleaning	10-15 days	3–4 days
Citizens involved in political action	50	130
Visits to area by local politicians	0	4

Most of the indicators were designed to measure the impacts of these activities (see Table 4). The table demonstrates the community's success in improving solid waste management and drain maintenance, which have helped to reduce flooding and waterlogging problems. Note also that the community has become more politically active in calling the attention of local government to these issues and demonstrating its successes. As a result of this work, some of these indicators are now being collected by local government in other wards in Gorakhpur.

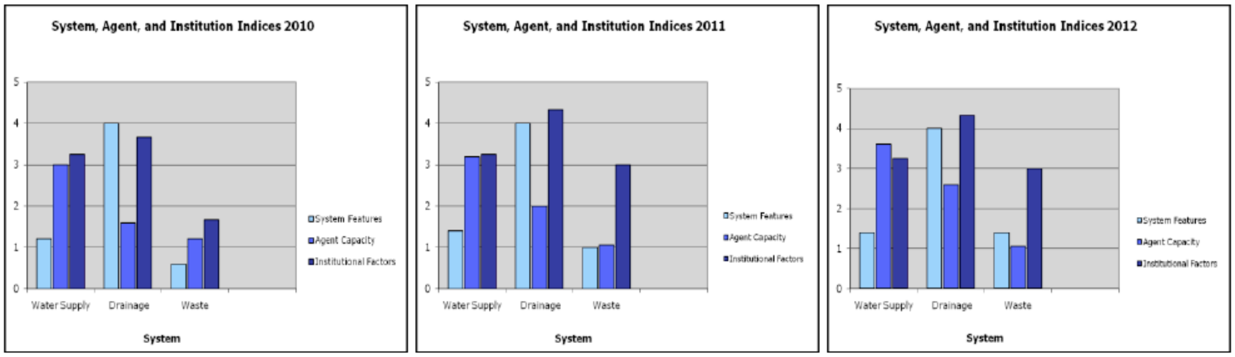
Can Tho: Indicators were collected for water supply, resettlement, and public health for multiple years, which varied depending on the indicators. The Climate Change Coordination Office led the indicator development process, first attempting to define meaningful indicators based mainly on the CRF and climate vulnerability assessments. This led to considerable difficulty matching available data to their preferred indicators, resulting in numerous revisions in the indicators selected, and some for which no data was available. Indicators for the water sector show little change over several years of data, with generally good performance of the water system except on measures of access (percentage of households served). Most poor households receive water supply at subsidized rates, but the number of households receiving support for installation of water connections has declined in recent years despite increasing demand. Resettlement due to climate change (e.g. flood exposure or riverbank erosion) has increased as a proportion of all resettlement in recent years, but the system has not been able to meet this growing demand. In addition, as average housing costs have increased, the support provided for resettlement comprises a smaller proportion of total costs. Infrastructure in resettlement areas is generally good, although solid waste collection is not provided. In the health sector, investment in new hospitals and staffing have increased substantially in recent years, and health insurance is available to all poor households registered in the city. In addition, incidence of diseases related to climate seems to be declining, and mortality rates are very low and relatively stable (Ky et al., 2012). The indicators were shared with relevant sectors and provide a basis for them to integrate climate change issues into their own internal sectoral planning efforts.

Da Nang: The city collected indicator data in three quite different sectors, but only for a single year (2011). Water supply is a public service managed largely by a single government-owned corporate entity, the Da Nang Water Company. Flood prevention and management is a key disaster risk management task which is coordinated by a local government inter-agency committee, but whose functions are implemented by a wide range of local government departments, non-government organizations (e.g. Red Cross), and voluntary community groups. The third sector was the tourism sector in a particular coastal district of the city that has been designated for tourism development but currently consists largely of steep mountains and forest cover. Conclusions of the analysis were limited as it consisted only of a single year, but it suggested that the water system was not resilient to climate change, due to obsolescent system controls and source vulnerability to salinization and low dry season flow rates (see dashboard above – Fig. 1). The water company found this analysis useful, although most of the issues were already known and plans exist to address them. In terms of flood prevention and management, index scores were higher than for water supply, across all 3 resilience categories. The main issues identified were the lack of integration of climate change and community participation in flood prevention planning. For Son Tra district tourism, resilience was found to be low due to frequent storm damage to tourism facilities and very low levels of disaster planning and preparation in this sector. These results were provided to the relevant sectors and government agencies with recommendations that they should provide guidance for planning and investment and that indicator monitoring should continue at the sectoral level (Climate Change Coordination Office, 2013).

