Evaluation that counts: A review of climate change adaptation indicators & metrics using lessons from effective evaluation and science-practice interaction

Keywords: climate change adaptation; evaluation; urban; science usability; science-practice interaction

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Abstract

Amid growing effort towards the implementation of climate change adaptation, serious interest is emerging about how to evaluate adaptation success using indicators and metrics (I&M). Cities are among the leading experimenters developing I&M, but many other entities also view I&M as a tool for providing clarity and accountability about the goals and progress of adaptation. The current landscape of this work is scattered: I&M examples, frameworks, and guidance documents reflect motivations, contexts, and approaches as diverse as the field of adaptation itself. This study systematically surveys the "growth industry" of I&M, including a special focus on I&M approaches developed *for* cities anywhere and *by* US cities in particular. We classify these I&M efforts into four domains: those developed in academia, by program sponsors, boundary organizations, and on-the-ground implementers. With attention to theory on (program) evaluation and on science-practice interaction, we surface a broad range of I&M evaluation purposes and collaboration practices. We conclude that evaluation of adaptation progress and effectiveness – if it is to usefully inform the adaptation practices of cities or other adaptation implementers – would benefit from greater attention to the best practices and guidance offered in the related, but largely still separate, fields of evaluation and science-practice interaction.

1. Introduction

Climate change adaptation (hereafter simply "adaptation") is moving to center stage for policy-makers, managers and scientists. Due to rapidly emerging and escalating climate change risks, scholars and practitioners alike now realize the imperative of effective response. Communities involved with adaptation implementation are thus compelled to make sense of what successful adaptation is and how it can be measured (Moser and Boykoff 2013; Bours, McGinn, and Pringle 2014 & 2015; Moser et al. in prep.). Consequently, adaptation evaluation is an area of growing importance among the sponsors, implementers, researchers, and beneficiaries of

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these efforts. Mirroring related areas of sustainability science and practice (e.g., sustainable development goals, ecosystem health indices, corporate sustainability scorecards), an increasingly busy thread of the adaptation evaluation discussion focuses on indicators and metrics (I&M, see Box 1) as instruments for measuring progress, identifying needs and gaps, and assessing effectiveness.

Interest in I&M is evident across scales, sectors, and spheres of practice in which adaptation is occurring (for an overview of indicator frameworks see Leagnavar, Bours, and McGinn 2015; for examples of evaluation and indicator frameworks in international development see Schipper and Langston 2015; for national-level indicator review see Ford et al. 2013; and for discussion of evaluation of local adaptation efforts see Baker et al. 2012 and ISC et al. 2016). Academic contributions mainly focus on specific aspects, such as evaluating the deliberative process used in adaptation planning (Webler et al. 2014) or needed and observed changes in institutional capacity to support adaptation (Adler et al. 2015).

Box 1. Defining indicators and metrics

Numerous definitions of indicators and metrics may be found in literature on monitoring and evaluation. We offer the following definitions as most pertinent to how we view the landscape of indicators and metrics with respect to climate change adaptation success investigated in this paper.

Indicator: A quality or trait that suggests ("indicates") effectiveness, progress, or success.

Metric: A variable that can be measured (if quantifiable) or tracked (if qualitative) that represents the indicator.

As these examples and the attempts at synthesizing this literature suggest, adaptation I&M are emerging across the world, albeit unevenly, in many different contexts and for diverse purposes and users. This surging interest may be funder-, researcher-, or user-driven (but rarely, to date, by government policy). Some aim at developing unique, context-specific evaluation and I&M frameworks, while others constitute cross-cutting attempts to learn from these individual endeavors and propose widely applicable indicators of adaptation success. Such organic development is to be expected, partly because these are still early days for understanding what effective adaptation might be and how to achieve it. Also, many are just now grappling with the topic, seeking guidance, yet also requiring very context-specific information. The downside is a scattered I&M landscape that makes it difficult to track and discern the benefits of evaluation as part of the adaptation process. While this paper does not evaluate the quality or utility of I&M per se, it does point out criteria that may be useful in navigating this landscape today and, in the future, evaluating it.

While adaptation has been studied and been promoted by federal agencies for many years, and a significant number of broad state adaptation plans or strategies exist, urban areas are among the leaders of planning and implementing adaptation in the US (Bierbaum et al. 2012). US cities are also among the first to ask what might constitute "success" and how to track progress and measure effectiveness. A few cities lead with first attempts to track performance on adaptation plan elements,

support ongoing adaptive management of resilience strategies, and communicate with constituents, elected officials, and funders about their progress (e.g., Solecki et al. 2015; City of Baltimore 2013). Additionally, efforts by NGOs and researchers external to city governments are actively considering how to measure progress toward a well-adapted or resilient city (e.g., Arup and Rockefeller 2014; ND-GAIN Urban, this issue). But, as a recent working group of the Urban Sustainability Directors Network (USDN) on resilience I&M found, the relevant examples are overwhelming and lacking clear guidance; few cities are prepared to sort out all the nuances that one might consider (ISC, USDN, and DC 2016).

This paper makes a new attempt at characterizing and synthesizing the existing literature. The novel contribution of our analysis is to assess the existing I&M literature through two lenses: that of the long-standing theory and practice of *evaluation* and that of *effective science-practice interactions*. We think I&M are a special case of potentially usable knowledge relevant to planning and decision-making, and of evaluation as a potential site of science-practice interactions. This leads us to ask who I&M are being developed for and who they are being developed by, what the intended use of I&M is, and to critically reflect on the process of developing them. Our results can inform cities developing indicators, but they also encourage scientists and practitioners to carefully consider the underlying motivations as well as process for developing adaptation indicators.

2. Theory and Methods

This paper emerged from a transdisciplinary research project aimed at understanding the effective development and uses of I&M while helping US coastal communities develop practically relevant and feasible I&M through a stakeholder-driven and -engaged process (results of this work are forthcoming). This systematic review of the literature served as input into the co-design and co-production of developing I&M. Below we summarize relevant elements from (program) evaluation theory and science-practice interaction to set the stage for our analysis described subsequently.

