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Extreme heat adaptation planning: a review of evaluation, monitoring, and reporting

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Extreme heat events are increasing in intensity and duration. Although heat adaptation planning is increasing across the US, the effectiveness of adaptation strategies across contexts remains unknown. Evaluation helps heat adaptation planners understand the impact of investments and increase accountability. To understand how evaluation is or is not happening in extreme heat planning, we purposively sampled and analyzed 65 plans that would likely include extreme heat adaptation strategies. We found that although 55% ($n = 36$) of plans included heat evaluation or monitoring plans in some form, fewer than 30% ($n = 19$) were associated with subsequent reports. Of these, only 6 were implemented as planned, and none were implemented at the regional or neighborhood level. We also found that monitoring indicators did not match the heat impacts, vulnerabilities, and needs identified in the plan. We provide evaluation recommendations to guide and support evaluation and monitoring efforts in the heat planning process.

Keywords: evaluation; climate change; adaptative management; extreme heat; planning

1. Introduction and background

Extreme heat events are increasing in duration, intensity, and scale (Habeeb *et al.* 2015; USGCRP 2018), affecting people, animals, ecosystems, and infrastructure across rural, suburban, and urban landscapes (Lima *et al.* 2021; Sun *et al.* 2022; Wilson and Black 2022). Co-occurring events such as extreme heat, electrical grid failures, and drought

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can compound these impacts (Kenward and Raja 2014; Stone *et al.* 2021). While collective efforts such as tree planting, operating cooling centers, implementing new technologies, and educating the public can mitigate some of these impacts, coordination is challenging because the problem of heat is not under the purview of just one governmental department or unit (Keith *et al.* 2019). Extreme heat plans are one response to this challenge (Keith *et al.* 2019; Meerow and Keith 2022; Randazza *et al.* 2023).

1.1. Types of extreme heat planning

Broadly, two categories of plans address extreme heat: 1) plans that respond to heat events (heat emergency response plans) and 2) plans that mitigate heat impacts (heat adaptation plans). Typically led by public health and emergency management departments, governments use **heat emergency response plans** to coordinate responses to extreme heat events to reduce near-term heat-related illness and death (Dwyer *et al.* 2022; Kotharkar and Ghosh 2022). These plans often use locally relevant heat thresholds, the temperature at which a heat alert is activated, for a targeted response to begin (Adeyeye *et al.* 2019; Pascal *et al.* 2013).

In contrast, **heat adaptation plans** aim to mitigate the impact of extreme heat through longer-term prevention strategies (Dare 2019; Keith *et al.* 2019; Meerow and Keith 2022). Heat adaptation strategies appear in general sustainability plans (Turner *et al.* 2022) and standalone heat plans (City of New York 2017; State of California 2022). These plans include ecosystem-based strategies like urban tree planting programs, green infrastructure and water features, cool pavements and walls, ordinances and incentives, and strategic directions for increasing the capacity of individuals and communities to respond to extreme heat events (Black-Ingersoll *et al.* 2022; Coseo and Larsen 2015; Manni *et al.* 2022; Sinha *et al.* 2022; Zhang *et al.* 2021; Zölch *et al.* 2016).

1.2. Evaluation is needed for heat adaptation planning

Planning and evaluation are inextricably linked. An analysis of 18 organizations using the Centers for Disease Control and Prevention (CDC) Building Resilience Against Climate Effects (BRACE) framework found that their evaluation activities were more effective when health planners used an evaluation plan (Joseph *et al.* 2023). Yet evaluation or monitoring is included in only 24% of heat plans in Europe (Martinez *et al.* 2022) and 30% of those in the United States (US) (Turner *et al.* 2022). Evaluating and reporting on plan implementation helps to make a stronger case for planning to the public (Oliveira and Pinho 2010) and helps public managers adjust strategies because not all strategies work equally well in all contexts. Furthermore, creating evaluation plans at the beginning of the process forces planners to think ahead and better articulate goals for planning efforts. Governments tend to borrow from one another with regard to planning and policy creation. Establishing best practices for evaluation early in the planning process facilitates institutional learning across government agencies (Hintz *et al.* 2018).

1.3. Research question and paper structure

This paper supports more effective heat adaptation planning and evaluation by answering the following research questions:

1. How prevalent is evaluation in planning for extreme heat, and how is it happening?

2. What are the weaknesses and gaps in these evaluation processes?

We start with a literature review of best practices for using evaluation in the planning cycle. We then share our content analysis methods of 65 planning documents across federal, state, city, and neighborhood level plans. For plans that indicated an intent to evaluate, we conducted a web search to determine if evaluation and monitoring were occurring and how it was reported. We share our findings in four categories: 1) evaluation in the planning process, 2) plans for future evaluation, 3) monitoring and indicators, and 4) how evaluation is or is not happening. We conclude by discussing common barriers to evaluation, recommendations for planners and evaluators, and monitoring and indicator selection for extreme heat planning.

2. Literature review

2.1. *Evaluation in the planning process*

Evaluation occurs both during the planning process and after plan adoption (Guyadeen and Seasons 2018). See Figure 1. During the planning process, planners use **"ex-ante" evaluation** to select strategies or alternatives that best meet plan goals or the needs of the population served (Oliveira and Pinho 2010; Shahab *et al.* 2019). **Planning process evaluation** measures how the efforts to engage communities, transfer power, collaborate, and coordinate