Quy Nhon: Like Da Nang, this city developed indicators only for 2011. They chose sectors that are economic and environmental priorities: mangrove (restoration), tourism, and fisheries. The indicators were intended to help the relevant agencies to assess their capacities and performance in implementing the climate resilience plan developed for Binh Dinh province, to guide resilience interventions. The Climate Change Coordination Office was unable to find data for some of their indicators, but generally the index scores were low for mangrove ecosystem resilience, and for institutions. This reflects the limited scope of restoration efforts so far. For the tourism sector, the indicators suggest that tourist infrastructure is not highly vulnerable, but that managers and operators have not done enough to plan and build capacity for disasters and climate change. The fisheries sector has reasonably resilient infrastructure in place, but the poor planning, preparation, information provision, and capacity of key actors are serious weaknesses (Nguyen, 2013).

Bandar Lampung: Index scores were prepared in each of three systems from 2010–2012: water supply, drainage, and solid waste management. Over the 3 years of observation, the scores of the water sector changed very little (see Fig. 4 below). City water supply is constrained by limited surface water sources, and 75% of the population meets their water needs from other sources, chiefly groundwater. Over the study period, water leakage rates declined slightly in the distribution system, improving revenue; and plans were developed by the water utility for improved system management during droughts and floods. For solid waste, system and institutional indices increased over the period, due to an increased share of solid waste being collected, and improved coverage in vulnerable sub-districts. While response times for emergency complaints improved, the sanitation company's net revenues fell. Drainage showed the greatest scoring improvement over the study period, due to increased storm drain construction, improved response time to clogged drain complaints, improved planning and reporting, and relatively less flooding in slum areas compared to other parts of the city (Megaputri et al., 2013).

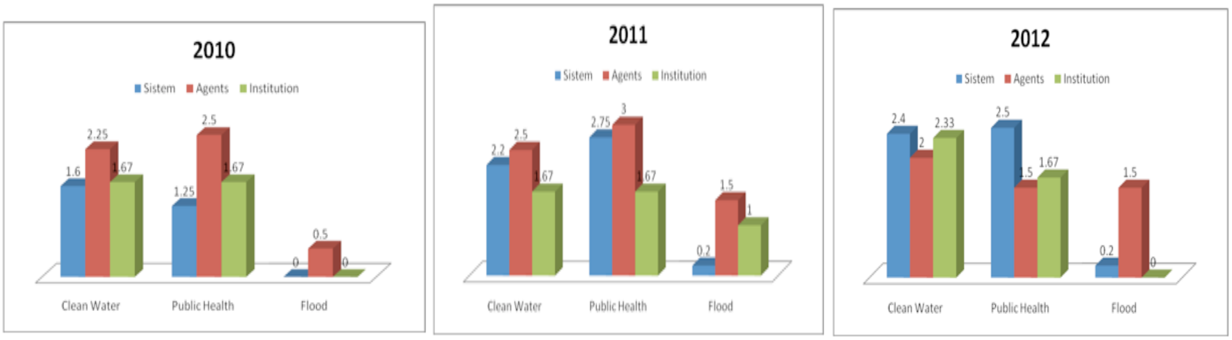
Fig 4: Resilience Indices for Bandar Lampung: 2010–2012 (Megaputri et al., 2013)



2010 2011 2012

Semarang: In Semarang, indicators for water supply, public health, and flood protection were compared for three years: 2010–2012 (see Fig. 5 below). The index values for water supply showed an increase in system and institutional indicator values, but a decline in agent capacity. Over this period, distribution system coverage increased, as did the number of households served by alternative domestic water supply services (including rainwater harvesting), although leakage rates increased. At the same time, subsidies and financing mechanisms increased the affordability of new water supply services for the poor, and the water utility improved its plan for addressing water scarcity and potential supply constraints. In public health, system performance increased while agent capacity decreased, due to increases in medical personnel and more effective dengue control measures, but also higher fatality rates from dengue infection. Indicators in flood management showed no change in system scoring, but an increase in agent capacity due to improved planning capabilities, greater community involvement in flood control, and improved community flood adaptation measures. A flood early warning system was installed in 2011, but operations were temporarily suspended in 2012 due to a construction project ("City Level Resilience Indicators and Data Collection for Semarang," 2013).

Fig 5: Resilience Indices – Semarang 2010–2012 (from city report)



8. Discussion: Comparisons and applications

Despite the common conceptual framework, consistent training, and ISET guidance, one of the striking observations about the resilience indicators developed by the 8 cities is their diversity. Even when comparing indicators within the same sector, such as water supply, cities used quite different measures to identify changes in resilience for their own purposes. From our interactions and discussion of these differences, it would appear that they are due to several factors. First, there are real differences in the problem context in each city. Taking water supply as an example, a common issue may be dry season water shortages (exacerbated by increasing precipitation variability and warmer temperatures). However, this may manifest itself in different cities as a different combination of problems that might include saline intrusion, insufficient diversity in surface and/or groundwater sources, insufficient seasonal storage, lack of water demand management measures including rainwater harvesting, low penetration of more reliable urban water distribution systems, or lack of city influence on upstream watershed management and reservoir management. Different factors are at play in each city, and the varied governance contexts also provide different opportunities for cities to influence these factors. So for indicators intended to monitor the effects of local planning and management decisions, it would be sensible that the definition of relevant indicators vary from city to city.