2.1 *Evaluation Theory and Practice*

To ground and contextualize our review, it is helpful to draw on the field of evaluation theory and practice. That field, of course, predates the emergent excitement over its application to adaptation. Although the terms evaluation and evaluation research are relatively recent concepts, the activities that are typically considered under these rubrics are not. Evaluation is now well established, primarily due to restraints on resources and the corresponding scrutiny of the effectiveness and efficiency of existing programs (Rossi et al. 2004; Shaw et al. 2006). In an increasingly "results-driven" environment, evaluation is critical for developed and developing country institutions alike. Activities conducted or sponsored by these institutions, in both public and private sectors, often include requirements to track, review, and appraise aspects of organizational functioning

and outcomes, and improve overall accountability in the public and private sector (Robson 2000; De Lancer Julnes 2006).

Generally, evaluation has one or more of the following purposes: (1) assessing the need for a program or project, (2) helping with design and action logic, (3) guiding implementation, (4) assessing outcomes and impact, and (5) evaluating cost and efficiency. To the extent evaluation serves as a systematic investigation of system interventions to inform actions, policies and improve social or environmental conditions, it can be broadly applied to most, if not all, societal issues regardless of sponsorship by government agencies, international organizations, private foundations and philanthropies, and non-profit and for-profit organizations (Rossi et al. 1994). Deliberate adaptation – even if not understood as a formalized bundle of projects or program but as a set of loosely affiliated interventions in human or natural systems to make them better adapted to changing climatic conditions – can benefit from the systematic evaluation of associated decisions, processes, actions, and outcomes.

Rossi et al. (1994) argue that "good" evaluation questions must be appropriate and answerable and must be able to be addressed by using the research procedures available to the evaluator. In this view, determining the specific questions on which the evaluation should focus requires locating oneself on the "evaluation hierarchy" (Figure 1). This hierarchy is built from families of evaluation questions corresponding to the five evaluation domains listed above: program or project need, design and action logic, process and implementation, outcome/impact, and cost and efficiency (from bottom to top). Naturally, there are interdependencies between these levels – they are not mutually exclusive – nor do they need to be carried out in a hierarchical sequence but by concentrating at a particular level, the evaluation can be designed and distinguished appropriately. As we will show in our analysis, adaptation-specific evaluation efforts in practice—intentionally or not—address various levels of this hierarchy, sometimes focusing on only one, and other times at several levels at once. Ultimately, though, different questions call for different designs (Robson 2000) and a theory of change[4] and corresponding action logic frame or model[5] can guide and inform the evaluation focus and questions. Once this change theory has been clarified, the development of indicators and corresponding metrics can proceed and serve the implementation, ongoing monitoring, and eventual evaluation of results.

Figure 1. A hierarchy of evaluation functions

[4] Gertler et al. (2010) defines a theory of change as a description of how an intervention is supposed to deliver the desired results.

[5] Theories of change can be visually depicted using theoretical models, logic models, results chains, impact pathways and so on. For example, a results chain will map the following elements: inputs, activities, outcomes, immediate or first-order) outcomes and final (higher-order) outcomes (Gertler et al. 2010).

Figure Source: Adapted from Rossi et al. 1994

Hearkening to the adage – "what gets measured, gets done" – our review of I&M found that an overarching motivation for I&M development is the desire for clearly identifiable quantitative evaluation measures. However, the evaluation literature argues there are distinct advantages to addressing evaluation questions through a variety of complementary, independent, and interactive monitoring and evaluation practices. The result of this can be jointly agreed upon objective and subjective perspectives, captured both quantitatively and qualitatively. The ideal combination depends on the specific evaluation purpose(s) intended. While funders frequently call for quantitative outcome measures, such "hard numbers" are often difficult to obtain. Increasingly, evaluators criticize this narrow perspective as missing crucial changes that have been achieved or failing to support the range of reasons why evaluations are being conducted (Estrella 2000; Behn 2003). A carefully designed, mixed-methods approach used at different evaluation levels, allowing detailed reporting of context-appropriate program outcomes may produce the richest insights, albeit more through resource intensive processes.

A pragmatic posture is often taken in conditions of limited funding and expertise, or when other constraints may require structuring the inquiry in a way that does not represent the perspectives of all involved (Rossi et al. 1994). This draws attention to the interaction between the evaluation sponsor, evaluator, and evaluated (i.e. stakeholders). Evaluation can be conducted independently by one or more evaluators or collaboratively, with representatives of the sponsor and stakeholders involved. This spectrum of possibilities represents different orientations toward planning, conducting, and interpreting the results of the evaluation. Establishing an evaluation framework that identifies stakeholders and involves them early, continuously, and actively can yield evaluation outcomes that are both responsive to their concerns and useful with respect to their needs.

2.2 Science-Practice Interaction: Usability & Co-Production of Knowledge
Emerging best practices in adaptation also stress the importance of interaction and inclusive deliberation between knowledge producers and users to enhance the usability of tools and information in planning and decision processes (Reed 2008; Lemos, Kirchhoff, and Ramprasad 2012; Moss et al. 2013). Briley, Brown, and

Kalafatis (2015), summarizing a growing body of literature and case experience on the matter, put it succinctly:

> Direct, iterative relationships between science and decision-making stakeholder communities remain a key ingredient for the development of effective policies for addressing climate-related problems. (p. 43)

Amid many proposed strategies for fostering interaction, co-production situates producers and users of knowledge in a collaborative setting where research questions, methods, data, results, and the actual activities of knowledge generation are collaboratively considered and executed (Kirchhoff, Lemos, and Dessai 2013). While some scholars are quite strict in delineating what counts as co-production, others recognize it as an umbrella term for variously intense levels of science-stakeholder collaboration. Klenk and colleagues (2015) placed four types of interactions under the broad heading of co-production, with escalating responsibilities and opportunities for stakeholder participation in each: 1) Linking; 2) Match-making; 3) Collaborating; and 4) Coproducing (in the stricter sense).

In this study we view adaptation I&M effectively as an information source and decision-support tool created by an evaluator for a stakeholder (in our case, cities as adaptation implementers). This is why we connect thinking about the role of interaction in the development of evaluation with understanding of how interaction between different constituencies (e.g., indicator developer, user, and others) can shape and perhaps enhance the robustness and utility of I&M. To explicitly consider the role of interaction in the development of I&M, we adapt the distinctions proposed by Klenk et al. in our analysis (see Supplemental Materials, section 2). While their categorization serves as a useful heuristic for thinking about different purposes and levels of responsibility for researchers and practitioners working together, much richer typologies exist that consider the broad range of activities, attributes, and values to characterize interaction at this interface (e.g., McNie, Parris, and Sarewitz 2016).