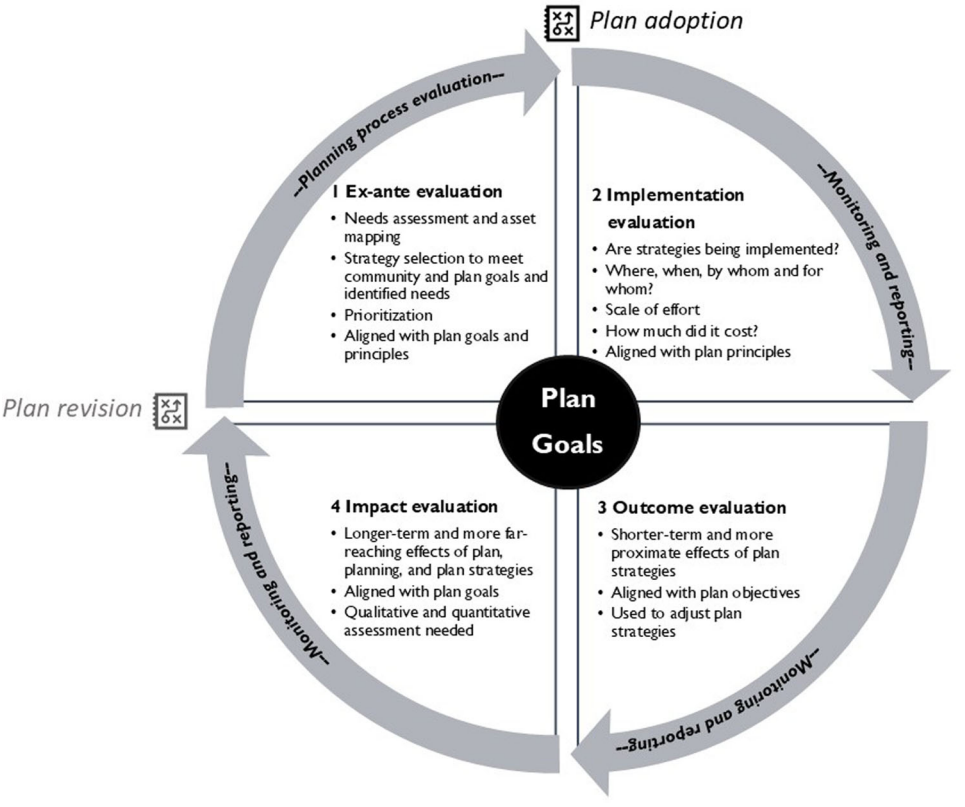

Figure 1. Evaluation in the planning cycle.

did or did not succeed (Guyadeen & Seasons 2018). Evaluation after plan adoption generally considers 1) the extent to which plans are implemented, 2) the shorter-term outcomes of implementation, and 3) the long-term impacts of plan strategies. Evaluation approaches can be qualitative, quantitative, and participatory (Cousins and Whitmore 1998; Issel 2021; Reach Effectiveness Adoption Implementation Maintenance, n.d.). **Implementation evaluation** (also known as process evaluation) measures whether the strategies in a plan occur and to what extent (Laurian *et al.* 2004). Ongoing monitoring supports adjustments to plan implementation. Simple measures of implementation evaluation include adherence to timeline and budget (Issel 2021). **Outcome evaluation** measures the more direct products of plan strategies, such as the extent to which tree planting programs result in increased tree canopy or if coordinated outreach efforts result in greater use of cooling centers.

Finally, **impact evaluation** occurs after a period of implementation. Evaluators try to understand to what extent the plan and plan strategies are producing the desired outcomes or addressing challenges, such as fewer heat deaths or reduced economic losses (Oliveira and Pinho 2010; Shahab *et al.* 2019; Waldner 2004). One approach for linking plan strategies to longer-term impacts includes 1) logic mapping to theoretically connect why plan strategies logically connect to desired plan goals, 2) monitoring of quantitative indicators that operationalize plan goals, and 3) qualitative interviews and discussions with stakeholders after plan implementation to identify the extent to which plan strategies likely lead to the desired outcomes (Laurian *et al.* 2010).

Evaluation is not always recognized as a positive exercise. It is time-consuming and resource-intensive. Depending on the evaluation design, the evaluation metrics chosen can foreclose a more holistic understanding of a given intervention.

2.2. Monitoring and indicator selection

Indicators point to whether a program or effort is moving toward the desired end goal (Resilience Metrics n.d.). Monitoring a wide range of indicators helps identify potential maladaptation or unintended consequences, allowing for the adjustment of strategies. For example, tree planting can contribute to residential displacement (Jelks *et al.* 2021), and residential air conditioners can increase pedestrian air temperatures or increase the financial burden on low-income households (de Munck *et al.* 2013; Ortiz *et al.* 2022). Monitoring indicators for climate adaptation should be timely, reliable, convincing, and relevant across institutions (Haasnoot *et al.* 2018).

2.3. Plan quality and evaluation implementation research

Plan quality evaluation focuses on the internal characteristics of the plan and sometimes the extent to which quality leads to implementation (Berke *et al.* 2006 2013; Hossu *et al.* 2020; Rudolf and Grădinaru 2019). Implementation and monitoring are one of the seven principles of sound climate change planning (Meerow and Woodruff 2020). However, the criteria by which climate change-related plan quality is evaluated in this research focuses on the monitoring plan and reporting responsibility and less so on integrating the monitoring results' analysis into policy and program improvement (Keith *et al.* 2023).

2.4. Evaluation of heat adaptation plans

Most scholarly research on extreme heat plan evaluation relates to heat event emergency response planning (Dwyer *et al.* 2022; Kotharkar and Ghosh 2022; Randazza

et al. 2023). Modeling and retrospective studies are conducted to determine the optimal locally relevant threshold to reduce heat-health impacts and death (Benmarhnia *et al.* 2019; Carmona *et al.* 2017; Golechha *et al.* 2021; Maung and Tustin 2020). The World Health Organization directs evaluators to look at communications, weather forecasts, building performance, high-risk patients, and real-time health data, including mortality (Matthies 2008).

Heat adaptation plan evaluation is especially challenging because heat strategies are not limited to one standalone plan and instead occur in comprehensive, climate action, and other sustainability plans. Evaluation of networks of plans is one emerging response to this challenge (Quattro and Daniels 2022; Woodruff *et al.* 2024). For this reason, a plan integration tool was developed for planners to track the implementation and intersection of these plans (Plan Integration for Resilience ScorecardTM for Heat: Spatially Evaluating Networks of Plans to Mitigate Heat (Version 1.0), n.d.). While some literature evaluates plan impacts, a gap remains in how heat adaptation plan documents themselves intend to evaluate and monitor outcomes (Berke *et al.* 2006; Oliveira and Pinho 2009).

3. Methods

We conducted a qualitative content analysis of 65 plans from federal, state, regional, and municipal sources to understand how planners approached evaluation and monitoring in heat planning. Plan analysis is especially appropriate for heat adaptation research, as planning documents may be the only public-facing documentation of inter-agency and inter-jurisdiction coordination (Keith *et al.* 2021). Most plans are adopted by governing bodies and indicate a measure of government accountability, which is essential for climate adaptation (Mees and Driessen 2019).