In addition, the available data also varies from city to city. In most cases, cities reported that the indicators they ended up with were not the ones they would have preferred to use. They had derived various indicators that more accurately and clearly represented the resilience values they wished to monitor, but found that data was not available and could not easily be collected on a regular basis. This suggests that with additional resources, the city partners themselves would be able to identify and collect data on indicators that could more appropriately track the key resilience factors linked to their main vulnerabilities. It also underlines that some of the final indicators reported by city partners are relatively weak in terms of measuring resilience values deemed important by local partners themselves. In some cases, cities kept indicators in their final set, even though they could not collect data for them, just to make the point that they would like to see data collected for this purpose.

The question of data availability is a crucial one, and proved to be a major constraint in all the cities. GEAG essentially had no option but to collect indicator data itself at the ward level, mostly from primary sources through household surveys. Hat Yai also used household surveys for supplemental data collection. This is probably not a viable option for many cities or for long-term application. While to some extent data can be collected with additional effort and resources, it will be important to justify carefully the benefits of such data collection in relation to the costs involved.

The ISET Climate Resilience Framework was used explicitly by partners to understand the concepts of resilience to be able to frame indicators, and to explain the concepts and indicators in order to engage technical expert agencies in collaboration on their development. This process tested the relevance and applicability of the CRF in many different urban contexts, and its practicality as the foundation of a linked tool to guide indicator development. The conceptual framework required the definition of new terminology and its translation into local context. But from the experience of the authors and the feedback of local informants, the biggest challenges in the process were related to the specifics of indicator definition and data collection, rather than understanding the conceptual framework. In this respect, the framework demonstrated its practical value as a platform for local planning and monitoring of climate resilience.

The process of discussing specific indicators, their meaning, and available data had many unexpected benefits. In Chiang Rai and Hat Yai, exploration of resilience indicators helped better define resilience issues, stakeholders, and pointed to the lack of reliable data on key issues. In Semarang, city government departments recognized through review of the resilience indicators that despite devoting large annual budgets to flood prevention and relief, they had no good measures of whether the problem was getting better or worse. In Bandar Lampung, the indicators were seen as important enough to merit inclusion in annual State of the Environment reporting, and the process of developing them helped to build recognition of the importance of integrating resilience into regular planning and departmental management processes. In both Indonesian cities, the aggregated dashboard visual display was very helpful in highlighting problem areas for reporting and prompting planning effort to respond to these. The indicators demonstrated to city government in Gorakhpur that modest community led interventions could dramatically reduce climate vulnerability issues that the government themselves had dismissed as unsolvable.

Part of the reason for the unexpected length of time needed for indicator development had to do with this learning and capacity building effort. Even the cities' core groups sometimes found that their understanding of resilience was challenged when they had to come up with specific indicators. The process of indicator development, and the tools provided for that purpose, enabled them to translate the general concept into more concrete terms for local application and to build their own experience and understanding of the conceptual framework. All of the cities reported that while this iterative and collaborative process took more time than expected, the time was well spent in building capacity in resilience planning across multiple agencies.

ISET follow-up revealed that local partners also found themselves unable to devote attention to indicator development because of conflicting demands from other aspects of the ACCCRN program, including the development and revision of funding proposals for city level resilience interventions, the recruitment and training of local counterparts as officials left office or were re-assigned, and the management of complex intervention projects that provided resources for local partners and supported project staff. The resources provided for indicator development were small, and the indicators were not prerequisites for other components of the ACCCRN program, so they typically became a lower priority task for partners scrambling to meet urgent deadlines. In some cases, the key local government partners were preoccupied with implementation and management of other ACCCRN projects, and so local consultants were engaged to do some of the research and data collection for indicator development. Local partners consistently overestimated their ability to devote time and resources to indicators in their progress reports and workplans, and the priority of this task slipped in relation to other ACCCRN program requirements.

In Vietnam, the indicator development process was led by the city Climate Change Coordination Offices, which had received core funding from ACCCRN. This enabled the

Vietnamese cities to complete an initial set of indicators relatively early. However, there were still challenges: participatory and collaborative teamwork across sectors and departments was unusual in Vietnamese cities and it required time to explain and to engage with other sectors. To a large extent, the indicator development process was novel in other cities as well: it dealt with a new subject and new kinds of data, and it involved participatory and muti-stakeholder consultation processes that were unusual in technical planning.

There were other reasons for the delays in indicator development. The concepts and tools had to be translated into local languages in Indonesia, Thailand, and Vietnam to be useful to local government and other partners. This process itself helped to better clarify concepts, as many of the English concepts have no precise counterparts in local languages. These processes of interpretation of the concepts, of giving them local meaning, and of developing specific examples all required interaction, discussions, deliberation, and explanations that helped to build consensus on what the key issues were in the context of each particular city. In addition, reviews by ISET also sometimes further delayed local progress. But in some respects, the greatest benefit of indicator development was the learning that accompanied these iterative and deliberative processes of interpretation, review, and revision, even though they were time-consuming.