2.3 Data Collection and Analysis

To consider the landscape of I&M, we conducted a systematic review of indicator development and usage focused specifically on climate change adaptation. This involved surveying a broad swath of academic (peer-reviewed) and grey literature, including actual examples of, or guidance about, adaptation I&M. Due to the overlap with many closely related societal and management issues, this review also led us to I&M approaches used in disaster risk reduction, development, ecosystem health, sustainability, and so on. However, only documents specifically including adaptation I&M are formally considered in this review (for a full list of examples see Supplemental Materials).

The identification of relevant literature involved three sampling approaches:

(1) Compiling all relevant documents containing I&M already known to the research team at the outset of the review;
(2) Conducting a series of systematic keyword searches on Google in January 2016 with the search terms: “climate change adaptation indicators”, “climate

change adaptation metrics", "climate change resilience metrics", and "climate change resilience indicators." The top 50 results for each search were examined and a subset retained when appropriate.

(3) Utilizing an extensive database of U.S. local and tribal adaptation plans compiled by Woodruff & Stults (2016), to fill gaps and acquire additional examples of I&M from municipal contexts.

The resulting list of 43 climate adaptation-specific I&M "documents"[6] excludes any solely focused on climate change vulnerability[7] and exposure, or solely on greenhouse gas mitigation.[8] Examples of I&M and evaluation approaches outside the adaptation context were selectively reviewed for this study based on our appraisal of their relevance and importance to our focus. Our database also excludes the much larger universe of meta-level discussions about indicators in general, or monitoring and evaluation practice and adaptation evaluation, though several are referenced throughout this paper as background.

The subsequent systematic review was guided by the following question:

(1) Who are the I&M developed for?

- For which geographic scale and type of entity were I&Ms developed?

(2) Who are the I&M developed by?

- Were the I&M developed by academics, sponsors/funders, independent outside entities, or adaptation implementers?

(3) *What is the intended use of the I&M?*

- What motivated the development of adaptation I&M?
- What was the evaluation purpose, if any, for the I&M example (see hierarchy, Figure 1)?
- What other purposes, intended use(s), planning or policy context(s), and intended audience(s) were specified?

(4) What was the process of developing the I&M?

- What methods were used in developing and tracking I&M?
- What level of documented interaction occurred between program managers, evaluators, and other stakeholders in the development and selection of I&M?[9]

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[6] We use the term "document" to describe each distinct set of I&M reviewed in this study. In actuality, the I&M set may consist of a dedicated document (e.g., published report), a section of a larger document, a website, or a set of related documents.

[7] Logically, one may view vulnerability indicators either as "outcome" measures of past societal adaptations (or, rather, of the failure to adequately adapt) or as "baseline" measurements against which the effectiveness of current and future adaptations may be compared.

[8] Some climate mitigation activities also benefit adaptation (e.g., increasing urban tree cover captures carbon emissions and provides cooling shade). If the indicators served both purposes, and the adaptation benefit was explicitly recognized, the document and examples were retained.

[9] Because the study is based on document analysis alone, only documented interaction could be assessed. It is possible that these descriptions are overstated (i.e., are idealized, suggesting that more occurred than did in reality) or understated (i.e., many informal interactions occurred that were not formally captured in the documentation).

2.4 Organizing Domains

After cursory review of approximately 200 resources resulting from the three search approaches, and eliminating duplicates and documents considered out of scope, 43 documents were retained for further examination, dating from 2007-2015. Clearly, this list is not exhaustive, given the limitations of each of the searches. However, we achieved a satisfactory level of saturation in terms of novel approaches and sample indicators discovered. While we expect to have missed some relevant documents, we are confident that the organizational framework and the overarching insights gained from our analysis are robust.

We identified four distinct literature domains, which we organized according to the resource's primary originator:

I. *Academic*: Includes I&M examples from within academia and other traditional research contexts.

II. *Boundary organization*: Includes "top-down" I&M examples from independent, third-party organization-driven evaluation efforts.[10]

III. *Sponsor*: Includes I&M development and guidance emanating from sponsors, such as international aid groups and development banks.

IV. *Implementer*: Includes "bottom-up" examples developed by those engaged in or enacting adaptation strategies (here termed implementers).

Supplemental Materials, section 2 provides more detail about the analytical approach utilized for the classification of I&M document by domain, placement within the evaluation hierarchy and the type of interaction.

[10] While these efforts may have been sponsored by and are potentially relevant to funders of adaptation, we treat these as separate from the *sponsor domain* because they often included a broader focus or mandate. Sponsors are not dictating the design of the evaluation or certain I&M.

Table 1: Domains of indicator and metric (I&M) development along a continuum of developer-implementer interactions

Predominantly I&M developer-driven knowledge generation → Predominantly user-driven action support

Domain	Academic-driven	Boundary Organization-driven	Sponsor-driven	Implementer-driven
Motivations	• Learning and advance of scientific knowledge about adaptation • Theory development	• Learning about the state of adaptation, state of adaptedness • Developing adaptation guidance • Assessing adaptation effectiveness • Communication	• Assessing program need • Learning about program design • Tracking program outcomes • Assessing program effectiveness • Ensuring accountability, efficiency	• Communication • Supporting adaptation planning • Fundraising, budget justification • Accountability, good governance • Learning/adaptive management
Audiences	• Academic • Boundary organizations, sponsors, implementers (implied or assumed, but not primary)	• National, local governments • NGOs • Private sector, investors	• Self/sponsoring entity staff • National governments • Int'l. development community	• Self/implementing entity staff • Elected officials • Funders (governmental, philanthropic) • Public
I&M Developer-Adaptation Implementer Interaction	• I&M developer may or may not also evaluate adaptation activities; • Adaptation actions and implementers are research subjects	• I&M developer is independent of sponsor, implementer • Client of evaluation may or may not include adaptation action implementer	• I&M developer is sponsor of the adaptation action implementer being evaluated	• Evaluator = developer of I&M = adaptation action implementer • May consult academic or other sources and expertise

3. Results

Here, we first present our survey of I&M documents arrayed across the four domains of literature and characterize each. Table 1 places them along a spectrum from predominantly I&M developer-driven efforts aimed at the generation of generalizable knowledge on one end to predominantly user-driven I&M development efforts aimed at supporting adaptation action on the other. Clearly, there is overlap and those developing I&M in any one domain learn from other domains. However, motivations and purpose or intended use – and thus, intended audiences – vary markedly, making the distinction reasonable.