We used purposive sampling to identify plans that were most likely to include heat adaptation strategies. Using professional networks and the Google search engine, we found **nine standalone extreme heat adaptation plans**: one state-level plan, two regional plans, four municipal plans, and two neighborhood-level plans. All but one were from the US. We then looked for plans from multiple levels of governance to identify heat adaptation strategies and evaluation included in broader planning efforts. We analyzed all **26 federal climate adaptation plans** produced by Executive Order 14008 (Biden 2021). The plans provided us with an overview of where heat planning and evaluation may or may not be happening at the highest level of government in the US (Biden 2021). We then pulled plans from an existing database of 175 plans in the 50 most populated municipalities in the US that was created through previous research about how local governments plan for extreme heat (French and Hondula 2021; Turner *et al.* 2022). From this database, we identified **20 urban plan** documents that included a heat statement related to studying or monitoring in the Northeast and Midwest US because we assumed these would have the highest likelihood of including an evaluation strategy or plan. If the plan had been updated, we analyzed the most recent plan. Finally, we analyzed **ten regional climate resilience plans** in New York State to look for approaches to evaluation and monitoring outside of municipal geographies. We selected New York, the Northeast, and Midwest geographies because this research was part of a larger research project for the New York State Department of Environmental Conservation. See Table 1 for exclusion and inclusion criteria.

In total, the 65 plans covered a variety of jurisdictions: 26 federal, one state, ten regional, five metro-region, 21 municipal, and two neighborhood-level plans (see Appendix 1). The geographic bias towards large cities and a variety of scales reflects our purposive sampling designed to identify places most likely to have heat strategies incorporated in plans, and potential monitoring and evaluation as follow up (Gabbe *et al.* 2024). While the number of plans analyzed is smaller than more automated plan analyses, our interest in the varied ways monitoring and evaluation show up is conducive to qualitative, "smaller *n*" analyses (Lieberson 1991).

For each plan document, we answered the following five questions: 1) Is extreme heat identified as a hazard in the plan? 2) Is there a strategy to respond to extreme heat? 3) How was evaluation used during the planning process? 4) How are evaluation and monitoring planned for? And 5) What indicators are included in the evaluation and monitoring plans? We used qualitative analysis software and spreadsheets to code the plans for heat adaptation actions, where evaluation occurred in the planning cycle and to what extent, and indicators or metrics related to heat evaluation.

For plans that indicated an intent to evaluate or monitor, we reviewed websites, dashboards, reports, and evaluation activities to determine how governments implemented that monitoring and evaluation. Using the Google search engine, we searched the plan lead authors' website and the web search terms "plan name" AND "report* OR eval* OR monitor*." We created a code book that described the coding process (see Appendix 2). Two coders worked together to code each plan twice, and both coders also followed the methodology for uncovering whether the evaluation was happening, resulting in an 81% agreement in results. We reviewed the evidence for each discrepancy to finalize the pattern coding. The table of plans, all associated monitoring and evaluation activities, indicators, and codebook are linked [https://doi.org/10.5061/dryad.vhhmgqp1t]. In this paper, we refer to each plan by its short name, constructed using the geography and the plan type.

Table 1. Plan inclusion and exclusion criteria.

Source category	Source justification	Inclusion criteria	Exclusion criteria	Total included in analysis
Stand-alone heat plans	Entire plan is about heat	All heat adaptation plans at any scale in any geography, in English	Plans that focus on extreme heat event response only	9
Federal climate adaptation plans	Highest level of heat planning in the US.	Comprehensive. All plans included.	N/A	26
Database of 175 plans in the 50 most populated metro areas in the US (French and Hondula, 2021; Turner *et al.* 2022)	Plans already analyzed and coded for relevance to extreme heat adaptation	Plans coded as including a heat statement related to study or monitoring in the Northeast and Midwest US.	Plans that were not in the two regions of interest. Plans that do not have a heat statement coded as related to studying or monitoring	20
Regional plans	Identify heat adaptation strategies, including evaluation outside of urban areas	Comprehensive. All ten climate resilience plans in New York State included.	N/A	10

Table 2. Summary of heat evaluation efforts by planning jurisdiction.

		Plan document analysis				
Planning scale	#	Extreme heat is a hazard	Extreme heat strategy	Evaluation for strategy selection	Evaluation/ monitoring plan or indicators (heat relevant)	Evaluation/ monitoring implemented publicly
Nation	26	25	8	5	8	7
State	1	1	1	1	1	1
Regional	10	7	5	5	3	0
Metro-region	5	5	5	4	5	0
City	21	21	20	12	18	11
Neighborhood	2	2	2	2	1	0
Total	65	61	41	29	36	19

4. Results

4.1. Summary by plan jurisdiction

Of the 65 plans, 61 mention extreme heat or increasing temperatures as a hazard, and 41 include a strategy(s) to address extreme heat explicitly. Twenty-nine (29) plans describe evaluation for strategy selection during the planning process. Thirty-six (36) plans include direction for future evaluation, monitoring, or specific indicators. Of these 36 plans, 19 (52%) implemented the evaluation or monitoring in a publicly accessible report or dashboard. However, only six of these plans reported evaluation or monitoring as described in the original planning document. The implemented evaluation or monitoring reports were all for plans where the lead author's legal jurisdiction matched the planning area (nation, state, or city). We found no evaluation or monitoring associated with the region, metro region, or neighborhood plans. See Table 2 for details.

4.2. Evaluation in the plan document

This section summarizes how evaluation occurs or is planned for each of the five categories of plan evaluation: ex-ante evaluation, planning process evaluation, implementation evaluation, outcome evaluation, and impact evaluation (see Section 2.1 for descriptions).

4.1.1. How is evaluation during the planning process described in the planning documents? (ex-ante evaluation) how is the evaluation of the planning process described in the planning documents? (planning process evaluation)

Twenty-nine plans described a process or criteria by which strategies were selected for inclusion in the final plan. In some cases, the evaluation criteria were implied through the mention of public workshops, surveys (public support), heat vulnerability mapping (sensitivity), or modeling (effectiveness) to determine plan strategies and priorities (Phoenix Neighborhood Heat Plan, Boston heat plan, Miami heat plan, and Philadelphia neighborhood heat plan). Other plans identified specific criteria such as capital and recurring costs, flexibility, co-benefits, cross-sector benefits, equity, the

existence of a local champion, effectiveness, ambitiousness, public interest, visibility, ROI, impact feasibility, effort, and safety (Finger Lakes, City of Boston hazard mitigation plan, Chicago CAP, Columbus Green Community Plan, West Sydney, Miami). We also found a lack of direction for evaluation of the overall planning process in the plan documents.