When participants described the process as being iterative, collaborative, and deliberative, they referred to the following characteristics:

- A relatively consistent group of diverse stakeholders with varying expertise continued their involvement over a period of time.
- They met several times to interpret the issues and share their knowledge.
- They debated the merits of different kinds of data, and of normative targets.
- They went back to revise indicators and collect new data when they decided the original versions were inappropriate.

The engagement of diverse local organizations in the indicator development process not only spread understanding of climate resilience, but also strengthened internal management capacities. For example, normalization and indicator scoring allowed the introduction of policy intent into the measurement process. By identifying preferred targets, or even directions of desired change and comparing these to measured indicator levels as they changed over time, the resilience planning team helped tie the indicators to explicit performance expectations, and where such expectations were not explicit, to make them so. This process helped to clarify the intentions and expectations of system managers. In this way, through deliberative interaction with technical experts from multiple sectors, the generalized and somewhat abstract characteristics of resilience were given specific and measurable dimensions, and linked to management goals and development performance. For example, in Semarang the organization of the information in this way was an eye-opener for city technical staff. They realized they had no data to tell them about flooding and whether it was getting worse or better, despite spending budget every year on flood management[12].

The processes used by the cities for indicator development started in different places. In Vietnam, the cities typically focused on sectors as the organizing themes for indicator development. In Gorakhpur and in the Thai cities, the focus was on issues or hazards to address. Note that each of these approaches has strengths and weaknesses. A focus on sectors provides a way to engage with relevant local government line agencies so that they can integrate resilience indicators into their planning processes. But it may miss cross-sectoral issues such as coastal erosion, poverty reduction, resettlement, or risk assessment in urban development. A focus on issues responds more clearly to problems perceived at the community level, but may have difficulty linking to sectoral and fragmented planning processes.

A particular challenge of the structure of the ACCCRN program was that it focused planning and interventions on reducing climate vulnerability for the urban poor. Especially in Thailand, partners felt this programmatic focus distracted attention from the overall urbanization and urban systems context, leading to interventions and sectoral indicators tied to vulnerability and poverty that were not well connected to the institutional structures for urban development and planning.

Local leadership of the indicator development process was largely responsible for the capacity building outcomes. If the indicators had been externally developed, there would have been much less need for the interaction and interpretation of concepts. But this “bottom-up” approach to indicator development also generated challenges. Local officials might have preferred in some cases to have indicators defined for them. It would have been simpler for them and would have given more direction and specificity to their work. The collaborative and iterative processes led to widespread discussion and reflection on resilience, but did not always lead to clear, easily interpreted indicators. The exploratory approach suited some groups better than others.

The trade-offs identified in the background to this paper remain. In the context of ACCCRN experience, and the diversity of indicators and definitions that the cities came up with, it is hard to see how local partners would have been able to work with a pre-determined set of standard urban resilience indicators. They would not have understood how the indicators were linked to resilience, how they were derived or used in planning, nor would they likely have been able to find data. The most productive part of the indicator development experience in ACCCRN was the learning tied to deliberation around the meaning, derivation, and data for locally relevant indicators. On the other hand, some of the resulting indicators are difficult to interpret or compare across contexts.

The hybrid approach adopted for ACCCRN, which could loosely be described as “expert-supported, bottom-up”, seemed to be effective at building local engagement and

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[12] Reported from workshop discussions by project coordinator and co-author A.D. Sari

capacity. In all cases, the ISET resilience framework proved to be relatively easy to use at a conceptual and explanatory level, but the effort came in fleshing out local details. This took a long time, in part because of the intrinsic demands of the iterative and collaborative process, and in part because the resources dedicated to indicator development were very limited. This is a reasonable condition for assessing transferability: resources for this kind of exercise are likely to be limited in any city.

This experience suggests that resilience indicators can be developed locally, even under conditions of limited capacity and experience, from the CRF and a prior assessment of local climate vulnerabilities. However, the process requires staff time commitments across multiple sectoral agencies, so it will be smoother if there is a strong local initiative and support from senior levels of local government executives to free up the required resources.

In any case, whether externally or locally defined, the key constraint to developing practical, coherent, and meaningful indicators is availability of data. All the local partners reported difficulties in finding data to match indicators they had defined. This was especially true for indicators related to institutional elements of the resilience framework: measures of equitable access, governance, and public information. The most commonly used indicators for this element were related to subsidies to ensure access by the poor to key services (e.g. municipal water distribution, public health clinics), the extent of community participation in planning and decision making, and the availability of public information related to system vulnerability or climate hazards (such as water quality warnings, or flood early warning systems). The experience of the local teams suggests that while institutional issues are recognizable to local poverty reduction advocates and government, that there are few sources of useful data in this area from which to build effective indicators. This could be an important area for future study.