Table 2 summarizes the results of the 43 I&M documents by domain, evaluation function, and interaction level.

Table 2: Overview of I&M development efforts across four domains

	Domain			
	Academic	**Boundary Org**	**Sponsor**	**Implementer**
Total Number (n=43)	6	19	6	12
Date range	2009-2015	2010-2015	2007-2015	2007-2015
Evaluation function*				
Assessing Program/Project Need	4	12	2	1
Supporting Program Design & Action Logic	1	11	6	3
Guiding Implementation	2	15	5	9
Assessing Outcomes & Impact	4	12	5	9
Evaluating Cost and Efficiency	1	5	0	1
Interaction Level**				
None (stated)	5	6	4	3
Linking/Match-making	0	8	2	6
Collaborating	1	3	0	2
Coproducing	0	2	0	1

* Numbers do not add up to *n* as documents may have more than one evaluation function.
** The Klenk et al. (2015) distinction between linking and match-making was not clearly evident from the documents reviewed; thus they are combined here.

In the discussion of each domain below, we highlight selected examples; the Supplementary Materials online offer the complete list of all documents included in this review with links to their sources.

3.1 Academic I&M development efforts

Six I&M documents were classified as academic. While they identified specific indicators, the apparent purpose of this domain was generally to explore theoretical foundations and general guidance for I&M development. The main motivation was advancement of scientific knowledge about the state of the adapting system or sector about the adaptation process itself, aimed predominantly at academic audiences. Most of the academic approaches sought to either identify the underlying

need for adaptation efforts or focused on outcomes that would indicate a resilient or well-adapted system. While practice-oriented audiences are also often listed as interested in the results, the documents suggested researchers seldom interacted with communities of practice in the development of these indicator.

As an example of a more theoretical exploration of indicators, Stadelmann et al. (2014) aimed to find two indicators of "adaptedness" that would integrate many aspects of value to those adapting to climate change: avoided financial loss and lives saved. An example of more applied I&M development within academia, Solecki and colleagues developed a methodology and set of potential climate change adaptation indicators for New York City as part of the work of the New York Panel on Climate Change (Solecki et al. 2015).

Table 3: Examples of academic I&M approaches

Name	Author(s)	Context	Motivation	Evaluation Function(s)*	Level of Collaboration
New York City Panel on Climate Change 2015 Report Chapter 6: Indicators & Monitoring (2015)	Solecki et al.	Urban (NYC)	Learning support/adaptive management; accountability/gover-nance: "to provide relevant information on the effectiveness of current and future response strategies."	1, 4	Collaborating
Vulnerability and Resilience in the Face of Climate Change (2009)	Malone	National	Understanding what resilience is through indicator-based research	1, 2	None stated
Universal Metrics to Compare the Effectiveness of Climate Change Adaptation Projects (2014)	Stadelmann et al.	Adaptation /Develop-ment Project	To identify a universal metric for adaptation success that can support adaptation finance decision-making and evaluation	4, 5	None stated

*Key: 1) Assessing Program/Project Need; 2) Supporting Design & Action Logic; 3) Guiding Implementation; 4) Assessing Outcomes & Impact; 5) Evaluating Cost and Efficiency

On balance, academic indicator discussions gravitate more toward the idealized rather than the pragmatic. In other words, academic approaches generally strive towards identifying what would constitute "good" indicators because they describe

a system or relationship well, rather than what may be achievable or relevant in an applied context. While this can produce important insights, Malone (2009) argues that a weakness of this kind of research is that it lacks the "view from below," the ground-level perspectives of individuals, households, and managers that are experiencing the hazard or change.

Due to their independence from sponsors or adaptation implementers, they can also be more frank and critical, even if what they propose to monitor is too resource intensive for practical deployment at scale. Table 3 lists several examples of adaptation-outcome focused academic I&M development efforts. Not explicitly considered in our dataset are examples of I&M development that are relevant to but not strictly focused on the evaluation of adaptation such as social (or integrated) vulnerability and disaster resilience indicators (e.g., Cutter, Ash, and Emrich 2014).

3.2 Boundary organization-driven I&M development efforts

The largest domain of I&M development efforts discovered in our study are those occurring outside of academia by NGOs, higher-level government agencies, foundations, consultancies, or international institutions. While not necessarily "boundary organizations" in a strict sense (Guston 2001), we utilize this term here to describe institutions playing supporting role to adaptation implementation that is formally neither a part of either the arena of academia or policy-making yet still engaging with both. In the context of the particular I&M resource assessed, we found these institutions perform boundary-spanning functions (e.g., Cash et al. 2003), whether between research and practice or between various constituencies within practice. Not surprisingly, most of the resources in this domain exhibited some level of interaction between indicator developer, potential indicator users, academics, and other stakeholders. However, six of the nineteen resources explored did not exhibit any kind of interaction despite being intended for external use.

Motivations of developing I&M in this domain include offering guidance for policy development at different scales; communication to various stakeholders (e.g., investors, implementers, or citizens) about adaptedness or adaptation progress; and exploring definitions of resilience and adaptednesss through indicators. As for the evaluation functions in this domain, the various efforts cover all five purposes and intended audiences are diverse, ranging from national and local governments to international agencies, NGOs and the private sector. Importantly, the I&M developer is typically independent of the sponsor and the adaptation implementer in the sense that neither requires or dictates that certain I&M are reported.

I&M work in this domain can involve academics, NGOs and international agencies and aims at motivating entities (e.g., organizations, nations) to collect the relevant information to show progress. One prominent example is the University of Notre Dame's Global Adaptation Index (ND-GAIN 2015) (Table 4), which is developed by a university-based research institute, advised by a diverse board of academics, practitioners, and members of the private sector, and intended for use by private

and public investment groups such as corporations and development banks. ND-GAIN is currently developing an urban adaptation index which involves input from external experts, but also the very communities assessed by the index (ND-GAIN Urban, this issue).

Efforts in this domain are "top-down" in the sense that they are not created by (and often do not involve) the actors for whose use the I&M are intended (except occasional advisory roles). Their intended broad applicability allows comparisons (e.g., country to country or city to city) and thus enables relatively easy synthesis or summative appraisal. How well it serves the implementing entity(ies) is difficult to assess from the I&M frameworks themselves. To our knowledge these efforts have not yet been evaluated for their usefulness to different audiences. Thus it is unclear which type of audiences they serve best and in what ways better than specific, place-based adaptation planning and implementation efforts.