4.1.2. How are evaluation and monitoring planned for in the planning documents?

Thirty-six (36) of the 65 plans described an intention to evaluate or monitor. The most common format for the evaluation plan is a strategy or strategies that outline evaluation efforts and responsibilities within a broader plan document. For example, the California heat plan includes three strategies, one of which is:

> Track C- Goal 4 R3 Convene a task force to assess the effectiveness of built environment interventions, including cooling surface technologies. (p. 51)

Less frequently, the plans include a separate section related to monitoring and evaluation (Baltimore and Columbus climate action plans). The West Sydney heat plan frames all plan strategies using four plan-level quantitative targets and directions to form working groups around establishing and monitoring these targets. Another example of a plan-level evaluation approach is identifying a process for evaluating whether the plan and strategies are meeting equity goals (Environmental Protection Agency plan, Chicago climate action plan).

Generally, the plans distinguished between implementation evaluation and outcome or impact evaluation, though most of the plans were focused on one or the other. Of the 24 plans with an evaluation plan, 17 implied implementation evaluation, and 22 implied outcome or impact evaluation.

Where plans identified an evaluation lead, the most common approach was to name a steering committee, often involving higher education institutions, to monitor, evaluate, and update the plan (for example, the Philadelphia hazard mitigation plan, Baltimore climate action plan, Miami heat plan). The West Sydney heat plan describes how a free-standing non-profit think tank will evaluate plan strategy effectiveness, while the California heat plan identifies a task force within the Office of the Governor as the lead. The Boston resilience plan identifies three collaboratives: one for implementation reporting, one for monitoring, and one for evaluation. While some plans imply an evaluation phase, the timing is unclear when and how the evaluation will happen.

4.3.3. Monitoring and indicators

Twenty four plans that included extreme heat strategies also included a monitoring plan. Fourteen plans included both an evaluation and monitoring plan. In some cases, there were indicators but no plan for monitoring (e.g. Miami). The most common indicator was the number of trees planted. Plans also have percent tree canopy cover as a goal, with some specifying priority areas, such as those with higher vulnerability or low canopy coverage. Energy efficiency and residential weatherization retrofits were the most common indicators associated with building strategies. Heat stress emergency room visits, hospitalizations, and heat deaths were the most common outcome

indicators associated with human health. Implementation metrics included the number of small area plans related to climate risks and climate health metrics in city planning efforts. There was only one indicator of budget or finance (percentage of city capital budget spent on parks facilities), although this was frequently a criterion indicated for evaluating future strategies. Only one indicator related to congregant settings and no indicators related to correctional facilities or schools. There were no indicators related to animal health or farmer and farm worker health aside from "passage of county legislation protecting outdoor workers." Heat measurements, such as average daytime temperature, urban heat island (UHI), or heat vulnerability indices, were typically referenced only in background sections but not included in evaluation or monitoring. The spreadsheet of all 399 indicators is available [https://doi.org/10.5061/dryad.vhhmgqp1t].

4.3. Are governments monitoring and evaluating what is indicated in the plan?

Of the 36 plans with evaluation or monitoring plans related to heat, 19 implemented some form of evaluation or monitoring that was publicly accessible (53%). However, only six reported the evaluation described in the plan document, all of which were the annual reports on implementing a federal climate adaptation plan. Of the 17 plans with no associated evaluation reporting, eight were associated with a network of plans that referenced aspects of the original plan but no reporting on the original plan. We found one associated "drop-down" evaluation plan but no reporting.

Of the 13 plans that indicated an intention to monitor or evaluate their strategies, but did not implement and report as planned, we identified six patterns. These patterns include progress reporting, impact evaluation, selective reporting, data only, online circular referencing, plan updates. These patterns are summarized in Table 3 and described below:

1. Plan for implementation evaluation, report on something else. The federal adaptation plans have a yearly progress reporting mechanism established in the plan document. While the plans include implementation indicators, the first annual progress reports do not report these indicators.

Table 3. Patterns of evaluation implementation in planning for extreme heat.

Pattern	Count
Evaluation or monitoring report, product, or evidence available publicly	19
Implemented as planned	6
Plan for implementation evaluation, report on something else	3
Plan for outcome/impact evaluation, report on implementation	3
Positive reporting only	6
Standalone monitoring or data product	5
Website and documents with circular references	8
Through plan update	2
No evaluation or monitoring was found	**17**
Constellation of plans and reports	8
Drop-down plan for evaluation	1
No reported evaluation, monitoring data products, or further follow-up	8

Note: Evaluation/monitoring products can fall into multiple typologies, so the count is greater than 19.

2. Plan for impact evaluation, report on implementation progress. Where governments report on evaluation and monitoring activities, the actual reporting overwhelmingly focuses on implementation evaluation. In contrast, the evaluation language in the plan documents implies a desire to evaluate the impact and effectiveness of strategies.
3. Selective reporting of positive messages. A variation on the above, the reports describe a process that varies from the original plan, typically reporting on indicators and implementation metrics that communicate positive change or success.
4. Report of data with no interpretation. This pattern is where data is reported via document or dashboard, but the data and trends are not interpreted as positive, negative, or neutral. In some cases, this is a heat map web application that overlays vulnerability indicators such as age or income with heat risk based on land surface and adaptive resources such as cooling centers (Boston, Washington, DC, California, Philadelphia).
5. Website and documents with circular references. Another common pattern of evaluation outcome product is that there is a website landing page associated with the heat adaptation plan, with links and references to resources such as toolkits, adjacent planning efforts, and taskforces, some of which report on or evaluate previous planning efforts. For the Detroit Climate Action Plan, an economic impact report of the proposed action strategies from the plan was reported on, but nothing else. The three plans from Washinton, DC, are now housed in the initiative and website "Sustainable DC," which brings together the plans and associated annual reporting. The reporting reflects planning in multiple plans and initiatives, even though the original plans did not outline this approach to evaluation.
6. Evaluation through plan update. Sustainable DC, mentioned above, and the New York City sustainability plans are examples of evaluation through plan updates. Plans that are updates of previous plans tend to report on the implementation of previous plans and carry some indicators forward. Thus, the plan update process is an implementation evaluation built into the planning cycle. However, this is not made explicit in the original planning documents.