The main lessons from this experience for other cities who wish to develop resilience indicators of this type can be summarized as:

- The approach should be based on a coherent conceptual framework, so that all participants share an understanding of what they are attempting to measure.
- The work will require executive-level support, a small leadership team, and a diverse technical support group that may include community members.
- The conceptual framework should be interpreted jointly in context, so that local vulnerabilities drive the selection of priority indicators.
- The process of developing indicators should be iterative, collaborative, and deliberative to gain the maximum benefit.
- The team should expect the effort to be more time-consuming the first time, because of struggles to interpret and agree on indicators, data, and normative scoring
- The key constraint will probably be availability of data for the most relevant indicators.
- The main benefit to the process will be a shared understanding of how resilience relates to diverse city operational practices and investment plans across multiple sectors.

The development and use of resilience indicators is, of course, part of a larger system of planning information and local governance. In this context, the process of indicator development, when undertaken by the agencies that are expected to use them, is itself an indicator of capacity and climate resilience. Resilience indicators that are developed, applied, and used in climate vulnerable sectors demonstrate both the increased mainstreaming of climate adaptation in these sectors, and systematic capacity for both planning and learning, essential for resilient agents.

9. Sustainability: How are the Indicators Likely to be Used?

The ongoing application of the indicators for local planning and monitoring purposes is related to at least five important factors: 1) the understanding by local users of what the indicators mean and why they are relevant to resilience; 2) indicators that are directly linked to the most important contextual climate vulnerability issues facing the city; 3) indicators for which data are readily available; 4) incentives to integrate climate resilience issues into sectoral planning; and 5) indicators that are strongly supported by theory or conceptual frameworks (i.e. have high explanatory power). The challenges, as we have explained above, is that it is difficult to address all these conditions simultaneously. The ACCCRN resilience indicator development process emphasized local leadership, which strengthened the first 4 factors, building understanding, ownership, contextual relevance, and feasibility in a context where local policy encouraged planning for climate resilience. But there were compromises in the rigor of the resulting indicators, where preferred indicators could sometimes not be used due to data limitations.

It is difficult to predict what the results will be in terms of continuing to use resilience indicators after the conclusion of the ACCCRN program. In Gorakhpur, the resilience indicators were collected largely by household surveys, supported by project funding. These surveys are not sustainable without additional outside funds. However, the indicators were effective in demonstrating to local government the benefits of small-scale infrastructure investments. For example, community construction of 750 meters of drains, using community-generated funds and voluntary labor, prompted the local government to add its own drainage improvements downstream to further enhance the ward’s drainage. The measurement of flood impacts demonstrated a major decline in inundation in this area from 20 days in 2010 to just a few hours in 2013 (Gorakhpur Environmental Action Group (GEAG), 2013). The demonstrable success of the interventions in Mahewa ward has prompted interest from the city government in collecting similar data in other parts of the city, and it has built the capacity and interest of community leaders and local researchers in identifying and applying relevant indicators to measure the delivery of key public services.

In Bandar Lampung, the city’s report on resilience indicators described how indicator results led to consideration of new city regulations for rainwater harvesting. It also described interventions suggested by the indicator scores (some of them already planned) and recommended that the indicators be used in the preparation of statutory urban spatial and environmental plans (Megaputri et al., 2013). While there was discussion of integrating the resilience indicators into the city’s annual State of the

Environment reporting, other elements of this report are nationally funded while resilience indicators are not, making it difficult to integrate them easily on a continuing basis.

In Semarang, indicators that directly relate to departmental policies and objectives already, such as for flood protection, have attracted attention and may be continued as part of that sector's planning and monitoring efforts. There is also interest in expanding indicator collection to other sectors. The indicator results will be made public and used by BAPPEDA.

In both the Indonesian cities, Mercy Corps continues to work with local partners to build confidence in application of the resilience indicators, which are typically data that are already collected for other "business-as-usual" monitoring applications. They are collecting examples of how the resilience indicators can be used to strengthen local planning processes in order to demonstrate the value of continued use of the city resilience indicators. In Semarang, this work will be led by the Initiative for Urban Climate Change and Environment (IUCCE), which is the formalized successor to the city's Climate Change Team. New donor-funded interventions for climate adaptation will use the indicators to monitor their contributions to city-wide resilience.