Table 4. Examples of boundary organization-driven I&M approaches

Name	Author	Context	Motivation	Evaluation Function(s)*	Level of Collaboration
Coastal Resilience Index (2010)	Mississippi-Alabama Sea Grant	Community (U.S. Coastal)	Provide community leaders with "simple and inexpensive method of predicting if their community will reach and maintain an acceptable level of resilience." helps to identify problems and help prioritize resource allocation	1	Linking
Notre Dame Global Adaptation Index (ND-GAIN) (2014)	University of Notre Dame	National	To "help businesses and the public sector better prioritize investments for a more efficient response to the immediate global challenges ahead."	1, 4	Linking
A Climate Adaptation Plan for the Red Lake Band of Chippewa Indians (2015)	Chippewa Indians & Model Forestry Policy Program	Tribal (Chippewa Tribal Comm.)	Not explicit; but success indicators in plan accompany individual action items	2, 4	Coproducing
Indicators of Urban Climate Resilience (2014)	Tyler et al. (I-SET)	Urban	Reaching consensus on preferred direction of change and qualitatively assessing improvement	1, 2, 3, 4, 5	Collaborating

*Key: 1) Assessing Program/Project Need; 2) Supporting Design & Action Logic; 3) Guiding Implementation; 4) Assessing Outcomes & Impact; 5) Evaluating Cost and Efficiency

3.3 Sponsor-driven I&M development efforts

At their very essence, I&M are meant to support evaluation and, not surprisingly, adaptation funders requiring formal program evaluation have been at the forefront of I&M development. Work in this area is voluminous and broad, extending much beyond what is reported here. Schipper and Langston (2015) as well as Bours, McGinn, and Pringle (2015) offer reviews of various frameworks for resilience/adaptation I&M. The six sponsor-driven I&M development efforts we included here seemed motivated by the desire to inform adaptation program design, and assess progress and outcomes. While these evaluations probably also ultimately assess whether financial investments are cost-effective, it was surprising to see that cost and cost-efficiency were not explicit indicators here.

Table 5: Examples of sponsor-driven I&M development

Name	Institution	Context	Motivation	Evaluation Function	Level of Collaboration
Tracking Tool for Climate Adaptation Projects (2014)	Global Environment Facility (GEF)	Development Portfolio	To report on results achieved by GEF funded adaptation interventions	2, 3, 4, 5	None stated
Resilient Cities Framework (2015)	Rockefeller Foundation & Arup	Urban	Evidence-based articulation of what city resilience is	2, 4	Linking
Adaptation Made to Measure (2015)	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Development Project	To provide clear evidence of how adaptation actions reduce vulnerability; enabling results-based monitoring of development projects that are now incorporating climate change adaptation	2, 3, 4	None stated

*Key: 1) Assessing Program/Project Need; 2) Supporting Design & Action Logic; 3) Guiding Implementation; 4) Assessing Outcomes & Impact; 5) Evaluating Cost and Efficiency

Efforts in this domain were conducted by sponsors (or their consultants) for the sponsoring agencies themselves, including international and national governments and philanthropic funders. They generally exhibited low levels of interaction in the development of indicators, suggestive of a primarily internal motivation for their development and use. For example, the Global Environment Facility (GEF) and German International Development Agency (GIZ) focused on indicators for the efficacy of project-level and portfolio investments, but there was no documented evidence that project implementers had participated in the identification of indicators for that purpose (GEF 2014; Olivier, Leiter, and Linke 2012). A prominent exception is the Resilient Cities Framework developed by the Rockefeller

Foundation (2014), which involved outside consultants interacting with the Foundation-funded 100 Resilient Cities participants (Table 5).

Given hierarchical tendencies between sponsors and funding recipients, there is a risk of the evaluation being somewhat self-serving so as to perpetuate the funding stream. I&M may sometimes become too narrowly focused on quantifiable metrics for ease of reporting or because they narrowly focus on gaining policy and funding support, rather than try to learn deeper lessons about adaptation practice.

3.4 Implementer-driven I&M development efforts

Implementers of adaptation activities in municipalities and elsewhere are developing their own evaluation frameworks and adaptation indicators. These efforts are rapidly growing as many entities discover the value of I&M for communication, adaptation planning, fundraising, showing accountability, and to support their own learning and adaptive management (Moser et al., in prep). Thus, the primary audience for these efforts is the adapting entity itself (staff and elected representatives), in addition to funders and the wider public. Most often, the developers of the I&M system are the same as the adaptation implementers, although they may consult external experts or resources.

Table 6 lists selected examples of the twelve resources classified in this domain. The STAR Community Rating System, a sustainability assessment and accreditation tool designed for and with U.S. cities includes a subset of adaptation-related indicators (STAR Communities 2015). Additionally, a wide variety of indicators are found within the relatively small number adaptation plans already developed and adopted by U.S. cities (Woodruff and Stults 2016). Our web search surfaced additional cities, such as Berkeley, CA, that developed I&M outside formal planning documents but that still strive to track progress on adaptation efforts. Some of these indicators take the form of (near-)comprehensive performance metrics attached to individual actions (e.g., Baltimore, MD; Keene, NH); others characterize more holistically a vision for success within the community (e.g., Swinomish Tribe, WA); while yet others offer a selection of easy-to-track measurements that serve as placeholders for additional indicator development in the future (e.g., La Plata, NM; Santa Cruz, CA).

Although sometimes informed by broader currents of discussion and principles for indicator selection, these "bottom-up" implementer-driven indicators tend to be grounded in pragmatism: indicators that are not necessarily comprehensive or ideal but identified as measurable and useful by the entity developing them. A potential weakness thus of this domain is that some indicators, while trackable, may lack validity in characterizing the actual adaptedness/resilience of the system under consideration. They may also suffer from the self-service problem of sponsor-driven assessments. Thus, these indicators may run the risk of providing an incomplete or inaccurate portrayal of adaptation progress or lack thereof, potentially leading to maladaptation or a false sense of progress. Some cities are developing their own

I&M while participating in externally-driven I&M efforts. Future work needs to explore the differences in approaches and the relative benefits of doing both. .