5. Discussion

5.1. Synthesis of results

Most governments are not monitoring nor evaluating what is indicated in their plan. Of the 65 analyzed plans, 36 indicated a desire for some form of evaluation or monitoring, and we found evidence of only 19 evaluation or monitoring reports (Table 2). The six evaluation reports implemented as planned are all related to implementation or process evaluation, a pattern that has been found elsewhere (Scott and Moloney 2022). Our finding of multiple plans and reports associated with evaluation also matches existing research on a network of plans as an approach for climate adaptation (Quattro and Daniels 2022; Woodruff *et al.* 2024). Most reports were associated with climate or sustainability plans, which is where heat strategies were also most likely to be located, according to an analysis of 19 plans and 293 municipalities in California (Gabbe *et al.* 2024). Our finding of no evaluation reporting for regional planning areas reflects previous findings on the challenge and need for regional action for climate adaptation (Termeer *et al.* 2011).

Within the plan documents using evaluation in their heat planning, we found the following three weaknesses: 1) lack of accountability for post-plan evaluation as evidenced by lack of clear leadership, implementation steps, or timeline, 2) disconnect of evaluation approaches across the plan document, and 3) lack of plans for evaluation of the planning process. While the collaborations detailed in many of the plans for evaluation are likely needed, there needs to be a clear lead with accountability outside of the planning process. Similarly, there was limited evidence of timelines for evaluation and reporting. An exception was the implementation and evaluation plan for Keeping Metro Boston Cool: A Regional Heat Preparedness and Adaptation Plan:

> Each year an implementation checklist will be reviewed at a quarterly coalition meeting with qualitative feedback on how it's going that will then be shared out at another meeting, where they will discuss lessons learned and shift priorities and or funding ideas. (p. 53)

Our analysis of the use of evaluation within the plan documents shows a disconnect between evaluation practices across the planning phases. There was no cohesive narrative linking plan goals, selection evaluation of strategies for inclusion in the plan, evaluation approaches, and indicator selection. For example, the Chicago climate action plan identifies an evaluation strategy to include:

> Co-developing meaningful key performance indicators, evaluation processes, and reporting strategies in coordination with diverse stakeholders. (p. 154)

However, the criteria by which strategies are selected can easily be an initial framework for evaluation, and the indicators used to identify vulnerabilities, risks, and needs in heat planning can easily be repurposed as indicators for monitoring. There is no need to "restart" evaluation planning after plan adoption. Many plans include a statement that indicates impact evaluation without any clear implementation evaluation process. However, it is difficult to assign causality of the impact to the plan without demonstrating its implementation (Laurian *et al.* 2010).

We also found that often, indicators for evaluation do not logically flow from a plan's overarching goal. For example, while the Miami heat plan described outdoor worker protection as a community priority, the monitoring metric did not include heat illness broken out by industry. This highlights the need for heat plans to be explicit about the intended goals of heat adaptation strategies and who the targeted population is. This will enable a more logical connection between plan goals and evaluation metrics.

The lack of indicators related to public swimming, fisheries, agriculture, cooling centers, water, and worker health reflects a disconnect between what is being evaluated and the strategies that have the most effectiveness and evidence for improving equity (Hamstead 2023, 2024; Widerynski *et al.* 2017). In the case of ecosystem-based adaptations, most indicators are related to tree plantings, yet long-term maintenance is just as essential for a healthy urban forest canopy (Roman *et al.* 2015). For the evaluation of green space access, indicators need to more precisely assess how access to green spaces helps populations adapt. There was no evidence of logic models, although they are an established way to link plan goals, strategies, outcomes, and indicators using an underlying theory of change (Issel 2021). Both an implicit and explicit theory of change operating in planning and logic models could help users identify likely outcomes. Contrary to the expectation that reporting would take several years to be

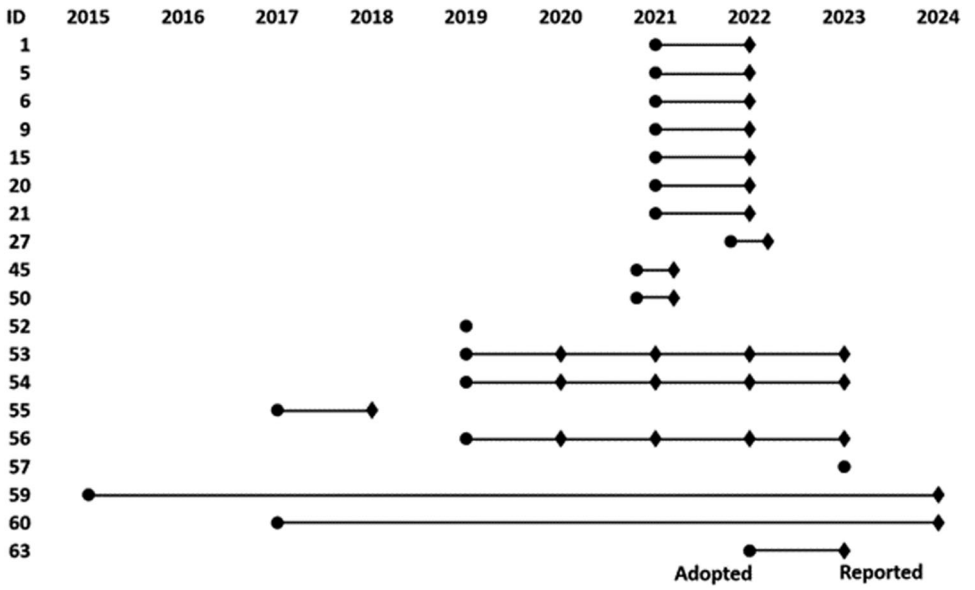

Figure 2. Timing of evaluation and monitoring reports.

published, we found that the reports related to heat planning are published the year or the year after the plan is adopted (see Figure 2). In some cases, it seemed as though the monitoring efforts were coincident to the planning, suggesting that the plan writers were aware of and building from existing or emergent efforts.

5.2. *Addressing common barriers to evaluation in planning efforts*

Obstacles to evaluation in planning include the lack of financial and staffing resources, staffing turnover, knowledge, competing priorities, political constraints and cycling, a focus on the future, lack of methods training, and a disconnect between planning departments and those tracking indicators (Guyadeen and Seasons 2016; Laurian *et al.* 2010; Seasons 2003). Impact evaluations that yield null or negative findings are minimally a communication challenge and, at worst, a legal liability, especially when coming out of internal processes. Conversely, overly critical impact evaluations of one aspect of a plan or policy can undermine otherwise good efforts. Maladaptation itself is difficult to assign a metric (Juhola and Käyhkö 2023).