In both Thai cities, some of the indicators have been rolled into project monitoring for interventions funded by the Rockefeller Foundation as part of the ACCCRN program. In Da Nang, the city's Climate Change Coordination Office recognizes that future applications of the indicators will depend on whether they meet the planning needs of the relevant sectors, and they have specifically encouraged sector planners to lead indicator development for that reason. In Can Tho, the indicators have been loaded onto the CCCO's public website, and the city's Climate Action Plan (as approved by the Ministry of Natural Resources and Environment) includes a mandate for measurement of indicators by the city's Department of Natural Resources and Environment. CCCO will serve as an advisor for this purpose. In both Chiang Rai and Hat Yai, it is too early to say how the indicators will be used. There are no coordinating agencies for the key issues (water management and flood management, respectively) in either city, and civil society users may be more diligent in tracking change than any government agency with only fragmentary responsibility.

Indicators may also be useful for non-government purposes, particularly for community groups mobilizing to address climate vulnerabilities or disaster risk reduction. They are also of interest to applied research organizations who are working on climate change and adaptation issues in the local context. In some cases, the indicator development process may be continued by such community or research groups rather than by government agencies. Instead of being incorporated in formal government planning processes, the indicators may be used to increase accountability and prompt more explicit policies and interventions to address the needs of groups vulnerable to climate hazards.

Because the indicators have been developed either concurrent with or in advance of sectoral planning processes that would integrate climate adaptation and resilience building, they are not yet well anchored in planning processes or targets. In the Thai cities, indicators were developed in response to multi-stakeholder goals and objectives for the relevant climate problems, but there are no government agencies with clear mandates to address these. In other cases, preferred levels for indicators are implied through the scoring process, which is negotiated with local experts and technical agencies for each indicator set. In Gorakhpur, the community-developed indicators serve as a tool for promoting local government accountability and service delivery. From their origins in a general conceptual framework, resilience indicators are beginning to be applied in a variety of ways as tools for mainstreaming climate adaptation into local planning.

In some cases, priority vulnerability issues are not well measured by indicator sets developed so far, primarily due to data limitations. Local climate adaptation coordinators have reported dissatisfaction with their indicators for this reason, and expressed an interest in improving the existing indicator sets. This suggests an agenda for future work, strengthening indicators, and devising low-cost data sources for ongoing monitoring. Enhancements of the current indicators should focus on areas of high vulnerability, where key measures of infrastructure performance, agent capacity, or enabling institutional features are not yet well monitored. In cases such as this, experience from this project demonstrates that investment in data collection for key indicators may actually serve as a catalyst for articulating and defining resilience performance targets using the resilience framework.

In most cities, the working groups responsible felt that the indicators should be made public. In Gorakhpur, this was an essential element of the community's strategy to make local government more accountable. In Can Tho, the indicators have already been made public on the CCCO website, and in Indonesia the indicator reports are publicly available. There was broad recognition among partners that resilience indicators should inform the public about changing climate vulnerabilities and increase the accountability of local government over time.

The indicators have been specifically developed for longitudinal application in each city, to monitor changes in climate resilience, and support local adaptation planning efforts. They are not, in their current form, appropriate for comparative purposes. The experience with resilience indicators in ACCCRN suggests some areas of common concern between cities, such as water supply, public health, drainage, and flood management. It is possible to use the resulting indicators to develop potential measures that could be shared between different cities. We can see, for example, in Appendix 1 that there are close similarities between some of the indicators used in different cities. However, it is not immediately obvious that indicators which would be valuable in comparing climate resilience between different cities would also be the most useful in guiding planning and monitoring for individual cities. Differences in local institutional frameworks, vulnerabilities, and exposure to climate impacts all mean that individual cities, or community groups within those cities, are likely to have divergent interests in monitoring climate resilience. This is not to deny the value of comparative indicators of climate resilience, including standardized measurement and scoring tools, for other applications. The experience with resilience indicators in ACCCRN should provide some useful practical guidance based on the experience of multiple cities to support such an effort. But we would not expect that comparative indicators would necessarily also be helpful for local planning.

10. Conclusions

This paper describes an approach to measuring climate resilience for local planning and monitoring purposes. Indicators of climate resilience for these purposes cannot easily be standardized. Because the resilience context varies depending on the exposure, vulnerabilities, and capacities of city-level actors, different indicators will be more relevant to different cities. And in all cases, availability of data is likely to vary substantially between cities. Indicators always provide only a fragmentary picture of a complex resilience situation. But local planning and adaptation management are useful applications of resilience indicators, if they can be constructed from a shared conceptual framework for climate resilience. The approach described in this paper ensures that relevance and application of the resilience indicators remain in the hands of the local organizations driving the process of their development.

Initially conceived as a relatively straightforward data collection exercise, the most important aspect of indicator development in ACCCRN turned out not to be the indicators themselves, but the process of developing them. Local leadership meant that multiple partners at the local level had to become familiar with the conceptual framework and to interpret this framework in order to apply it to indicator development. This took more time, but it became a major benefit of the indicator development process, in the experience of all the authors. This deliberative, iterative, and collaborative learning process played an important part in building capacity of local organizations to work productively with the concept of climate resilience.