Table 6: Examples of implementer-driven I&M approaches

Name	Author	Context	Motivation	Evaluation Function(s)	Level of Collaboration
City of Berkeley Climate Adaptation Indicators (2015)	City of Berkeley, CA	Local (Berkeley, CA)	Tracking implementation of Climate Action Plan and communicating outcomes to community	4	None stated
Sustainability Tool for Assessing and Rating (STAR) Communities (2015)	STAR Communities	City/County (US)	To help define sustainability, present a vision how communities can progress, offer a certification system to recognize communities that achieve levels of sustainability.	2, 3	Coproducing
A Stronger, More Resilient New York (2013)	NYC	Local (NYC)	Following the adage, "what gets measured, gets managed"	1, 3, 4	Linking
Adapting to Climate Change: Planning a Climate Resilient Community (2007)	Keene, NH	Local (Keene, NH)	To evaluate progress toward achieving the stated goal; providing performance measures; estimating time for completion; specifying scope	3, 4	Linking

*Key: 1) Assessing Program/Project Need; 2) Supporting Design & Action Logic; 3) Guiding Implementation; 4) Assessing Outcomes & Impact; 5) Evaluating Cost and Efficiency

4. **Discussion**

Our review of adaptation I&M reveals an astonishingly broad landscape of approaches, contexts, and ultimate purposes. While it is certainly expected that evaluation approaches for adaptation should be diverse in all these ways, our stocktaking revealed a heterogeneity that cut across geographic scale, sector, and domain and seemed to suggest little coherence at this time.

However, the organizational approach we arrived at—utilizing the "hierarchy of evaluation" and a simplified typology of modes of interaction—expands the discussion about adaptation I&M beyond the question of what makes for a "good indicator" to focus more on what makes for an effective evaluation practice

(Leagnavar, Bours, and McGinn 2015). Although opening up the discussion in this way does not lead to easy conclusions about climate change adaptation I&M, we believe it helps to more appropriately reckon with the difficult task of making I&M relevant, credible and legitimate (Cash et al. 2003). Below we address insights about the challenges and opportunities associated with I&M that we derived through our analytical approach.

4.1 I&M development purposes and pathways

Our results emphasize and explain how not all I&M development purposes and pathways are or should be identical and why some approaches may be more relevant or useful in certain contexts than others. We found significant differences in the intensity of interaction between I&M developer/evaluator, adaptation implementers (i.e., those evaluated), and I&M users. If evaluation is understood as a site of science-practice interaction, existing understanding suggests that greater co-production would result in more usable I&M. Thinking more carefully and critically about the process of I&M development and the use of indicators in practice would help ensure that the scarce resources devoted to developing and tracking I&M are invested wisely and ultimately help accelerate much needed progress on adaptation.

Our review also showed that evaluation and the choice of I&M involves value choices and as such is a political act. I&M for evaluating adaptation progress and effectiveness can serve a diverse set of potentially productive uses, but this is not assured without careful attention to the fact that adaptation involves diverse interests, complexities, uncertainties, and difficult trade-offs among societal values. Thus, not all I&M serve the use they intend, and in fact some interests may not be well served by the selected I&M. To face this challenge explicitly, development/use of I&M should begin by understanding the evaluation purpose the indicators are designed to serve and whose interests they consider or not. This could inform the level of interaction most appropriate for the I&M development at hand. Reaching out to communities of stakeholders, experts, and peer groups (e.g., city to city collaboration) is likely to be a winning strategy for improving evaluation and indicator quality specifically and for increasing community engagement in adaptation more generally.

4.2 Productive uses of I&M

Our analysis was not focused on assessing whether I&M examples were actually being utilized or whether utilization was, in fact, helpful to end users. However, it is noteworthy that our review surfaced very little evidence of indicator use in practice or evaluation of the benefits of use. In several instances, such as in an I&M development project focused on Asian cities (Tyler et al. 2014), it was suggested that I&M development actually served as a catalyst for community discussions about a broader vision for adaptation action. Thus, future work will be needed to evaluate evaluation efforts to more systematically examine their value and explore tradeoffs between burdens associated with I&M development and ongoing tracking and the utility that derives to users and other stakeholders.

Our analytical framework suggests, however, that the joint development of I&M can be productive and useful in that it is an opportunity for (repeated) science-practice-stakeholder interactions. Over time, this interaction will reveal ways in which I&M can serve multiple evaluation functions. For example, the indicators of community health elicited through a survey of the Swinomish Indian Tribal Community (2010) in the Pacific Northwest went far beyond an inventory of actions or mundane outcome statements to explore the depths of what a thriving community—in the eyes of tribal members—would look like. While this indicator set provided the basis for at least preliminary assessment of adaptation implementation performance, it also revealed important attributes of the community's vision for itself and its values. In this way, indicators with or without their related metrics may substantially further the deeper thinking and visioning ultimately required of communities to successfully adapt to climate change.

4.3 Capacity requirements for I&M

By far, the most evident constraint – sometimes explicit, oftentimes implicit – to the development of I&M is the capacity required to design, track and adequately utilize them over time. Many of the indicators reviewed here require systematic, long-term, detailed monitoring of social and/or environmental phenomena. These capacity requirements are not really reckoned with in the I&M examples reviewed here.

While the excitement for adaptation I&M is growing, adaptation evaluation, like all evaluation, should not be undertaken unless there is an audience interested in and capable of receiving and using the findings. In this sense, good evaluation practice recognizes the very real capacity constraints associated with monitoring and interpreting indicators. The exercise of evaluation is demanding, accompanied by stresses and strains, and implies an increased workload even if the benefits of evaluation make other work more effective. Thus, it is better to deliver simple evaluation designs than to embark, but not deliver, on more sophisticated efforts (Robson 2000).

The analytical framework we offer brings attention to the critical interaction between evaluator, adaptation implementer and other stakeholders, as well as to the purpose of evaluation. It underlines the importance of this interaction that goes beyond mere selection of metrics. In and of itself I&M development thus can help build adaptive capacity (including technical know-how, institutional capacity and social capital) or help identify where capacities are required. As such evaluation as a practice may become instrumental in justifying capacity building investments.