Challenges specific to heat include how heat planning, monitoring, and evaluation are spread across multiple levels of government and agencies, with federal agencies supporting climate data, municipalities implementing, and counties tracking health data (Keith *et al.* 2021). Most heat impacts result from compounding impacts, such as heat and drought or heat and grid failure, complicating matters further. Furthermore, the methods and tools across the disciplines used to understand heat impacts are so different they may be unrecognizable, as exemplified by the controversy over the causes of the 1995 Chicago heat wave deaths (Browning *et al.* 2006; Duneier 2006; Klinenberg 1999, 2006). There also might be assumptions that most heat interventions are uniformly positive.

Finally, it is difficult to identify what program or intervention is responsible for a given outcome because the local context constantly changes and time horizons of

impacts are mismatched (Dinshaw *et al.* 2014). In Phoenix, heat response programs reach around 50 to 100% more people than three years ago, but the number of unsheltered people also increased (City of Phoenix 2024).

5.3. Recommendations for heat adaptation evaluation, monitoring, and reporting

Based on our analysis of the implementation of evaluation and reporting, we offer the following recommendations for planners and evaluators of extreme heat adaptation. For a full list of recommendations that draw upon the community of practice this author group represents, see Appendix 3.

1. **Focus on the structure of planned evaluation efforts**. Most plans for evaluation are never implemented, so focus on how evaluation will occur rather than what exactly will be monitored. Specify reporting and decision-making associated with data collection. One critique of monitoring and evaluation is that a disproportionate amount of time is spent on collecting data compared with using it to make decisions and allocate resources (Seasons 2003).
2. **Pull monitoring indicators from the planning process.** Most plans have succinct and compelling descriptions of the challenge of extreme heat and include quantitative indicators in a range of categories. Examples include days above locally relevant temperature thresholds, record temperatures, land surface temperature maps, heat vulnerability maps, heat-related hospitalizations, emergency room visits or deaths, excess deaths during heat waves, economic impacts, soil moisture, funding for tree planting, economic losses due to labor productivity, and outdoor worker death disparities. These would make significant indicators for evaluation and include baseline data already captured in the plan document.
3. **Monitor and report on implementation.** The published reports shared indicators and accounts of implementation, such as participants engaged, and trees planted. Plan to evaluate what is most likely to be monitored and reported. Furthermore, implementation monitoring can better support procedural equity goals with reporting on timeline, budget indicators, and relevant data such as who, what, and where is getting funded and resourced (Malloy and Ashcraft 2020).
4. **Start reporting soon after plan adoption.** The evaluation reports we found happened within a year or two after adoption and likely reflect that political will power for evaluation was embedded within the plan writing process, rather than a product of the process. Where possible, tie heat adaptation evaluation into existing monitoring, evaluation and reporting processes.

Recognizing that political will represents a significant factor in the implementation of evaluation, monitoring and reporting, we invite planners and evaluators to use evaluation frameworks that account for the political context of evaluation such as realist evaluation, qualitative comparative analysis, process tracing and outcome harvesting (Aston *et al.* 2022). While quantitative indicators dominate evaluation and monitoring plans in the plans we analyzed, they are the not the only nor the best form of accountability.

5.4. Future research

Our research examined the symptoms of the barriers to evaluation and monitoring of extreme heat adaptation. Future research should investigate the political economy of

evaluation implementation. More research is needed to understand practitioner mental models of how they connect the goals of heat adaptation planning and strategies with their approach to robust, reliable, and repeatable evaluation strategies and how they think about consistency in evaluation metrics across time and space.

6. Conclusion

We reviewed 65 plans from federal, regional, state, and municipal sources to understand how planning documents approach evaluation and monitoring strategies to mitigate extreme heat impacts to individuals and communities. Evaluation is a type of plan implementation and should be treated as such, which requires appropriate background research, prioritization, goal making and accountability as any other plan intention. This research is timely because of the acceleration in local, regional, and state heat planning efforts, which often move forward with weak or unclear evaluation plans. This paper will help planners leverage existing resources to better understand their work's impact on the populations they serve. Our analysis refines the metrics supporting evidence-based adaptation actions while providing a foundation for measuring and working towards equity and risk reduction goals. By showing how existing heat and heat-related plans draw from existing resources and partners to evaluate impacts, this paper provides a template for others hoping to coordinate across multiple levels of government to maximize impact.

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Data availability statement

The data that support the findings of this study are openly available through Dryad at https://doi.org/10.5061/dryad.vhhmgqp1t

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Appendix 1

ID	Name of document	Lead author	Year Adopted	Scale
1	2021 Climate Action Plan	US Department of Health and Human Services	2021	Nation
2	Climate Readiness Plan in Response to Executive Order 14008	US Agency of International Development	2021	Nation
3	Action Plan for Climate Adaptation and Resilience	US Department of Agriculture	2021	Nation
4	USACE Climate Action Plan	US Army Corps of Engineers	2021	Nation
5	Department of Commerce 2021 Climate Action Plan for Adaptation and Resilience	US Department of Commerce	2021	Nation
6	Department of Defense Climate Adaptation Plan	US Department of Defense	2021	Nation
7	US Department of Education Climate Adaptation Plan	US Department of Education	2021	Nation
8	2021 Climate Adaptation and Resilience Plan	US Department of Energy	2021	Nation
9	Climate Adaptation Action Plan	US Environmental Protection Agency	2021	Nation
10	Climate Change Risk Management Plan	US General Services Administration	2021	Nation
11	Department of Homeland Security Climate Action Plan	US Department of Homeland Security	2021	Nation
12	Climate Adaptation Plan	US Department of Housing and Urban Development	2021	Nation
13	Department of the Interior Climate Action Plan	US Department of the Interior	2021	Nation
14	DFC Climate Action Plan Under Executive Order 14008	US International Development Finance Corporation	2021	Nation
15	US Department of Justice Climate Action Plan	US Department of Justice	2021	Nation
16	Climate Action Plan	US Department of Labor	2021	Nation
17	Climate Action Plan	US Millennium Challenge Corporation	2021	Nation
18	Climate Action Plan	US National Aeronautics and Space Administration	2021	Nation
19	Climate Action Plan	US National Archives and Records Administration	2021	Nation