In all of the cities, this capacity building began with the core group responsible for climate resilience planning and ACCCRN coordination, but then it expanded to other local government departments, civil society organizations, researchers, and other levels of government who became involved in developing or reviewing the indicators. This also led to greater clarity about the climate resilience problems in each of the areas for which data was collected; better understanding of the linkages of climate resilience to sectoral planning; better definition of potential interventions to address resilience issues; and greater recognition of the role of climate change planning and coordination groups within and outside local government. All these outcomes contribute, in themselves, to greater capacity and responsiveness and, hence, to climate resilience at the local level. The process of developing resilience indicators has laid a foundation for systematic mechanisms of monitoring and learning that are essential for resilience.

The ISET Climate Resilience Framework (Tyler and Moench, 2012) proved effective as a common conceptual platform for indicator development, but it had to be supplemented by local contextual knowledge in order to develop sensible indicators. While it would also be possible to develop a standardized, externally defined set of indicators based on this conceptual framework, it is not clear how useful this would be for planning and monitoring of key local issues.

In particular, our experience suggests that data availability is a key constraint for development of meaningful resilience indicators for local planning. In developing countries in particular, many cities have very limited data related to key public services, institutions, and agent capacities. While project funding can support initial baseline and monitoring of project performance for resilience-building interventions, this does not really address the longer-term needs of rapidly growing cities to better manage their climate exposure through improved planning and monitoring.

However, the ACCCRN indicator development process shows how a practical conceptual framework and iterative interaction of diverse knowledge holders can be used to identify a small number of key indicators in any city for which resource investment in data collection would be worthwhile. With this process, cities can better justify application of their own resources, or attract external resources from research organizations, planning, or feasibility studies for infrastructure investment. By understanding more specifically what information they need and why, local governments are better placed to find cost-effective measures to acquire that data.

A key conclusion from this work is the requirement to link urban climate resilience indicators to ongoing local processes of planning and management across sectors that are most vulnerable to climate change. The connection between the conceptual framework for climate resilience and local planning processes, in which resilience building needs to be integrated, is best made through the engagement of those planning agencies themselves. Monitoring changes in resilience through relevant planning processes is more complicated where there are no agencies clearly responsible for management of the crucial climate issues, as in the case of the Thai cities, but even in this situation the development of resilience indicators helped to define the problems, the agencies at different levels of government who needed to be involved, the interests of different stakeholders and the shape of potential interventions—in short, it helped frame a planning process.

In most of the cities, the resilience indicator teams recognize that the continuation of data collection and analysis will depend on the value of the indicators to planners in the relevant sectors, as well as their value in ongoing climate adaptation planning and management. As a result of developing their own indicators from the principles outlined by the climate resilience framework, these principles are much more widely understood in the ACCCRN cities, and practical approaches to embedding climate resilience as a policy and planning objective are gaining broader recognition. While climate resilience is not yet mainstreamed as a planning objective across multiple sectors in these cities, the introduction of resilience indicators in this way has helped prepare for this next step.

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Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Water Supply									
Leakage rate	X	X	X			X	X		
System coverage	X	X	X			X	X		
Current production / planned or required		X	X						a measure of planned capacity growth
Storage capacity				X		X			
Diversity of sources		X		X		X			incl rainwater harvest, demand mgmt
Share of supply from groundwater		X							combine w. diversity
Frequency of quality failures			X			X			
Capacity limits under stress						X			turbidity, flow limits
% waste water treated before discharge				X					
Nature of control systems						X			technical redundancy
Guidelines for water supply planning				X					
Supportive actions to implement water supply plan				X					
Unit cost of production		X							
Cost recovery (O&M)	X		X			X	X		
Plans for CCA		X	X			X	X		
Training effort							X		Cost of training to respond and rectify failures
Budget for supply expansion			X						
Quality testing frequency							X		Frequency?
SOP for service disruption and complaint			X						
Complaint response	X								
Emergency supply plans			X						
Number of different sectors involved in water planning				X					
Number of organizations involved in water planning				X					

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Accessibility to poor	X	X	X				X		BL - increasing block tariff Sem - support program
Community involvement in setting water tariff			X						
Public information about water supply and quality			X						
Flood prevention and drainage									
Flood shelters		X				X			Number/ capacity
Flood gauges						X			
Length of dikes						X			
Protected forest area upstream		X				X			
Area flooded	X	X			X	X			Need for normalization
Diversity of drainage system			X						
Length of drainage system			X						
Frequency of routine drain cleaning	X		X						
Green space as % of urban area		X							
Effectiveness of EWS		X			X				0 = none
Flood damage / yr		X							Normalized
Fatalities / yr		X				X	X		Normalized to flood? Rolling average?
Critical infrastructure outages due to flooding					X				
Length of recovery to "normal" function in days					X				
Communications effectiveness						X			Equipment, reliability
Reservoir controls follow protocols						X			
City-wide Disaster Mgmt plans in place		X	X		X				HY: number communities with plans
City wide organization for Disaster Mgmt		X							
Complaint response effectiveness	X		X						
Number evacuated						X			