5. Conclusion

In the midst of the growing interest in evaluation, it is clear that adaptation I&M, like adaptation itself, is still in the early days of developing practice, let alone “best practice.” More work is needed to help reveal to a wider set of interested parties how indicators can be developed, what use they may have, and what capacities are required to receive the most benefit from them. In this sense, intense

experimentation across sectors, domains, and levels of governance is not only to be expected but necessary. At the same time, as more and more municipalities search for ways to evaluate their adaptation progress, identifying evaluation practices that are feasible yet robust becomes imperative.

Our analysis showed that, overall, evaluation and related I&M development serve a diversity of purposes for a variety of users. The level of interaction between I&M developers and ultimate users, however, was overall far less than one might hope for a type of information intended for practical use. Given the many calls for evaluation and accompanying need for I&M, significant financial, staffing, and technical resources will be required to respond adequately. The by now well-established lessons from effective science-practice interactions suggest that greater interaction between expert and user communities is needed to ensure that this investment will be both scientifically defensible and practically relevant.

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****SUPPLEMENTAL MATERIALS****

SECTION 1 (NEXT PAGE): TABLE OF INDICATOR AND METRIC DOCUMENTS

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Domain: Academic												
New York City Panel on Climate Change 2015 Report Chapter 6: Indicators & Monitoring	William Solecki et al.	2015	DOI	Local (NYC)	X	Learning support/adaptive management; accountability/governance: "to provide relevant information on the effectiveness of current and future response strategies."	x			x		Collaborating
Vulnerability and Resilience in the Face of Climate Change	EL Malone	2009	PDF	National		Understanding what resilience is through indicator-based research	x	x				None stated
Urban Climate Change Preparedness Score	Heidrich & Dawson & Reckien & Walsh	2013	DOI	Urban areas (UK)	X	Evaluate the status of climate change planning in major UK cities	x		x			None stated
New Method for Climate Change Resilience Rating of Highway Bridges	Anthony Ikpong and Ashutosh Bagchi	2014	DOI	Bridge		Incorporating climate change into metrics for bridge rating	x					None stated
Universal Metrics to Compare the Effectiveness of Climate Change Adaptation Projects	Stadelmann et al.	2014	DOI	Adaptation Project		To identify a universal metric for adaptation success that can support adaptation finance decision-making and evaluation				x	x	None stated
Resilience metrics to inform ecosystem management under global change with application to coral reefs	Peter J. Mumby and Kenneth R.N. Anthony	2015	DOI	Ecosystem		To support the operationalization of managing ecosystems for resilience				x		None stated

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Domain: Boundary Org Driven												
A Climate Adaptation Plan for the Red Lake Band of Chippewa Indians	Chippewa Indians	2014	PDF	Tribal (Chippewa Tribal Community)		Not explicit; but "success indicator/s" in plan accompany individual action items		x		x		Coproducing
Forest and Water Climate Adaptation: A Plan for La Plata County, NM	La Plata County, NM	2010	Website	Local (La Plata County, NM)		Not explicit, but it implied that purpose is to assist in the management and accountability of action step completion		x	x			Coproducing
Indicators of urban climate resilience	Steven Tyler et al. (I-SET)	2014	Website	Urban	X	Reaching consensus on preferred direction of change and qualitatively assessing improvement	x	x	x	x	x	Collaborating
Indicators to assess the resilience of health and emergency planning in England	HR Wallingford	2014	PDF	National (England)		To identify indicators for inclusion in statutory report to the UK government about preparedness of health and emergency planning	x		x	x		Collaborating
Tracking adaptation and measuring development (TAMD)	International Institute for Environment and Development	2014?	Website	Sub-national to International		Evaluate how well climate risks are managed at different scales; Assess connection between development outcomes and resilience		x	x	x		Collaborating

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Notre Dame Global Adaptation Index (ND-GAIN)	Notre Dame	2014	Website	National		To "help businesses and the public sector better prioritize investments for a more efficient response to the immediate global challenges ahead."	x			x		
Framework of milestones and indicators for Community-based Adaptation	Care	ND	PDF	National, Local Government, Household		Focused on the enabling factors of Community-Based Adaptation, help project teams in planning activities and tracking progress towards achieving the enabling factors		x	x	x		Linking
Business Action for Climate Resilient Supply Chains	BSR	2015	Website	Business (specifically, supply chain)		Helping a company to understand outcomes and impacts of climate actions, and helping the company adjust targets over time			x		x	Linking
Adaptation Indicators for National Adaptation Programme	Adaptation Sub-Committee of Committee on Climate Change	2014	Website	National (UK)		To be included in report prepared by independent, statutory advisory body to UK's National Adaptation Programme	x		x	x	x	Linking

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Coastal Resilience Index	NOAA	2010	PDF	Community (U.S. Coastal)		provide community leaders with "simple and inexpensive method of predicting if their community will reach and maintain an acceptable level of resilience." helps to identify problems and help prioritize resource allocation	x					Linking
National Climate Change Adaptation: Emerging Practices in Monitoring and Evaluation	Organization for Economic Cooperation and Development (OECD)	2015	Website	National (Adaptation Plan)		Learning and accountability; to evaluate progress on national adaptation plans	x	x	x	x	x	Linking
Sizing of climate resilience in the Bay Area	Bay Area Joint Policy Committee & SPUR	2014	PDF	Local, Regional (Bay Area, CA)	X	To evaluate state of climate change resilience progress in Bay Area region	x	x		x		Linking
Climate change adaptation indicators for the natural environment	Natural England	2010	PDF	National		To help advise other UK departments and organizations about what indicators could be useful			x	x		Linking

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Guidance Notes for National Indicator 188	UK DEFRA	2010	Website	Local (UK)		"To ensure local authorities [in UK] are sufficiently prepared to manage risks to service delivery, the public, local communities, local infrastructure and the natural environment, and to make the most of new opportunities."	x	x	x			None stated
Climate Resilience	Second Nature	2015	Website	City	X	To provide an initial list of indicators to help a community get going on resilience planning			x	x		None stated
Equity in Climate Adaptation Planning: Resilience Indicators	NAACP	2015	Website	Community		To be able to declare that community resilience has been achieved in ways that provide protection for those most marginalized	x	x	x	x		None stated
State and Territorial Epidemiologists Adaptation Indicators	State and Territorial Epidemiologists Adaptation Indicators	2015	Website	Statewide		Unclear; appears to be in service to org. members, i.e. state and territorial epidemiologists		x	x			None stated
States at Risk	Climate Central and ICF	2015	Website	Statewide		Unclear; appears to be to create a comparative index of the state of preparedness of US 50 states	x	x	x			None stated