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ID	Name of document	Lead author	Year Adopted	Scale
20	Climate Change Action Plan	US Smithsonian Institution	2021	Nation
21	2021 Climate Action Plan	US Social Security Administration	2021	Nation
22	Climate Action Plan: Revitalizing Efforts to Bolster Adaptation & Increase Resilience	US Department of Transportation	2021	Nation
23	US Department of the Treasury Climate Action Plan	US Department of the Treasury	2021	Nation
24	US Department of Veterans Affairs Climate Action Plan	US Department of Veterans Affairs	2021	Nation
25	Climate Action Plan	US Office of Personnel Management	2021	Nation
26	Climate Adaptation and Resilience Plan	US Department of State	2021	Nation
27	Protecting Californians from Extreme Heat: A State Action Plan to Build Community Resilience	State of California	2022	State
28	Capital Region Sustainability Plan	City of Albany; Capital District Regional Planning Commission	2012	Region
29	Cleaner Greener Southern Tier Regional Sustainability Plan	Southern Tier Regional Consortium	2013	Region
30	Mid-Hudson Regional Sustainability Plan	Mid-Hudson Planning Consortium	2013	Region
31	One Region Forward a New Way to Plan for Buffalo Niagara Final Plan	University at Buffalo Regional Institute	2015	Region
32	Western New York Regional Sustainability Plan	Western New York Regional Planning Consortium	2013	Region
33	Cleaner Greener Long Island Regional Sustainability Plan	Cleaner Greener Consortium of Long Island	2013	Region
34	Our Economy: North Country Regional Sustainability Plan	North Country Planning Consortium	2013	Region
35	Cleaner, Greener Communities Sustainability Plan for the Mohawk Valley	Mohawk Valley Planning Consortium	2013	Region
36	Finger Lakes Regional Sustainability Plan	Finger Lakes Regional Sustainability Consortium	2013	Region
37		Central New York Regional Planning	2013	Region

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ID	Name of document	Lead author	Year Adopted	Scale
	VisionCNY: Central NY Regional Sustainability Plan	and Development Board		
38	Regional Climate Action Plan: Creating equitable and just climate resilience in the Kansas City region	Mid-America Regional Council; Climate Action Kansas City	2021	Metroregion
39	2018 Hennepin County Multi-Jurisdictional Hazard Mitigation Plan	Hennepin County Emergency Management	2018	Metroregion
40	City of Philadelphia 2022 All-Hazard Mitigation Plan	Philadelphia Office of Emergency Management	2022	Metroregion
41	Turn Down the Heat Strategy and Action Plan	Western Sydney Regional Organisation of Councils	2018	Metroregion
42	Keeping Metro Boston Cool: A Regional Heat Preparedness and Adaptation Plan	Metro Mayors Climate Taskforce Metropolitan Area Planning Council	2022	Metroregion
43	Baltimore Climate Action Plan	City of Baltimore Office of Sustainability	2014	City
44	City of Boston Climate Action Plan 2019 Update	City of Boston	2019	City
45	City of Boston 2021 Natural Hazard Mitigation Plan Update	City of Boston	2021	City
46	Resilient Boston an Equitable and Connected City	City of Boston's Mayor's Office of Resilience and Racial Equity	2017	City
47	Resilient Chicago: A Plan for Inclusive Growth and a Connected City	City of Chicago Mayor's Office Resilience Team	2019	City
48	2022 CAP: Chicago Climate Action Plan	City of Chicago Office of the Mayor	2022	City
49	Columbus Climate Adaptation Plan	Byrd Polar and Climate Research Center	2018	City
50	Columbus Climate Action Plan	City of Columbus	2021	City
51	The Columbus Green Community Plan: Green Memo III	City of Columbus	2015	City
52	Resilient DC: A Strategy to Thrive in the Face of Change	Government of the District of Columbia	2019	City
53	Sustainable DC: Sustainable DC 2.0 Plan	Government of the District of Columbia	2019	City
54	Climate Ready DC: The District of Columbia's	Government of the District of Columbia	2019	City

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ID	Name of document	Lead author	Year Adopted	Scale
	Plan to Adapt to a Changing Climate			
55	Detroit Climate Action Plan	Detroiters Working for Environmental Justice	2017	City
56	Thrive Indianapolis	City of Indianapolis Office of Sustainability	2019	City
57	PlaNYC Getting Sustainability Done	City of New York	2023	City
58	Citywide Vision: Philadelphia 2035	City of Philadelphia	2011	City
59	Growing Stronger: Toward a Climate-Ready Philadelphia	City of Philadelphia Mayor's Office of Sustainability and ICF International	2015	City
60	Cool Neighborhoods NYC: A Comprehensive Approach to Keep Communities Safe in Extreme Heat	City of New York	2017	City
61	Miami Extreme Heat Action Plan	Miami Dade County Office of Resilience	2022	City
62	Heat Resilience Solutions for Boston	City of Boston	2022	City
63	Keep Cool DC: The District of Columbia's Extreme Heat Adaptation Strategy	The Government of the District of Columbia, Department of Energy and Environment	2022	City
64	Heat Action Planning Guide for Neighborhoods of Greater Phoenix	Nature Conservancy, Maricopa County Department of Public Health, Central Arizona Conservation Alliance, Urban Resilience to Extremes Sustainability Research Network, Arizona State University's Urban Climate Research Center, and Center for Whole Communities	2017	Neighborhood
65	Beat the Heat Hunting Park: A Community Heat Relief Plan	City of Philadelphia Office of Sustainability	2018	Neighborhood