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Number of drills / yr						X			
Community DRR and emergency training		X			X	X			
Funding for community DRR					X				
Community preparedness		X			X	X			Equipment, plans
% operating budget for drainage or flood protection			X		X				
review and update of drainage plan			X						
Building code specifies flood resistance					X				
Flood vulnerability maps widely available		X							Available / quality
Integration of DRR plans from community to city level					X	X			
Community participation in flood prevention plans			X		X	X			
Community involvement in drain maintenance			X		X				
% of flood problem areas in slums			X						
Availability of drainage complaint call centre			X						
Public Health									
Hospitals and clinics affected by floods							X		
Hospital beds / 1000							X		GKP needs to normalize data
% households with sewage connection	X								
Clinics / population	X	X							various facilities
Health staff / 1000	X						X		GKP needs to normalize data
sanitary sewage operating costs / revenues	X								
Rate of sewage complaint response	X								Combine 2 other indicators
Climate related disease incidence		X					X		Semarang dengue only

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Annual mortality due to climate related disease							X		
Annual mortality due to extreme climate events							X		includes floods, storms, lightning
Larval control program effectivness		X							
Community score on public health indicators		X							
Health communication budget as % of total							X		
Preventive health budget as % of total							X		
Health sector adaptation plans							X		
Number of district level facilities with climate plans							X		
Climate change activities within health service							X		
Penetration of household level practices		X							national survey data
% public facilities receiving hygiene training		X							
Community active lifestyles		X							survey data on healthy lifestyles
cost of basic medical exam for poor		X							
% poor population with health insurance (or public service)		X					X		
Vaccination program activity	X								
Outreach activiites - public health camps	X								
Tourism									
Days of road traffic disruption / yr						X			Blockages due to slides or road closures
Freq of air travel disruption								X	
Damage to hotels or historical sites						X		X	Normalized? Rolling average?

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
% of tourism revenue in rainy season								X	
% tourist facilities with backup plans for water, power supply								X	2 star or higher
Total annual number visitors								X	
Total annual sector revenue								X	
Tourism staff trained on climate hazard response								X	
Sector Plans for CCA						X		X	
Operator emergency preparedness						X		X	Plans, training
Share of tourism projects with local consultation and CC considerations								X	
Hazard warnings distributed to operators						X			
Warning signs at tourist sites								X	
Solid Waste Mgmt									
% households with SW collection	X								
Service coverage (districts served)			X						
% waste collected compared with need	X		X						
% waste collected by municipality	X		X						
Safe and hydrologically isolated landfill site?	X		X						
private sector engagement in SWM			X						
service complaints response rate	X		X						BL actually only that service centre exists
expenditures on SWM (?)	X								normalized to volumes or population
net revenue			X						
Staff / planned staffing			X						

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Community groups involved in collection			X						
Tariff structure facilitates access			X						
Community consulted on tariff			X						
Ecosystem Mgmt									
Mangroves									
Total area								X	
Seedling survival rate								X	
Lagoon area filled for urban development								X	
Length of bank eroded annually								X	
Number of staff provided awareness training on CCA / yr								X	
Number of community members provided awareness training on CCA / yr								X	
Share of mangroves in forest protection budget								X	
Number of forest violations / yr								X	
Reports document learning on mangrove mgmt								X	
Frequency / number of management consultations								X	
Quality of consultations								X	
Share of communes introducing management rules								X	
Share of villages introducing rules / commune								X	
Have reforestation and management plans considered CCA?								X	
Climate Resilient Agriculture									
Number of production models	X								

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Number of farmers involved in CRA	X								
% change in income for participants	X								
Farmers adopting new techniques	X								
Crops / year	X								
Fisheries									
Area damaged / yr by storms								X	
Storm losses of fishing boats / yr								X	
Average annual production (5 yr)								X	
Output loss due to disease								X	
Households trained in DRR / yr								X	
% fishers with DRR training								X	
% govt staff trained on DRR								X	
% of offshore fishers members of assocations								X	
% of boats with radios						X		X	
Sector budget for DRR / response								X	
Sector plans for CCA								X	
Enterprise or operator regulations considering CC								X	
Number of storm warnings / yr								X	
Resttlement and Housing									
Numbers resettled relative to need							X		
% houses with safe plinth levels	X								
% of resettlement areas with full infrastructure							X		
Actual resettlement compared to target							X		
Financial support to households							X		
Households have choice of resettlement area							X		

Climate Resilience Indicators Grouped By Sector and City

░ Systems Indicators ☐ Agent Capacities ▒ Institutions

Indicators	Gorakhpur	Semarang	B. Lampung	Chiang Rai	Hat Yai	Da Nang	Can Tho	Quy Nhon	NOTES
Long term land supply to 2020							X		
Number of HH voluntarily moving	X								