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Climate change adaptation indicators for Scotland (Framework)	Suzanne Martin and Anna Moss (ClimateXchange)	Ongoing	Website	Scotland		To "understand whether actions are leading to successful adaptation or unintended consequences"	x		x			None stated
Domain: Implementer Driven												
Sustainability Tool for Assessing and Rating (STAR) Communities	STAR Communities	2015	Website	City/County (US)	X	To help define sustainability, present a vision how communities can progress, offer a certification system to recognize communities that achieve levels of sustainability.		x	x			Coproducing
Adapting to Climate Change: Planning a Climate Resilient Community	Keene, NH	2007	PDF	Local (Keene, NH)	X	to evaluate progress toward achieving the stated goal; providing performance measures; estimating time for completion; specifying scope			x	x		Collaborating
Swinomish Climate Change Initiative Climate Adaptation Action Plan	Swinomish Indian Tribal Community	2010	PDF	Tribal (Swinomish Tribal Community)		"Ensure continuity of effort in responding to ongoing and emerging issues over the long term"; Incorporation of local knowledge and values into adaptation planning				x		Collaborating

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Disaster Planning and Preparedness Project (DP3)	City of Baltimore	2013	Website	Local (Baltimore)	X	Deliberate planning/governance: "To evaluate the success and limits of DP3" ; Learning/adaptive management: to be alerted when barriers are confronted and "consider strategies for overcoming those barriers."			x	x		Linking
City of Santa Cruz Climate Adaptation Plan	City of Santa Cruz, CA	2011	PDF	Local (Santa Cruz)	X	Not stated			x			Linking
A Stronger, More Resilient New York	NYC	2013	Website	Local (NYC)	X	Following the adage, "what gets measured, gets managed"	x		x	x		Linking
City of Waveland, Mississippi	Local Hazard Mitigation Plan	2013	PDF	Local (City of Waveland)	X	To comply with regulatory reporting requirements; monitoring for publication in subsequent annual reports	x		x	x		Linking
Global Indicator of Climate Change Adaptation in Catalonia	Catalan Office for Climate Change	2014	PDF	National		"To evaluate how well climate change adaptation is progressing...to determine the effectiveness of the measures to adapt to the impacts of climate change."				x		Linking

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Strategic Program for Climate Resilience	The Government of Mozambique	2011	PDF	Investment Project		Not stated; implied purpose to evaluate impact of investment projects on national adaptation		x	x	x		Linking
Laguna Woods Climate Adaptation Plan	City of Laguna Woods, CA	2014	PDF	Local (Laguna Woods, CA)	X	To provide a definition of success for each implementation action.		x	x	x		None Stated
City of Berkeley Climate Adaptation Indicators	City of Berkeley	2015	WEB	Local (Berkeley, CA)	X	Tracking implementation of Climate Action Plan and communicating outcomes to community				x		None Stated
The City of Lewes Hazard Mitigation and Climate Adaptation Plan	Lewes, DE	2011	PDF	Local (Lewes, DE)	X	Not explicit; but indicators identify how to determine whether adaptation strategy was either partially or completely successful			x			None Stated
Domain: Sponsor-driven												
NY Climate Smart Communities	NY State Department of Environmental Conservation	2014	Web	Local (NY)	X	To provide guidance to local communities on how to reduce GHGs, save taxpayer dollars, and advance community goals	x	x	x			Linking
Resilient Cities Framework	Rockefeller Foundation & Arup	2015	Website	City	X	Evidence-based articulation of what city resilience is		x		x		Linking

Name	Place/Inst./Author	Year	Link	Scale of Indicator	Urban?	Motivation	Evaluation Function(s)					Interaction
							1	2	3	4	5	
Monitoring and Evaluation Framework for Adaptation to Climate Change (draft)	United Nations Development Program Global Environment Facility	2007	PDF	Project/Portfolio		To strengthen the performance of individual projects as well as inform the management of entire SCCF and LDCF adaptation portfolios		x	x	x		None stated
Adaptation Made to Measure: Climate Change Adaptation Indicators List	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	2013	PDF	Development Project		To provide clear evidence of how adaptation actions reduce vulnerability; enabling results-based monitoring of development projects that are now incorporating climate change adaptation		x	x	x		None stated
NYSERDA Sustainability Indicators Guidance: 7. Climate Change Adaptation	NY State Energy Research and Development Authority	2013	PDF	Community (NY State)	X	To help with verification of anticipated benefits of projects supported by NYSERDA's Cleaner Greener Communities initiative		x	x	x		None stated
Tracking Tool for Climate Adaptation Projects	Global Environment Facility	2014	Website	Portfolio		To report on results achieved by GEF adaptation fund		x	x	x	x	None stated

SUPPLEMENTAL MATERIALS, SECTION 2

Description of criteria used in the I&M analysis

	Description
Domain	
1. Academic	I&M developed by researchers for research purposes or for suggested use in practical settings
2. Boundary-organization driven	I&M developed by intermediary organizations, working to support research and/or practice
3. Sponsor-driven	I&M developed by development banks, foundations, and other sponsors of adaptation practice for the purpose of evaluating program efficacy
4. Implementer- driven	I&M developed by entities such as local governments seeking to utilize indicators for purposes such as to evaluate and/or communicate progress on adaptation
Evaluation function*	
1. Assessing Program/Project Need	I&M that help characterize underlying vulnerability or exposure to climate impacts
2. Supporting Design & Action Logic	I&M that evaluate adequacy of plan/program to address considered risks; I&M that consider participation and level of plan adoption.
3. Guiding Implementation	I&M that track performance or process of achieving stated objectives
4. Assessing Outcomes & Impact	I&M that evaluate the ultimate outcomes achieved as a result of program
5. Evaluating Cost and Efficiency	I&M that evaluate the costs of program activities
Level of interaction**	
1. None (stated)	Interaction level low or unspecified
2. Linking/Match-making	I&M developer consults with outside experts, potential users, and/or stakeholders
3. Collaboration	I&M developed through collaboration across boundary of research and practice, or by broad and diverse coalition of stakeholders
4. Co-production	I&M developed through intimate and sustained collaboration while building capacity for long term effort on I&M and adaptation

* Based on Rossi et al. (1994)
** Based on Klenk et al. (2015)