Appendix 2

Item	Coding instructions
Name of document	This is the full name of the plan
Author	This is the lead agency of the plan.
Year Adopted	This is the year the plan was adopted or published
Extreme heat events	Y if extreme heat is recognized as a hazard in the plan.
Drought	Y if drought is recognized as a hazard in the plan.
Wildfires	Y if wildfires are recognized as a hazard in the plan.
Increasing temps	Y if increasing temperatures generally is identified as a hazard in the plan.
Heat related strategy in the document	Y if there is a strategy that responds to extreme heat. R if there's a strategy that could respond to extreme heat or related hazards, but is not identified specifically as such.
Needs assessment/ background	"Y" if there's indication that some sort of assessment of heat or the impact of heat to humans and the environment occurred as part of the planning process leading up to drafting the document. "U" if unsure.
Prioritization criteria for strategy selection	"Y" if the plan makes mention of some type of prioritization criteria or process for selecting which strategies will be in the plan. Example characteristics include feasibility, cost, efficacy, public support and/or equity.
Evaluation	"Y " if there is a plan to evaluate in the future
Process eval	"Y" if there is a plan to evaluate whether the heat strateg(ies) happened or not.
Outcome eval	"Y" if there is a plan or direction to evaluate the outcomes of the heat strategies or projects.
Plan level eval	"Y" if there is a plan/approach, either as a strategy, or at the plan level to evaluate longer term outcomes of the plan.
Monitoring	"Y" if there is monitoring identified/planned for in the plan document associated with a heat strategy or goal. "R" is monitoring in the plan that is relevant to extreme heat or related hazards, but is not identified specifically as such.
Indicators	"Y" if there are indicators identified in the plan that are directly related to extreme heat, strategies or impacts. "R" if the indicators are not directly related to extreme heat, but could be relevant to strategies.
Prioritization criteria for plan implementation	"Y" if there's a strategy or approach for selecting projects or strategies moving forward.
Extreme heat evaluating or monitoring implemented?	"Y" if you have found something, "N" for no
Evaluation typology	1. Plan for process, report on something else; 2. Plan for impact evaluation, report on process; 3. Selective reporting of positive items only; 4. Data only alone; 5. Constellation of plans website with circular references 6. Evaluation through plan update/re-write; 7. No, but there is constellation of plans 8. No, but there is a new evaluation plan

Appendix 3

This research came out of work to support the New York State Department of Environmental Conservation on New York State's extreme heat adaptation plan. Specifically, we were asked to give them guidance on how to include evaluation and monitoring in their planning and management. To answer this question, we conducted the research shared in this journal article. In response to the findings of this research and our experience as planners and researchers of extreme heat, we offer the following recommendations.

Recommendations for plan writers

1. **Plan for evaluation at the time of plan kick-off.** Invite evaluators to kick off meetings and discussions of goals and priorities. Set clear goals and decide what type of evaluation is desired, and then frame the needs assessment and background research, strategy selection, and evaluation plans around these goals.
2. **Focus on the structure of planned evaluation efforts**. Describe why evaluation should happen, who will lead it, who will contribute, and how it will be funded on reoccurring budget lines. Describe any enforcement or accountability mechanisms related to revisions to goals and actions if strategies are evaluated to be having particularly adverse outcomes for vulnerable communities.
3. **Match evaluation to funding and staffing resources**. Funding for research on regional best practices could come through the state to academic institutions, while funding for local monitoring could go to community organizations.

Recommendations for evaluators

1. **Connect evaluation to ongoing monitoring** at the federal, state, county, and local level.
2. **Specify reporting and decision-making associated with data collection**. One critique of monitoring and evaluation is that a disproportionate amount of time is spent on collecting data compared with using it to make decisions and allocate resources (Seasons 2003).
3. **Create a heat-action community of practice** to improve recruitment, educational training, new job positions, professional networking or concentrations within existing disciplinary professional organizations, and consider accreditation and licensing boards for professional state registration.
4. **Consider hiring an external evaluator for impact evaluation** who works collaboratively with an internal team to align how and why evaluation is used but enables space for constructive feedback on plan outcomes and impacts.

Recommendations for monitoring and indicators

1. **Pull indicators from the planning process.** Most plans have succinct and compelling descriptions of the challenge of extreme heat and include quantitative indicators in a range of categories. Examples include days above locally relevant temperature thresholds, record temperatures, land surface temperature maps, heat vulnerability maps, heat-related hospitalizations, emergency room visits or deaths, excess deaths during heat waves, economic impacts, soil moisture, funding for tree planting, economic losses due to labor productivity, and outdoor worker death disparities. These would make significant indicators for evaluation and include baseline data already captured in the plan document.
2. **Monitor the challenge.** It may be helpful to choose indicators that reflect the vulnerability being addressed (Kumar *et al.* 2016; Weis *et al.* 2016; Yu *et al.* 2021). Indicators that measure heat or temperature directly would be classified as an indicator of heat exposure. Population health, age, and socioeconomic status would be classified as a sensitivity

indicator. Adaptive capacity indicators could be measured regarding available resources to cope with an event, such as hospital beds or the capacity of cooling shelters.

3. **Use proxies** if necessary. While measuring heat across landscapes can be too resource-intensive for many smaller communities, proxies such as remote sensing ("HotSat-1: UK spacecraft maps heat variations across Earth" 2023) and machine learning could be used (Morgan *et al.* 2023). Heat indicators include land surface temperature (Black-Ingersoll *et al.* 2022) and outdoor, indoor, and nighttime air temperature (Coseo & Larsen 2015). Temperature and other thermometric measures do not fully capture how people experience heat (Hamstead 2023, 2024). Storytelling and surveying are two approaches to capture a more nuanced understanding of the impacts of extreme heat on individuals (Guardaro *et al.* 2020).
4. **At the strategy level, monitor implementation** with timeline, budget indicators, and relevant data related to implementation equity: who, what, and where is getting funded and resourced? Implementation can also be monitored at the agency lead level (e.g., parks department), simplifying the challenge of tracking every strategy.
5. For strategy effectiveness **(outcome evaluation), select just a few key strategies** or strategy clusters to monitor and evaluate to inform critical adjustments to adaptation efforts.
6. **Monitor impact indicators at the plan level**, aligned with progress towards overall goals, in line with Laurian et al. methods (2010). Heat-related illness is the most frequently reported indicator in heat emergency plan evaluation (Price *et al.* 2018) and heat strategy effectiveness (Krenz *et al.* 2021; McCarthy *et al.* 2019). Having a heat action plan group to analyze health outcomes and evaluate the excess health burden related to heat is critical. Heat illness data sources include the CDC near-real-time map, the EMS-heat tracking portal, and systematic surveillance of Google searches related to heat symptoms (Jung *et al.* 2019).
7. **Think beyond human health indicators for urban areas.** Trees and green infrastructure data for public spaces need more focused attention for tree and shade interventions with more direct public cooling benefits. While most indicators in heat adaptation plans relate to tree canopy coverage and tree planting, none of the indicators we found directly related to stewardship of new trees or existing canopy maintenance (Elmes *et al.* 2017; Roman *et al.* 2015). We also recommend an indicator related to any regional industry that is affected by heat, such as agriculture, an indicator related to rural adaptive capacity, such as distance to cooling centers, an economic impact indicator, and an indicator related to equity, such as worker heat health complaints by industry or geographic tracking of heat health impacts.